

Better Brain Interfacing for the Masses: Progress in Event-Related Potential Detection using Commercial Brain Computer Interfaces

Dr M Grierson

Director of Creative Computing
Department of Computing
Goldsmiths, University of London
London, UK SE14 6NW
m.grierson@gold.ac.uk

Mr Chris Kiefer

Research Assistant
Department of Computing
Goldsmiths, University of London
London, UK SE14 6NW
c.kiefer@gold.ac.uk

Abstract

Event-Related Potential (ERP) techniques are commonly used by researchers from a range of disciplines including psychology and medicine to stimulate meaningful ERP signals from the brain and interpret them through Electroencephalography (EEG). ERP signals are in most cases able to reliably reflect cognitive processes, and are widely used in Brain Computer Interface (BCI) research. We present work in progress towards the application of these techniques to emerging consumer-grade BCI technology. Our approach has an impact on the reliability and usability of consumer Brain Computer Interfaces in commercial contexts, and is already being adopted by our industry partners in the games and entertainment sector. It could also significantly reduce the cost and complexity of certain types of large scale ERP research. This work is being undertaken by the Embodied AudioVisual Interaction (EAVI) group at Goldsmiths, University of London, and is supported by the Arts and Humanities Research Council.

Keywords

Brain Computer Interface, Neuroscience, P300, Event-Related Potentials, Industry, Art, Games, Entertainment, Neurosky

Copyright is held by the author/owner(s).
CHI 2011, May 7–12, 2011, Vancouver, BC, Canada.
ACM 978-1-4503-0268-5/11/05.

ACM Classification Keywords

H.5.2 User Interfaces: Input devices and strategies;
B.4.2 Input/Output Devices: Channels and controllers.

General Terms

Brain Computer Interface, Neuroscience, P300, Event-Related Potentials, Industry, Art, Games, Entertainment

Introduction

The majority of ERP BCI applications attempt to illicit and detect a specific ERP signal called the P300 [4,5]. It is partly because the P300 occurs in response to novel stimuli (particularly in the case of a type of P300 called the P300a/P3a), or stimuli that causes a break in a consistent pattern. If a range of options are presented to the user in a way that makes them appear novel, the user's current preference i.e. the target, can be detected. ERPs can be challenging to elicit and detect, as they are very difficult to differentiate from background noise in the EEG signal. Further to this, the quality of consumer BCI EEG technology is very poor when compared to the research-level equipment commonly used in such scenarios. Despite these problems, we have been able to make significant early progress in the application of ERP techniques using the Neurosky Mindset, a low cost, single dry electrode EEG-based BCI that is being targeted at the games and entertainment market.

Previous Work

Our previous BCI work focuses on interactive audiovisual applications of P300 BCI techniques, predominantly interactive sound and music. The author's P300 BCI for music [3] was developed using the G.Tec mobilab wireless EEG device, and has been widely reported in the international press [9].

Companies such as Emotiv [6] and Neurosky [7] produce dry electrode based EEG hardware aimed at the general public. These devices are in many ways low quality, but the dry electrode technology makes EEG signal acquisition convenient.

Campbell et al [1] have presented work demonstrating successful P300 ERP based BCI control of a contacts database on a mobile phone with a wireless headset. This work uses the Emotiv Epoch. Our approach is similar, but functions instead on the Neurosky Mindset – a single electrode consumer oriented BCI prototype. This is the first time P300 technology has been deployed on this device.

Method

At present we have only attempted to utilise existing, well understood, tried and tested ERP paradigms, known to elicit a P300 oddball response – a P3a.

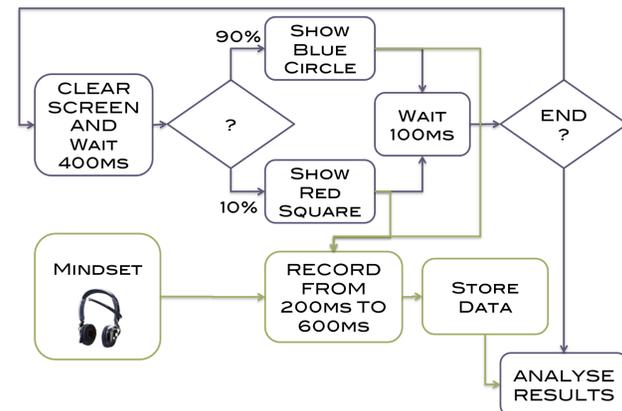


figure 1. Flowchart of the ERP paradigm used to test the Neurosky Mindset.

We used the Neurosky Software Development Kit (SDK) with the openFrameworks C++ creative coding toolkit [8] to create a template, which was capable of establishing a connection to the raw waveform detected by the device. This approach was taken to facilitate the future development of more complex audiovisual interaction softwares that use the Neurosky hardware, including 2d, 3d and multimodal ERP interaction scenarios. We ignored the available Neurosky filters entirely, apart from its primary filter, which appears to be excellent at detecting when the headset is properly positioned and receiving brainwave signals from the scalp with reasonably low-resistance.

We then used our template to create a C++ ERP paradigm detection library using conventional ERP averaging techniques (EAVI BCI Toolkit). This enables the rapid prototyping of a wide range of ERP detection scenarios, including the one shown above [fig. 1].

Various stimuli are flashed randomly on the screen at regular intervals. One of these is the target. In the case of the trial reported here, we used blue circles and red squares as the stimuli, with the red square being the target [fig 2].

Each time a flash is triggered, a 400 millisecond chunk of EEG data is stored and tagged to the stimulus. At the end of each run, results for each stimulus are averaged together.

If the averaged signal contains an amplitude peak within a reasonable range between 200 and 600 milliseconds after the onset of the stimulus, and the average area is greater than that of every other averaged peak area, it is judged to be a possible P300

target signal, as the target would be the peak with the highest average area under the peak [3]. This process is shown below [fig 2].

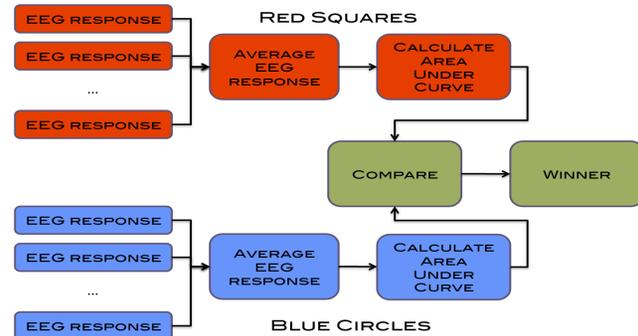


figure 2. Flowchart of the ERP averaging approach used.

Preliminary Results

Although we are still working to collect more results, we can report what appears to be 100 % accuracy in correctly detecting the red square as the target in the P300 detection paradigm described above. Through analysis of the brainwave data retrieved from the Neurosky Mindset, the red square target stimulus is always the winner. This is a very encouraging result, although we are well aware that this is an extremely simple example, and the stimulus types are not equal in size. However, it demonstrates that the device can indeed be used to differentiate the P300 signal from background noise in a common ERP paradigm.

This project benefits from industrial partnership with a UK games company specialising in the use of BCI. Following a recent demonstration of the technique described herein, they have begun work on using our ERP toolkit to develop commercial game prototypes

that use related ERP approaches for reliable and stimulating gameplay.

Discussion

Our results are significant, as the Neurosky Mindset is currently becoming very successful in the marketplace, and is simple enough to be reduced to a very small form factor for a variety of real-world consumer applications. Importantly, the Mindset electrode used in our tests is normally placed on the front of the head (roughly F1 in the international 10/20 system of electrode placement). F1 is not the best electrode position when attempting to measure P300 ERP signals. Depending on the type of P300 a researcher or developer may wish to measure, a higher, more central placement would be preferred. Fortunately, the Neurosky Mindset enables for the repositioning of the electrode, and their research devices can be used to create entirely bespoke single dry electrode headgear, allowing for more convenient electrode placement.

Applications of this work are not limited to commercial scenarios. It is clear that if these devices can be used to reliably conduct ERP experiments, they might have a genuine impact on psychology and psychophysics research.

Conclusion

We have presented work in progress that demonstrates the successful application of ERP detection techniques to low cost, single dry electrode EEG based BCI technology. This will significantly raise the chances of deploying more meaningful, usable and efficient BCI technology in an ever increasing number of consumer and real-world contexts, greatly improve the usefulness

and applicability of these devices with respect to meaningful Human Computer Interaction.

References and Citations

[1] Campbell, A et al : NeuroPhone: brain-mobile phone interface using a wireless EEG headset, proc ACM 2010.

[2] Grierson, M, Composing With Brainwaves: Minimal Trial P300 Recognition as an Indication of Subjective Preference for the Control of a Musical Instrument, Proc. ICMC 2008.

[3] Luck, S., "An introduction to the event-related potential technique". MIT Press, 2005.

[4] Nittoni, H., Nageishi, Y., Nakajima, Y., & Ullsperger, P., "Event-related potential correlates of individual differences in working memory capacity", Psychophysiology 36: 745-754 Cambridge University Press, 1999

[5] Woody, C.D., "Characterization of an adaptive filter for the analysis of variable latency neuroelectric signals". Medical and biological engineering, 5, 539-553, 1967

[6] <http://www.emotiv.com/>

[7] <http://www.neurosky.com/>

[8] <http://openframeworks.cc/>

[9] <http://news.bbc.co.uk/1/hi/technology/7446552.stm>