Chapter 5
Neurofeedback and Serious Games

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ABSTRACT

Neuroscience as well as computer gaming have rapidly advanced in the last decades. Yet, the combination of both fields is still in its infancy. One example of an emerging alliance is neurofeedback, where participants are required to learn controlling their own brain activity. So far, this kind of training is mostly applied in therapeutic settings, for example improving symptoms in epilepsy, attention-deficit/hyperactivity disorder, or autism spectrum disorder. However, there are some promising approaches that used neurofeedback in everyday situations for healthy subjects. This may prove especially valuable for serious games that aim to improve learning capabilities and cognitive aspects of individual users. The following chapter introduces the basic concepts and standards of neurofeedback. The different non-invasive imaging techniques are introduced along with successful applications in neurofeedback. Finally, benefits and pitfalls for future combinations of neurofeedback and games are discussed: while the former may profit from realistic and motivating video scenarios, the latter is expected to be a tool for evaluating and monitoring the direct effects on the user's brain.

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INTRODUCTION

In recent years, the number of neuroscientific studies trying to modify either behavioral or cognitive performance of people via the use of feedback training is rising enormously. There is ample evidence that the successful regulation of one's own brain activity can lead to improvements in either of those domains (Coben & Evans, 2010). As the term "feedback training" already suggests users are required to gain control over brain activity in repeated training sessions. This continued learning process can take about ten training sessions to achieve positive effects on cognitive performance (Vernon, 2005), whereas up to 30 or 40 training sessions are necessary to improve behavior such as attentional and self-management capabilities in children with attention-deficit/hyperactivity disorder (ADHD) (Gevensleben et al., 2010). Keeping the user's motivation high over prolonged time periods is thus one of the main challenges. Yet, traditional neurofeedback trainings generally use rather simple visual feedback modalities such as two-dimensional moving bars on a computer screen representing brain activity in real-time.

In this context, games offer a motivating, entertaining, innovative, and sensory rich alternative to traditional feedback modalities and seem to be well suited for feedback applications. While the primary purpose of conventional games is entertainment, we will refer to the term "serious games" as games that have educational and/or health-related aims besides entertainment (Wang, Sourina, & Nguyen, 2010, Breuer & Bente, 2010). The implementation of these kind of games or game elements in neurofeedback applications might proof beneficial in terms of maintaining motivation over repeated training session.

On the other hand, serious games may also benefit from neurofeedback: Physiological parameters of users can be recorded during gaming and directly fed back to the user. For instance, brain activation patterns can provide the user with feedback about one's current affective or arousal state, so that the user can determine whether he or she is in the right mood for learning. In this way, the ultimate goal of serious games, which is to optimize learning success, is further supported.

The aim of the present review is to discuss the usefulness of combining neuroscience and gaming. First, we will elaborate on neurofeedback concepts and their history. Second, we will elaborate on the benefits of combining serious games or game-elements and neurofeedback. In the third part of this review, we will describe different neuroimaging techniques and their application to neurofeedback. A comprehensive examination of the neuroscientific literature combining neurofeedback and game-like feedback modules will be presented. In the last part of this article we summarize our findings, present some possible limitations of neurofeedback and outline future perspectives.

BACKGROUND

Neurofeedback (NF) is a kind of biofeedback, also called neurotherapy in the literature (Lofthouse, Arnold, & Hurt, 2012). In NF applications, the user's brain activation is depicted in real-time with the goal of helping the user to gain control over specific aspects of the activity in his/her central nervous system. Hence, the user receives direct feedback about his/her actual brain activation pattern and consequently can learn to gain voluntary control over neural signals. By watching and listening to real-time multi-media representations of its own activity, the brain can modify its functionality and even its structure (Budzynski, Budzynski Kogan, Evans, & Abarbanel, 2009). The theory of NF often refers to these mechanisms as operant conditioning of brain activation (Kropotov, 2009): healthy, age appropriate brain activity is rewarded with visual, auditory or even tactile stimulation. In contrast, undesirable patterns of brain activity are ignored or even penalized (Coben & Evans, 2010).