Chapter 81
Brain–Computer Interfaces and Visual Activity

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ABSTRACT

There is growing interest in the use of brain signals for communication and operation of devices, in particular, for physically disabled people. Brain states can be detected and translated into actions such as selecting a letter from a virtual keyboard, playing a video game, or moving a robot arm. This chapter presents what is known about the effects of visual stimuli on brain activity and introduces means of monitoring brain activity. Possibilities of brain-controlled interfaces, either with the brain signals as the sole input or in combination with the measured point of gaze, are discussed.

INTRODUCTION

Brain states can be detected and translated into actions such as selecting a letter from a virtual keyboard, playing a video game, or moving a robot arm. Such devices, which do not require the user to perform any physical action, are called brain–computer interfaces (BCIs) or brain–machine interfaces (BMIs). Although brain–computer interfaces and brain–machine interfaces involve the same kind of interface technology, it is agreed for purposes of precision in nomenclature that the latter are based upon invasive signals whereas the former rely upon non-invasive signals. For this reason, the term ‘BCI’ will be used in this chapter.

It is important to remark that, although the main application of BCI technology has been centred in providing a new communication channel for patients with severe neuromuscular disabilities (Kübler et al., 2011), it is also a powerful tool for contribution to a better understanding of the brain and it provides a novel communication channel for human–machine interaction. Also, BCI prototypes have only been developed recently, but the basic

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ideas were already put forward in the 1970s. Initial successful experiments were based on analysis of the brain's electrical activity, namely, the visual evoked potential, generated in response to changes in gaze direction (Vidal, 1977).

We also wish to remark that some of the text included in this introduction has been extracted from the introductory chapter of the book *Towards Brain–Computer Interfacing* (Kübler & Müller, 2007). The curious reader is enthusiastically referred to this book, as it provides a still-timely overview of the BCI field (Dornhege et al., 2007).

Principles of BCI Systems

BCI research for communication and control is now possible because of both the neuro-scientific advances concerning the functioning of the brain and the powerful computing possibilities of current computers. Also, there is a growing awareness of the needs, problems, and potential of people with disabilities, as testified by the appearance of this book. No less important is the opportunity that BCI offers to investigate brain activity as an independent variable, in comparison to traditional psycho-physiological experiments. In the latter, the subjects are presented with a task or stimuli (independent variables) and the related brain activity is measured (dependent variable). Conversely, with neuro-feedback by means of a BCI, subjects can learn to deliberately increase or decrease brain activity (independent variable) and changes in behaviour can be measured accordingly (dependent variable).

An often overlooked direction of BCI applications beyond clinical and basic research aspects is the yet unexplored use of a BCI as an additional independent channel of human–machine interaction. In particular, brain signals can provide direct access to aspects of human brain state such as cognitive work load, alertness, task involvement, emotion, or concentration. The monitoring of these will allow for a novel technology that directly adapts a human–machine interface design to the inferred brain state in real time. Furthermore, BCI technology will in the near future be able to serve as an add-on in the development of new computer games, for example, fantasy games that require the brain-controlled mastering of a task for advancing to the next game level, where from our point of view there is great potential for the combination of gaze tracking and BCI technology. However, unlike in the field of gaze tracking, sensors are the bottleneck of today's invasive and non-invasive BCIs: invasive sensors can last only a limited time before they lose signal, and non-invasive sensors might need a long preparation time because of the use of conductive gel, depending on the number of electrodes used. In any case, the gel has to be removed later with soap and water, which makes the procedure uncomfortable, especially for patients.

Current BCI technology can be divided into two different approaches, although more or less all BCI systems rely primarily on a mixture of the two. The first approach is based on neuro-feedback and operant conditioning. Bio-feedback is a procedure that, by means of feedback on a (seemingly) autonomous parameter, is aimed at acquiring voluntary control over this parameter. Participants receive visual, auditory, or tactile information about their cardiovascular activity (heart rate or blood pressure), temperature, skin conductance, muscular activity, electrical brain activity (as shown by EEG or MEG signals), or blood-oxygen-level-dependent (BOLD) response (with functional magnetic resonance imaging (fMRI) or functional near-infrared spectroscopy (fNIRS)) and learn to regulate it voluntarily. When bio-feedback involves the control of neural signals, it is called neuro-feedback. In any case, the participants are presented with the task of either increasing or decreasing the activity of interest. By means of the feedback signal, participants receive continuous information about the alteration of the activity and success in the task is positively reinforced. Depending on the signal of interest and instruction, more or less extensive subject training is required for gaining sufficient voluntary control.

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