Real-time Measurement of Integrated Multichannel EEG-ECVT in Pre-Frontal Lobe

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Abstract: Brain Electrical Capacitance Volume Tomography (ECVT) has been developed as an emerging non-invasive brain imaging method. As a new method, Brain ECVT needs to be compared with a standardized method such as Electroencephalography (EEG). In this study, a real-time measurement of integrated multichannel EEG-ECVT was done in pre-frontal lobe. The measurement was done during close open eye and arithmetic stimuli. The measured signal was filtered using bandpass filter. Power Spectral Density (PSD) analysis was used to compare the measured signal between Fp1 and Fp2 locations. PSD analysis shows the conformity of the signal between the multichannel and between EEG and ECVT measurement.

Keywords: electrical capacitance volume tomography, electroencephalography, brain functional imaging, non-invasive

1. INTRODUCTION:

The evaluation of human brain functions can be done in two ways: an invasive method and a non- invasive method. However, the invasive procedure has risks such as infection and bleeding [1]. to reduce those risks, non-invasive brain functional imaging methods have become a necessity. Up to now several instruments are being developed to evaluate the brain function non-invasively such as functional Magnetic Resonance Imaging (fMRI) [2], Single Photon Emission Computed Tomography (SPECT) [3], positron emission tomography (PET) [4], Functional near-infrared spectroscopy (fNIRS) [5] and ECVT [6]. For brain functional imaging instruments, there are several requirements such as real-time measurement, non-invasiveness and mobility or practicality. Also, there is resolution requirements which are temporal and spatial resolutions which need to be met. ECVT as an emerging brain functional imaging method meets all of those requirements [7]. Unfortunately, there has not been a real-time comparison between ECVT with a standardized instrument such as EEG. In this study, we did for the first time a real-time brain functional measurement using multichannel EEG and ECVT.

2. METHODS

In this study, we used two integrated Brain ECVT and EEG sensors as shown in Figure 1. Two EEG electrodes were placed at Fp1 and Fp2 in the 10-20 international EEG system. The EEG electrode placement is shown in Figure 2(a). The ECVT measurement was done using two pairs of electrodes located around the EEG electrodes. The setup of EEG-ECVT integrated sensor is shown in Figure 2(b). A cap was then placed on top of the sensor on the subject’s head to prevent the sensor from moving during the experiment. The complete setup of the EEG-ECVT integrated sensor is shown in Figure 2(c). The subject was asked to sit on a chair while undergoing two experiment stimuli. The experiment setup is shown in Figure 3. Each experiment lasted for three minutes. In the first experiment, the subject was asked to close the eyes for 30 seconds then to open the eyes for 30 seconds and to repeat the cycles until three minutes were up. In the second experiment, the subject was asked to relax by closing the eyes for 30 seconds then the subject was asked to solve as many arithmetic problems as possible in two minutes. The subject was asked to relax again afterwards for 30 seconds.

The ECVT transmitter signal used 100 Hz frequency and 20 Volt peak-to-peak amplitude. The EEG measurement used a unipolar configuration where each channel was referenced to A1 or A2 channel.

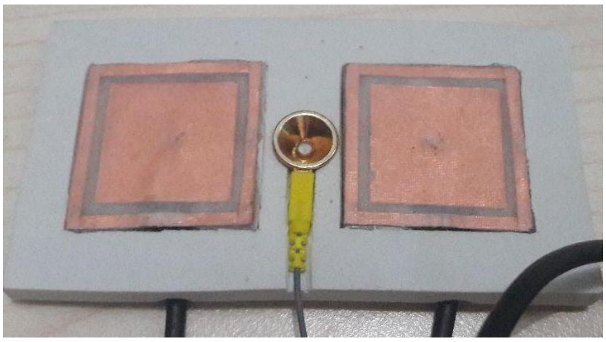


Figure 1. An integrated Brain ECVT and EEG sensor.

EEG signal was processed in EEGLab using bandpass filter between 0.5Hz and 35Hz and notch filter to remove the powerline frequency. PSD of the filtered EEG signal was calculated. Raw ECVT signal was processed in EEGLab using bandpass filter between 0.5Hz and 25Hz. The signal baseline was removed. Then, the filtered signal was analysed based on its power spectral density (PSD). Next, the PSD from EEG and ECVT signals was compared.

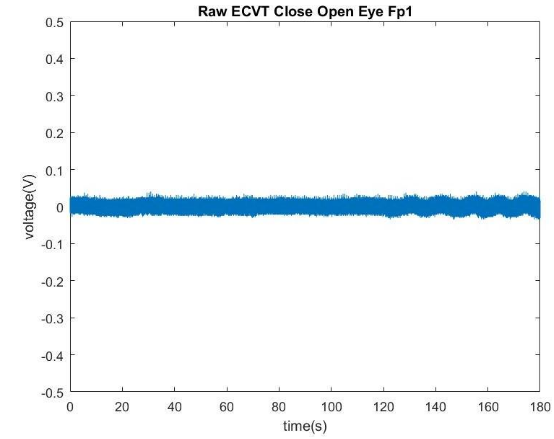
a b c

Figure 2. Integrated EEG-ECVT sensor placement on the subject's head.

Figure 3. Integrated multichannel EEG-ECVT measurement setup.

3. RESULTS

Figure 4 shows the raw signal from the ECVT measurement. Figure 4(a) shows the raw ECVT signal from Fp1 location during open close eye. While the raw ECVT signal from Fp2 location is shown in Figure 4(b). Figure 4(c) shows the raw ECVT signal from Fp1 location during arithmetic experiment. While the raw ECVT signal from Fp2 location is shown in Figure 4(d).



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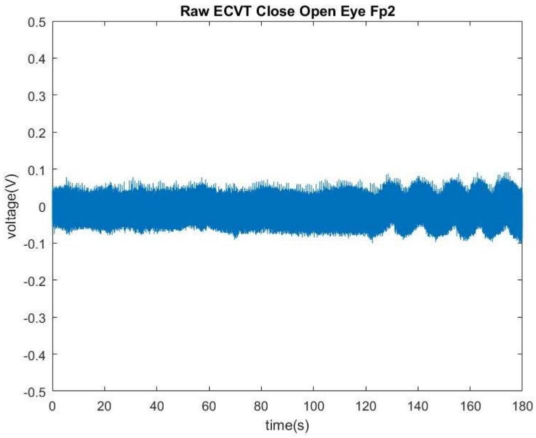

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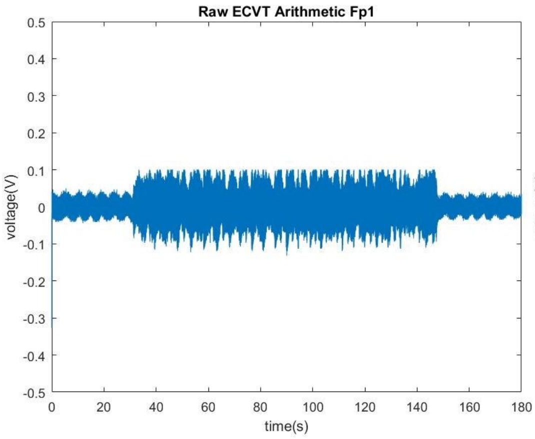

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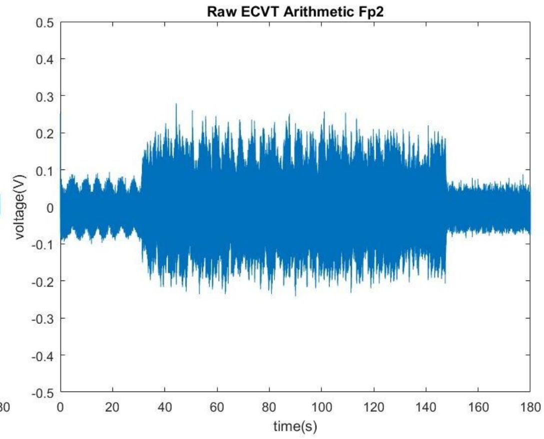
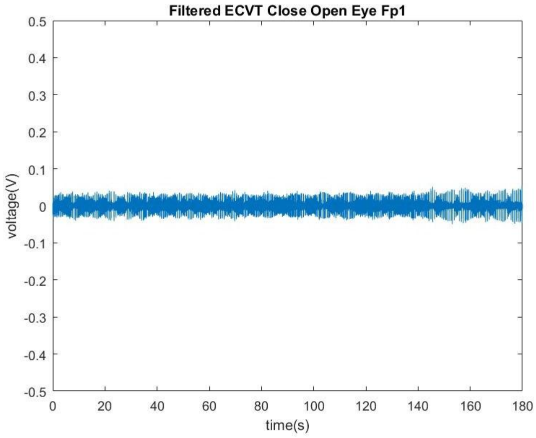


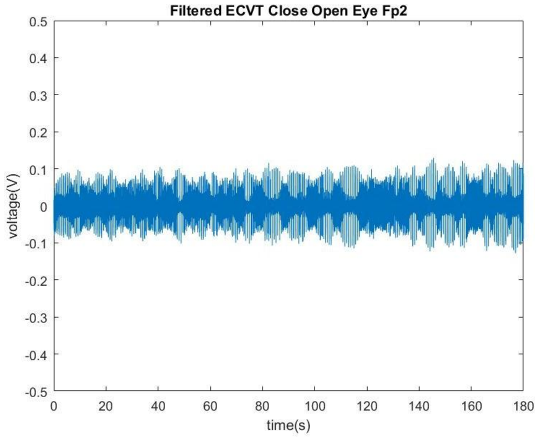
b

Figure 4. Raw ECVT signals.

Figure 5 shows the ECVT signal after being filtered using bandpass filter between 0.5 Hz and 25 Hz. Figure 5(a) shows the filtered ECVT signal during close open eye stimulus at Fp1 location. While the filtered ECVT signal from Fp2 location is shown in Figure 5(b). Figure 5(c) shows the filtered ECVT signal from Fp1 location during arithmetic experiment. While the filtered ECVT signal from Fp2 location is shown in Figure 5(d).



(a)



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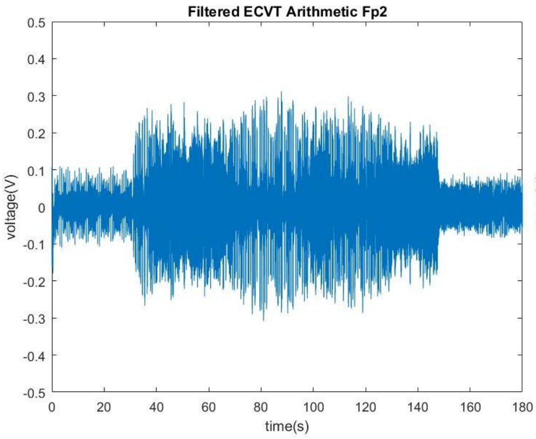

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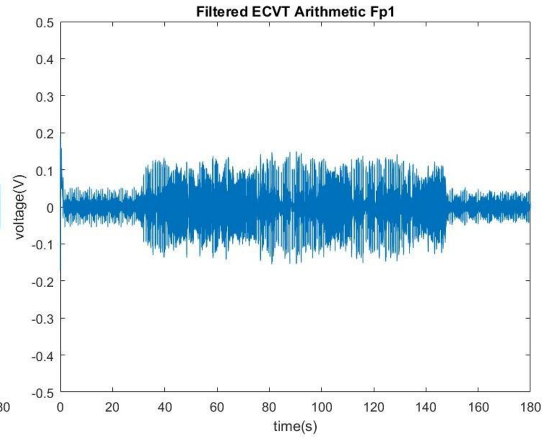
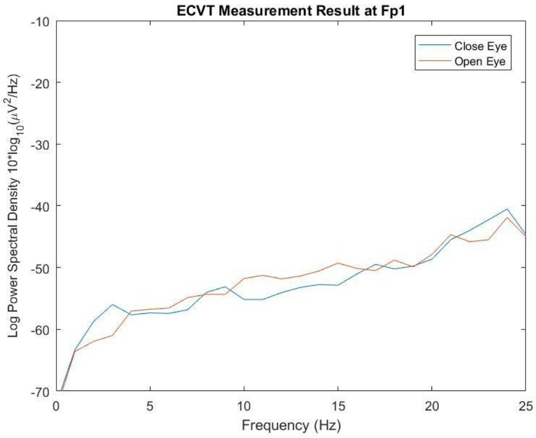
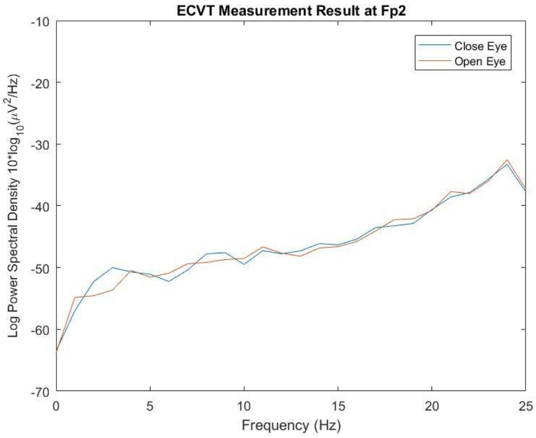


(d)

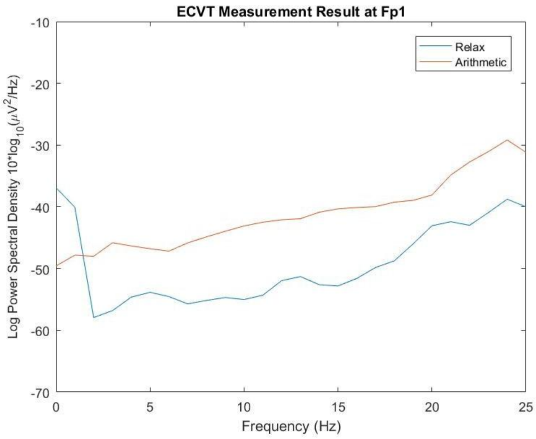
Figure 5. Filtered ECVT signals.

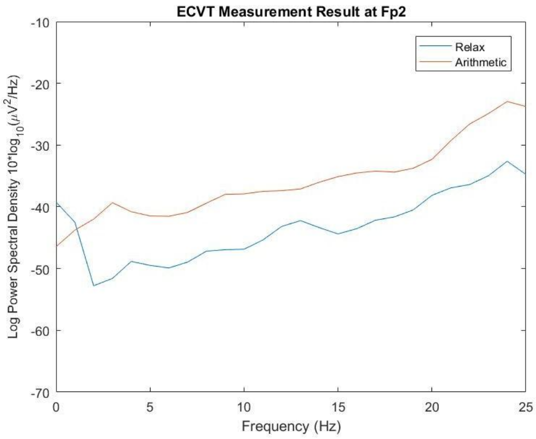
Figure 6 shows the Power Spectral Density (PSD) of the measured ECVT signal during close open eye and arithmetic task at Fp1 and Fp2 locations. Figure 6(a) shows the PSD of the ECVT signal during close open eye stimulus at Fp1 location. While Figure 6(b) shows the PSD of the ECVT signal during close open stimulus at Fp2 location. Figure 6(c) shows the PSD of the ECVT signal during arithmetic and relax stimulus at Fp1 location. While Figure 6(d) shows the PSD of the ECVT signal during arithmetic and relax stimulus at Fp2 location.





(a) (b)

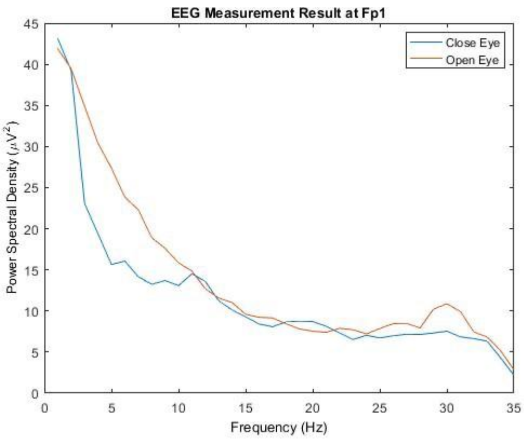


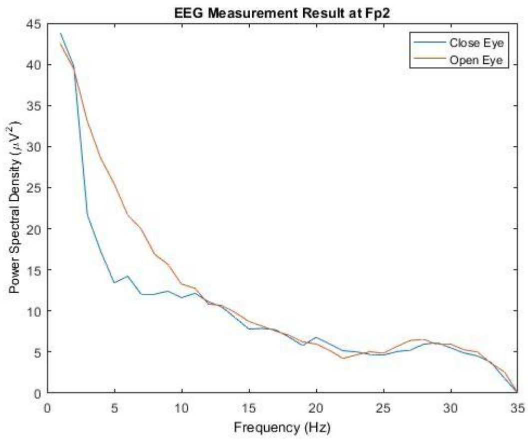


(c) (d)

Figure 6. Power spectral density (PSD) of the ECVT signals.

Figure 7 show the Power Spectral Density (PSD) of EEG Signal during close open eye at Fp1 and Fp2 channel. Figure 7(a) shows the PSD of the EEG signal during close open eye stimulus at Fp1 location. While Figure 7(b) shows the PSD of the EEG signal during close open eye stimulus at Fp2 location.





(a) (b)

4. DISCUSSIONS

This study is a continuation from the previous study where we used a single-channel sensor system. By looking at Figure 4, we could see that the raw ECVT signal from Fp1 and Fp2 locations is similar. However, the signal amplitude at Fp1 location tends to be smaller as compared to Fp2 location. This might be caused by the difference in standing capacitance between the ECVT electrodes. The raw ECVT signal during arithmetic stimulus has a visible difference in amplitude as compared to relax conditions before and after the task as shown in Figure 4c and 4d. This might be caused by the subject's hand movement which is required when typing the answers of arithmetic problems on a laptop computer.

The filtered ECVT signal in Figure 5 shows that the high frequency noise has been successfully removed from the measurement. However, the high amplitude signal during the arithmetic task remains as shown in Figure 5c and 5d.

The power spectral density (PSD) of ECVT signal in Figure 6a and Figure 6b shows no significant difference between close eye and open eye conditions for both Fp1 and Fp2 locations. On the other hand, the PSD of ECVT signal in Figure 6c and 6d shows a clear difference between relax and arithmetic conditions for both Fp1 and Fp2 locations. The PSD during the arithmetic condition is higher by 10 points than the PSD during relax condition.

The PSD of EEG signal in Figure 7a and 7b shows significant difference in frequency below 10 Hz where the PSD of open eye condition is higher than the PSD of close eye condition.

5. CONCLUSIONS

We performed an integrated multichannel EEG-ECVT measurement for the first time in this study. The PSD of the measured signal shows conformity between Fp1 and Fp2 channels for each experiment condition. The PSD of the ECVT and EEG signals also shows conformity for close open eye stimulus. Future work will include the EEG-ECVT multichannel measurement with all 10-20 international system electrode locations.

6. REFERENCES

[1] A. Gallagher, M. Lassonde, D. Bastien, P. Vannasing, F. Lesage, C. Grova, A. Bouthillier, L. Carmant, F. Lepore, R. Béland, and D. K. Nguyen, "Non-invasive pre-surgical investigation of a 10 year-old epileptic boy using simultaneous EEG-NIRS," *Seizure*, vol. 17, pp. 576-582, 2008.

[2] G. H. Glover, "Overview of functional magnetic resonance imaging," *Neurosurgery clinics of North America*, vol. 22, issue 2, pp. 133-139, 2011. doi:10.1016/j.nec.2010.11.001

[3] J. M. Warwick, "Imaging of brain function using SPECT," *Metab. Brain Dis.*, vol. 19, pp. 113-123, Jun. 2004. doi: 10.1023/b:mebr.0000027422.48744.a3. PMID: 15214511.

[4] A. Kumar, H. T. Chugani, "Functional imaging: PET," *Handb. Clin. Neurol.*, vol. 111, pp. 767-776, 2013. doi: 10.1016/B978-0-444-52891-9.00079-8. PMID: 23622224.

[5] R. E. Edison, U. Minako, D. Ippeita, D. Haruka, T. Daisuke, Y. Hidenori, O. Keiji, W. Eiju, "Determination of epileptic focus side in mesial temporal lobe epilepsy using long-term noninvasive fNIRS/EEG monitoring for presurgical evaluation," *Neurophotonics*,

vol. 2, issue 2, pp. 025003, 2015.

[6] R. Maharani, R. E. Edison, M. F. Ihsan, W. P. Taruno, “Average Subtraction Method for Image Reconstruction of Brain using ECVT for Tumor Detection,” *International Journal of Technology*, vol. 11, issue 5, pp. 995-1004, 2020.

[7] W. P. Taruno, M. R. Baidillah, R. I. Sulaiman, M. F. Ihsan, S. E. Fatmi, A. H. Muhtadi, F. Haryanto, and M. Aljohani, “4D brain activity scanner using electrical capacitance volume tomography”, *Proc. IEEE 10th International Symposium on Biomedical Imaging*, 2013, pp. 1006-1009.