



University
of Victoria

Graduate Studies

Notice of the Final Oral Examination
for the Degree of Doctor of Philosophy

of

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MSc (University of Victoria, 2011)
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“Event-Related Potentials as a Form of Neurofeedback Using
Low-Cost Hardware”

Department of Computer Science

Monday, July 25, 2016
8:30 A.M.
David Turpin Building
Room A136

Supervisory Committee:

Dr. Melanie Tory, Department of Computer Science, University of Victoria (Co-Supervisor)
Dr. James Tanaka, Department of Psychology, UVic (Co-Supervisor)
Dr. Colin Swindells, Department of Computer Science, UVic (Member)

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Dr. Michael Masson, Department of Psychology, UVic

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Abstract

The studies reported in this thesis demonstrate that low-cost hardware is capable of detecting neural responses to stimuli in the user's focus of attention, and that these responses increase in magnitude with training. Neurofeedback is a sub-category of biofeedback that is concerned with using brain signals as the source of training data in a feedback loop. The neurofeedback training procedures in this thesis focused on the P300 component, a time-locked event-related potential (ERP) that reflects the cognitive processes of attention and context updating. The current work provides preliminary evidence that neurofeedback based on rewarding correct P300 ERP is effective in increasing the magnitude of this response, which may address a specific reduction in the P300 response seen in individuals with ADHD.

Three main questions were examined: 1. Is the Emotiv Epoc, as an example of a low-cost consumer EEG, capable of reliably detecting the P300 component? 2. Is there a training effect whereby the P300 response gets stronger with practice? 3. To what extent is the P300 response affected by cognitive factors such as memory load and self-generation of prompts?

The studies employed an open source software framework—open source tools provide a transparent, crowd-supported means of conducting research, but are often difficult to initially use and the current thesis provides a guide within this content domain. The Emotiv Epoc headset was capable of detecting P300 ERP in a P3 speller task. The P3 speller is a well-studied paradigm in which users spell letters using only their thoughts as input, while the system determines the letter to be spelled by analyzing the strength and timing of the P300 ERP. In the training study, 12 participants completed five P3 spelling sessions. Although a P300 ERP training effect was observed, participant motivation and fatigue modulated this effect. In an attempt to improve motivation and increase interest in the task, a novel card game task was introduced. In this task—a variant of the card game “Concentration,” where players turn cards face-up one at a time to match pairs—the participants used a P300 attentional mechanism to select cards. This allowed for attentional training while offering a task whereby cognitive

difficulty could be manipulated. In these studies, the P300 ERP proved itself to be robust in regards to changes in cognitive difficulty, as well as internal versus external generation of prompts. This led to confidence in the separation of underlying cognitive and attentional processes and validated the focus of the P300 ERP on the attentional process.

The results indicated that ERP-specific neurofeedback is effective in increasing P300 magnitude, which is generally attenuated in attentional deficit hyperactivity disorders (ADHD). This dissertation does not involve any clinical populations as study participants, but the long-term potential of this research is to directly train a brain response relevant to clinical conditions. The paradigm can be implemented using low-cost hardware as opposed to research-grade instruments, which increases the likelihood of further research by the clinical community and lowers the barrier of entry for future exploration of the techniques.