 DOI: 10.3217/978-3-85125-467-9-201

Towards Mobile and Wearable Brain-Computer Interfaces

[1]N. Arora, [1]I. Walker, [1]L. Freil, [2]J. Thompson, [1]T. Starner, [1]M. Jackson
[1]*Georgia Institute of Technology, Atlanta, Georgia, USA,* [2]*United Sciences, Atlanta, Georgia, USA*

*85 5th Street, Atlanta, Georgia 30308, USA. E-mail: melody@cc.gatech.edu

Introduction: Brain-Computer Interfaces (BCIs) have not been adopted as a control paradigm for mainstream use because most BCI systems are cumbersome, difficult to set up, and do not generally perform well enough in mobile settings to replace existing input modalities. However, BCIs may have promise as part of multi-modal systems that augment interactions when the user's hands are not free and/or voice commands are not possible, often a requirement in highly mobile application domains. With recent advances in electrode capabilities, and improvements in the processing power of mobile devices and head-worn displays, it is now possible to acquire, send and process EEG signals in real-time on mobile devices. These improvements make it possible to build a wearable mobile BCI, which could provide alternate interaction methods for mainstream users as well as the disabled population. This abstract describes two pilot studies in our ongoing work designing and evaluating wearable-mobile BCI components.

Material, Methods and Results: In our first study, our aim was to design a BCI to detect SSVEP with all wearable components. Google Glass [2], was used to present two flashing visual stimuli to the participant, at 13 Hz and 17 Hz frequency simultaneously. Our EEG amplifier was an OpenBCI board that we clipped to the participant's belt using a custom 3D printed clip. We used three electrodes: occipital (Oz) as signal, mastoid for ground, and the earlobe for reference, to detect the SSVEP signal. We recorded the EEG data for offline analysis. Over 10 sessions, using the apparatus illustrated in Figure 1, we could detect to which of the two stimuli our participant was attending to with 76%-84% accuracy for 13 Hz and 67%-72% accuracy for 17 Hz, for amplitude spectra from PSD as feature for 1 second long sliding window SSVEP using 10 cross-fold validation RF classifier trained on each stimuli individually. We extended the experiment for walk-stop-watch stimuli scenario and found the accuracy to be 93% for single stimuli 1 second long sliding window SSVEP.

Figure1. *Google glass with SSVEP stimuli and OpenBCI Board*

The aim of our second study was to determine if we could replace the scalp electrodes with easily made customized in-ear electrodes adapted from the ear-electrode design discussed by Looney [1]. We used an eFit scanner to create a model of the participant's left ear. We then 3D printed an earpiece, and placed 3 pre-gelled Ag/AgCl ground plate electrodes covered with silver foil so they would contact the walls of the ear canal in the outer ear. Resulting in-ear electrode and Oz for comparison was attached to the wearable OpenBCI system and a flashing 13Hz LED located 6 cm away from the user. As demonstrated in Fig 2, the peak SSVEP amplitude for the occipital region is higher than ear canal, but SNR increased as well thus resulting in comparable accuracy of detection of 80-90% from ear and scalp using a wearable BCI.

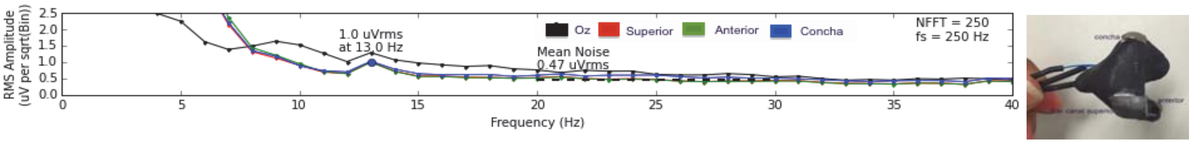

Figure 2. *(above) 13 Hz SSVEP responses from LED with occipital and ear electrodes. (right) Custom made earpiece with labeled electrode placements*

Discussion and Significance: The first prototype demonstrated that SSVEP signals could be collected from a fully mobile and wearable BCI system. Because the display was worn on the face and the bioamplifier was small enough to clip to a belt while still being capable of effectively detecting SSVEP, we conclude that it is now feasible to make a fully wearable BCI system using commercial components.

The second experiment demonstrated that we could substitute in-ear electrodes, making the BCI system smaller and less obtrusive. We have developed a quick, easy, inexpensive way to create custom ear-electrodes, which will enable our ongoing study to test a much wider range of users. Though there is more work to be done before wearable BCIs can be used in everyday life as simple control systems, these studies have shown the feasibility of the mobile and wearable approach.

References

[1] Looney, D., Kidmose, P., & Mandic, D. P. (2014). Ear-EEG: user-centered and wearable BCI. In *Brain-Computer Interface Research* (pp. 41-50). Springer Berlin Heidelberg.
[2] Starner, T. Project glass: An extension of the self. *Pervasive Computing, IEEE, 12(2)*, 14-16. 2013