

# Chapter 17

## Evaluating User Experience of Actual and Imagined Movement in BCI Gaming

**Bram van de Laar**

*University of Twente, The Netherlands*

**Boris Reuderink**

*University of Twente, The Netherlands*

**Danny Plass-Oude Bos**

*University of Twente, The Netherlands*

**Dirk Heylen**

*University of Twente, The Netherlands*

### ABSTRACT

*Most research on Brain-Computer Interfaces (BCI) focuses on developing ways of expression for disabled people who are not able to communicate through other means. Recently it has been shown that BCI can also be used in games to give users a richer experience and new ways to interact with a computer or game console. This paper describes research conducted to find out what the differences are between using actual and imagined movement as modalities in a BCI game. Results show that there are significant differences in user experience and that actual movement is a more robust way of communicating through a BCI.*

### INTRODUCTION

In the field of BCI, brain activity is recorded and automatically interpreted to be applied in various applications. Measuring brain activity is already well known in medicine using the electroencephalo-

gram (EEG). EEG is a proven method, which has a number of advantages over other methods: it is non-invasive, has a high temporal resolution, does not require a laboratory setting, is relatively cheap, and it is even possible to create wireless EEG head-sets.

BCI systems need to make decisions based on very short segments of EEG data to make it

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useful for different applications such as wheelchairs, robots, and personal computers. In the case of software applications, BCI can be used as an additional modality of control, for evaluation of the user or the application, or to build adaptive user interfaces (Nijholt et al., 2008a).

Games are usually the first applications to adopt new paradigms, driven by the gamers' continuing search for novelty and challenges (Nijholt et al., 2008b). Apart from them being a suitable platform to bring this new interaction modality to the general population, games also provide a safe and motivational environment for patients during training or rehabilitation (Graimann et al., 2007; Leeb et al., 2007b). Research has shown that using BCI instead of the conventional mouse and keyboard can add to the user experience by making a game more challenging, richer, and more immersive (Oude Bos & Reuderink, 2008). This was done by comparing keyboard control with BCI control for a simple game called BrainBasher, and evaluating the user experience with the Game Experience Questionnaire (IJsselsteijn et al., 2007). Both this game and this questionnaire were also used for the research described here, comparing actual and imagined movement.

Before BCI can be adopted by the general population there are still a number of issues that need to be addressed: artifacts in the recorded brain data (signals that do not stem from the brain), inter and intra-subject variability, inter and intra-session variability, long training periods, low transfer rates (of commands), and the phenomenon that some people are unable to use a BCI at all (Sannelli et al., 2008). Apart from that, more attention from the Human Computer Interaction community is required on how this new input modality influences the user experience, and how the interaction can be improved (Lecuyer et al., 2008).

While most research into using movement for BCI has focused on imagined movement, some clinical research shows that actual movement in fact elicits a more pronounced and therefore

better discernable signal in the motor cortex (McFarland et al., 2000).

Actual movement can also be used with other interfaces than a BCI. Interfaces such as a motion tracking system, for example, which are probably more reliable at this moment. One big potential advantage of a BCI however is that the measured brain signals are always preceding actual muscle activity at the limbs, and can be measured before the muscles activate. This advantage is amplified by the onset of a potential in preparation of a movement, the so called *Bereitschaftspotential*, or *Readiness Potential* (Kornhuber & Deecke, 1965; Shibasaki et al., 2006). A very useful aspect of the RP is the lateralized readiness potential (LRP), where the preparation of left-sided movement is reflected in a potential occurring at the right motor cortex, and vice-versa. Krauledat et al. (2004) show that this lateralized readiness potential can be used to classify actual movement even before the movement itself is carried out. This could give a gamer an advantage over other interfaces especially in fast paced, highly reactive games.

But using BCI can also provide other benefits. While measuring brain activity for detection of movement, whether actual or imagined, other information can be derived from the brain as well, such as the user's mental and emotional state. This could be used to make smarter applications which are more aware of the user.

## **RELATED WORK**

A few BCI games based on imagined or actual movement do already exist. A first-person shooter game in which the user could move using the keyboard, and turn by imagined movement was designed. Players learned to control the BCI by experimenting; no instructions were given beforehand. Other examples include the virtual environments of Leeb et al. (2005) the board game of Kayagil et al. (2007) and the game BrainBasher

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