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Using Simulated Input into Brain-Computer Interfaces for User-Centred Design

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Abstract. Evaluation and testing of Brain-Computer Interface applications using an electroencephalogram is time-consuming and tiring for end users. This paper describes the process of developing a simulator for a paradigm based on visual event related potentials. Used as input into a real BCI application, we demonstrate that simulation at this level is useful for debugging applications and obtaining feedback from end users quickly. The simulator itself also fulfills a user requirement as it can be used to 'handicap' a healthy person, creating a level playing field in a game between both healthy and disabled users.

Keywords: Brain-Computer Interfaces, User-Centred Design, Evaluation, Human-Computer Interaction, ERP, P300

1. Introduction

The goal of User-Centered Design (UCD) is to produce solutions that match the real requirements of end users. Methods to achieve this include user evaluation, rapid prototyping and iterative design, where user feedback is obtained at different stages of the development cycle in order to improve successive versions of prototypes. These are essential in designing for users with special needs as the gap in knowledge of what users want is greatest for designers [Thimbleby, 2008]. However, UCD is difficult to apply to Brain-Computer Interfaces (BCIs) because they are time-consuming to set up. In addition, there are ethical issues with requiring users to test and evaluate systems for long periods of time, since the concentration required to use a BCI leads to fatigue relatively quickly compared to other input mechanisms. We seek to address this by developing simulators that replace the input of electroencephalogram (EEG) signals into BCI systems, allowing users to provide valuable insight into applications without discomfort. Here we describe the development of a visual event-related potential (ERP) simulator, demonstrating its use in debugging and evaluating a BCI-controlled chess game.

2. Material and Methods

Classifier output data for 10 subjects from the BBCI group at Berlin Institute of Technology was used to calibrate the simulator, having been collected during BCI experiments using a visual ERP paradigm [Treder et al. 2010]. For each trial, a sequence of stimuli was presented on screen in an oddball paradigm; participants were required to focus attention on an infrequent target stimulus while ignoring frequent non-target stimuli. The inter-stimulus interval (ISI) was fixed at 175 ms. The number of stimuli between two targets was randomized from 1 to 9, thus target-target intervals (TTIs) ranged from 175 ms to 1575 ms. Distributions of classifier output values for target and non-target stimuli were determined separately for different TTIs, for good, bad and average subjects. These distributions served as the calibration data of the simulator.

The simulator was controlled via a computer mouse, operating as a proxy for the user's visual attention, in order to play a chess game that normally was controlled by BCI (Fig. 1). By placing the mouse cursor above it, the desired target was indicated. At each stimulus presentation, the pixel beneath the mouse cursor was sampled so as to identify when a target stimulation occurred. Monte Carlo sampling was used to draw values from the experimentally derived classifier output distributions according to target selection and TTI. Instead of the normal output from an ERP classifier, the simulator outputs were fed into the chess application which currently was under development. A chess player who suffered from no motor disabilities was asked to evaluate the game, with the simulator modeled to produce values for a selection accuracy of 84%.

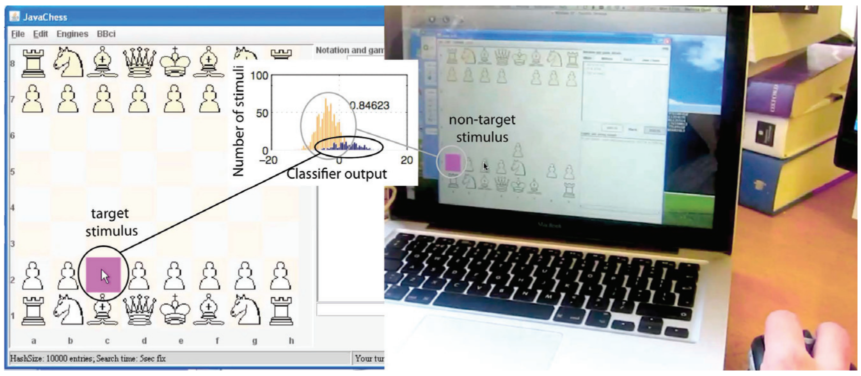

Figure 1. *Evaluating and debugging an ERP-based chess game using simulated BCI input, showing classifier output values being drawn from different distributions for target and non-target stimuli.*

3. Results

Classifier output means were found to increase with TTI, as in [Gonsalvez & Polich, 2002]**.** Output variance also increased with subject performance. Visual inspection using Q-Q plots and determining normality for each TTI using the Kolmogorov-Smirnov test indicated that the use of Gaussian distributions would be appropriate for simulation. Thus different means and variance for each subject were used as parameters for the classification output distributions for each TTI and for target and non-target stimuli, allowing us to model good, bad and average performance.

By using the simulator as input to the BCI, minor technical issues were identified that had not previously been known of. The chess player's evaluation of the chess game revealed major usability problems with the game. Lack of delays between selecting a chess piece and its target destination, and between players' turns, as well as the lack of feedback when chess pieces had been moved, contributed to a feeling of stress, confusion and de-motivation. The participant also commented that an 'undo' function was required since there were occasional errors in selection.

4. Discussion

User requirements can differ for healthy and disabled users [Thimbleby, 2008]. Although UCD techniques such as questionnaires and paper prototypes can help identify these, it is difficult to easily establish acceptance for individual applications given e.g. the high error rates in BCIs. We demonstrated that aside from debugging applications, use of a simulator that replaces real BCI input highlights usability problems that may be overlooked in isolation of a real BCI. Healthy participants can do initial evaluations to free precious time for discussing design issues that are specific to end users, based on informed knowledge of the actual system performance, yet without tiring too much.

In a recent video presentation of the simulated ERP chess game, a potential BCI user indicated that while playing a game against someone with no motor disability, he would like to have the opponent's input slowed down in order to play on the same level. This gives further motivation for developing simulators that model the low-level characteristics of BCIs. Further work on the ERP simulator should seek to model the distributions on additional factors such as different stimulus presentation methods.

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