Understanding and Proposing a Design Rationale of Digital Games based on Brain-Computer Interface: Results of the AdmiralMind Battleship Study

Alessandro Luiz Stamatto Ferreira, Juvane Nunes Marciano,
Leonardo Cunha de Miranda, Erica Esteves Cunha de Miranda
Department of Informatics and Applied Mathematics
Federal University of Rio Grande do Norte (UFRN)
Natal, RN, Brazil
alexmatto@ppgsc.ufrn.br, juvane@ppgsc.ufrn.br, leonardo@dimap.ufrn.br, erica@dimap.ufrn.br

***Abstract*—Brain-Computer Interfaces (BCIs) present great potential to the field of digital games, though the design of this kind of interface is still a challenge for most of the game designers and developers. In this work it is presented a literature review about digital games based on BCI, aiming to analyze the interaction design of these games, to identify the approaches applied, limitations and implications related to BCIs design. After the review, we accomplish a reflection about the design decisions involved in the development of digital games based on BCI. This approach leads to the construction of a design rationale developed to support the process of BCI-based games, with its use established on the design of a battleship game based on BCI. As contributions of this work, we highlight the literature review, design rationale and results of the study accomplished.**

***Keywords*—BCI, EEG, P300, SSVEP, HCI, designer.**

I. INTRODUCTION

The digital games industry is growing increasingly, attracting all kinds of people with innovations in several areas, such as hardware, software, 3D graphical interfaces and new ways of interaction. The scope of new interaction ways has motion sensors – e.g. Nintendo WiiMote sensors – accelerometers in smartphones, visual recognition of gestures – e.g. through Microsoft Kinect – and augmented reality. Even in this scope, one of the most promising interaction ways for the "future" is the one provided by Brain-Computer Interfaces (BCIs), which allows interaction desired by many users/players, i.e. control of games only through the brain, without using any physical artifact of interaction, even the innovative ones as the Adjustable Interactive Rings [35][36].

Nowadays, electroencephalography devices (EEG) are able to provide a BCI where the interaction is done by capturing the user's brain activity. The development of commercial[1] EEG headsets[2], for example, by NeuroSky (e.g., ThinkGear AM, MindWare, Mindwave Mobile and MindSet), by Emotiv (e.g., EPOC Neuroheadset and EEG Neuroheadset) and by BCINet (e.g., NIA Game Controller), allows end users to submerse in this "new" interaction paradigm, also in the context of digital games. The three most used detection techniques in BCI-based systems are: (i) **neurofeedback**, in which Alpha and Beta waves are used to estimate focus, relaxing/meditation and concentration of the user; (ii) **visual stimuli**, in which an element being watched by the user is recognized by detecting brain response to a visual effect that acts as stimulus; the detection depends on the visual stimulus used. A transient stimulation is characterized by elements that blink one by one and when the target element lights, that one observed by the user, the brain answers with a "surprise" wave – the P300 – detected by an EEG device. In an oscillating stimulus – called Steady State Visually Evoked Potential (SSVEP) – all visual elements blink simultaneously, each at a different frequency, which causes the user's brain to respond in a frequency similar to the frequency of oscillation of the target element; and (iii) **imagined movement**, in which it is possible to detect kinetic thoughts as, for example, the imagination of the user's right hand opening and closing, thanks to the synchronization and desynchronization of the Mu rhythm[3].

For this work, we start from previous results already achieved with accomplishment of research in the field of BCI. In [18], we describe the state of the art of interactive systems based on BCI, as well as present and discuss the main challenges of this domain. In the present work, our focus is to explore, specifically, digital games based on BCI, therefore, we investigate BCI in the digital games scenario, in order to identify approaches, its limitations, and implications related to the design of BCIs. Also, we develop a design rationale[4], which supports the design process of BCI-based games. Still, the developed design rationale, was applied in the design process of a battleship game explaining and discussing, in this study, the key issues in designing a BCI game.

[1] Information about each mentioned headset can be found, respectively, in: http://www.neurosky.com, http://www.emotiv.com, and http://www.bcinet.com.

[2] The term "headset" is used in this work to unify the various formats of capture devices that may include headbands, caps, bandanas, headphones and helmets.

[3] Mu rhythm is a pattern of brain electrical activity that occurs in the motor cortex, strongly related to the control of voluntary movements. A person suppresses this pattern when performing, imagining, or observing a motor action.

[4] Design rationale [27] is a document with an explicit listing of decisions involved in the design process. Each decision must contain the possible alternatives, their reasons and pro and con arguments.