Neuroresponsive Media: SSVEP-based Interactive Experiences

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Abstract. We aim at creating a new kind of experience whereby audiovisual content responds to participants' selections and preferences. We have developed a system that allows easily embedding flickering objects in 3D virtual environments. The system is integrated with an SSVEP-based BCI so that it detects when participants attend to the flickering objects. We have evaluted various types of stimuli, including moving stimuli and stimuli with high freqnencies, and implemented an audiovisual scenario of deep space in which various stars are used as BCI targets. We report on the results of our evaluation studies.

Keywords: EEG, SSVEP, BCI, virtual environments, fusion flicker threshold

1. Introduction

The field of human-computer interface is going through a paradigm shift, sometimes referred to as natural user interface (NUI). Brain-computer interfaces (BCIs) have the potential to become the ultimate interface; what could be more natural than controlling devices by thought alone? In practice, however, despite tremendous progress in the field, BCIs are still very difficult to control. In this research we aim at creating new kinds of BCI experiences that would be based on minimal participant effort, while retaining as much accuracy as possible. Specifically, we suggest a framework for audio visual experiences based on the steady-state visually-evoked potential (SSVEP) with BCI targets that are embedded inside the media content. Improvement of user experience is essential not only for healthy users of BCI, but also for patients who may want to use BCIs for various reasons from BCI to control devices.

SSVEP-based BCIs are usually based on low frequencies (5-20 Hz), while using analog stimuli display methods, such as light emitting diodes (LEDs). Our efforts are oriented towards using high frequencies on a screen, digitally and seamlessly embedded in media content. Frequencies higher than 35Hz are considered close or above the Critical Fusion Flicker Threshold (CFFT) – the threshold where a continuous flickering stimulus is perceived constant to the observer, an effect referred to as persistence of vision [Ferry et al., 1892]. BCIs based on high-frequency SSVEP have been successfully previously demonstrated [Wang et al., 2005] By using high frequency objects embedded in the media we aim to construct an interactive experience that can be more enjoyable than current SSVEP-based BCI. Moreover, our approach suggests a generic, flexible, and easy-to-use platform for future research and applications.

2. Material and Methods

2.1. System

We have used 8-channel EEG electrodes located on the subject’s occipital lobe (PO3, PO4, POz, PO7, PO8, O1, Oz, O2, and Fpz and right earlobe, using the 10-20 international system). The BCI hardware and software was developed by g.tec (Austria) and has been customized with their support. In addition, we use Unity (Unity Technologies, USA), a 3D game engine, to display the stimuli inside a virtual environment displayed on a back projected stereoscopic large screen ("power wall"). Since rendering speed is critical for accurate display of flickering stimuli we use a high end graphics card (Nvidia Quatro5000). The BCI system and the unity game engine communicate via a user defined protocol (UDP) over the Internet or over a local network.

In order to present frequencies reliably on a monitor or a projector one has to take into account the flickering refresh rate of the device itself. According to Nyquist’s sampling theorem [Nyquist, 1928], if N is the device refresh rate then it is possible to transmit frequencies as high as $N/2$. Given a frequency $m \leq N/2$, we define the square wave function $f(m)$:

$$f(m) = \begin{cases} 0, & \frac{x}{m} - floor\left(\frac{x}{m}\right) \leq 0.5 \\ 1, & otherwise \end{cases}$$

We sample *f(m)* and *x* in intervals of *1/N*, and *x* is incremented as an integer from *0* to *N*. This method enables us to represent all frequencies bellow or equal to *N/2* even if they do not divide *N*.

2.3. Procedure

A typical session has three parts: first the system computes a classifier, then we validate and improve the classifier with a cue-based classification task, and the third part is a free choice task. In a series of pilot studies we have explored various types of stimuli, varying mostly in shape, frequency, size, and motion, and have eventually settled on an immersive experience that includes a visualization of deep space. In the background there are small stars, intended to create the illusion that the user is moving in space (this experience is typically presented in stereoscopic display). Occasionally larger stars appear, and the user is expected to control these stars by "thought" There are four types of stars, each with different frequency; typically we use 17.1, 24, 30, and 40 Hz, using the 120 Hz projector. When an SSVEP response to a specific star has been detected, the star starts moving towards the user; otherwise it gradually fades out.

Figure 1. *A rich visual experience that includes controlling the behavior of stars with BCI.*

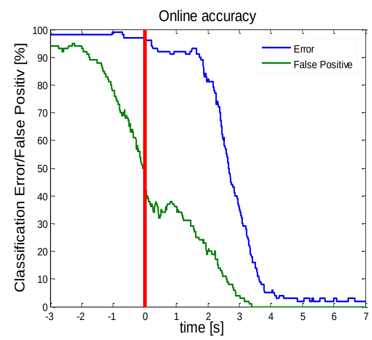

Figure 2. *Error rate and false positive classification, average of five subjects. Highest classification is after 3 seconds of stimuli appearance.*

3. Results

Ten subjects participated in the experiment (ages 24–50, 5 males and 5 females). All participants achieved 80% or higher classification accuracy rates in the cue-based BCI tasks. This is significantly above 25% chance level classification and thus establishes the validity of our display method. The highest rate of accuracy is obtained approximately 3 seconds after the stimulus appears (Fig. 2).

Our main focus is thus on the subjective experience in the free choice tasks. Subjects report that using the interface is very natural, and that the stimuli used for control are not intrusive; this is in sharp contrast to LED based interfaces. In dark lighting conditions even the flicker of 30 Hz stars is barely noticeable. We are now further studying issues of control, sense of agency, and experience in similar media experiences.

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