 DOI: 10.3217/978-3-99161-050-2-127

Multimodal Multivariate Granger Causality Between EEG and fNIRS during an Auditory Task

J. McLinden[1]*, B. Adeli[1], A. Cerullo[1], M. Shao[2], K.M. Spencer[3], M. van 't Wout-Frank[4], Y. Shahriari[1]

[1]*University of Rhode Island, Kingston, RI, USA;* [2]*University of Massachusetts Dartmouth, MA, USA;* [3]*VA Boston Healthcare System and Harvard Medical School, Boston, MA, USA;* [4]*Department of Psychiatry and Human Behavior, Brown University and Butler Hospital COBRE Center for Neuromodulation, Providence, RI, USA*

*2 East Alumni Ave, Kingston, R.I., USA 02881. E-mail: john_mclinden@uri.edu

Introduction: Multimodal noninvasive neuroimaging approaches, most often relying on simultaneously recorded electroencephalography (EEG) and functional near-infrared spectroscopy (fNIRS), have garnered interest in both open- and closed-loop brain-computer interface (BCI) applications by providing complementary information underlying neural function [1,2]. However, effective connectivity between electrical (EEG) and vascular-hemodynamic (fNIRS) responses remains poorly understood. Here we developed a multimodal multivariate Granger causal (mMVGC) framework to investigate the causal interactions between electrical and vascular responses during an auditory processing task designed to elicit the auditory steady-state response (ASSR).

Material, Methods and Results: Data were collected from 17 healthy participants using 15 EEG electrodes and 14 fNIRS channels spread across the Frontal/Fronto-Central (F/FC), Left Auditory (LA), and Right Auditory (RA) regions of interest. The task consisted of 72 blocks of auditory stimuli (15s) followed by a 15s resting state period. A full description of the experimental task and montage is provided in [1]. After rejecting artifactual independent components extracted from band-pass filtered EEG data (0.5-55 Hz), the amplitude envelope of the Hilbert transform of narrow-band filtered EEG signals was extracted for the α (8-13 Hz), β (13-30 Hz), and ASSR (38-42 Hz) bands. EEG features and fNIRS data were down-sampled to 4 Hz, filtered 0.02-0.5 Hz, and averaged within ROIs. For EEG, only the FC ROI was included for further analysis. Epoched signals were detrended and the temporal and ensemble averages were subtracted from each epoch. The Bayesian information criterion (BIC) was used to estimate the optimal multivariate autoregressive model order. mMVGC was estimated for the task and resting state periods separately using the MVGC toolbox [3]. Values were compared across conditions by using a permutation test with false discovery rate (FDR) correction. Selected results of this test are presented in Fig. 1. MVGC in the direction originating from RA fNIRS to EEG in the ASSR band (p = 0.001, Cohen's d = 0.88) was significantly different between the task and rest conditions.

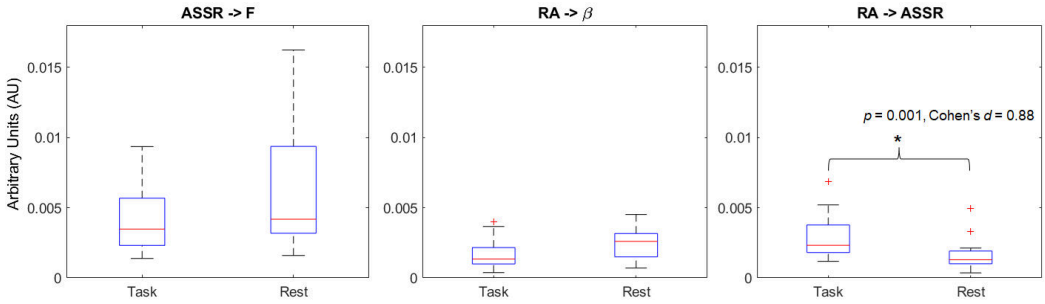

Figure 1: *Selected estimated MVGC values compared across the Task and Rest conditions. A significant difference between conditions was observed in the direction originating from RA fNIRS to EEG in the ASSR band, denoted with an asterisk (*).*

Conclusion: The difference across conditions in the direction originating from RA fNIRS to ASSR band EEG suggests that hemodynamic state in the auditory cortex may have a modulatory effect on the ASSR.

Acknowledgments/Disclosures: Study funded by the National Science Foundation [NSF- 2024418]

References:

[1] McLinden J, Rahimi N, Kumar C, Krusienski D.J., Shao M, Shahriari Y. Investigation of electro-vascular phase-amplitude coupling during an auditory task. *Computers in Biology and Medicine*, 169:107902, 2024.

[2] Hosni SI, Borgheai B, McLinden J, Zhu S, Huang X, Ostadabbas S, Shahriari Y. A Graph-Based Nonlinear Dynamic Characterization of Motor Imagery Toward an Enhanced Hybrid BCI. *Neuroinformatics,* 20(4):1169-1189, 2022.

[3] Barnett L & Seth AK. The MVGC multivariate Granger causality toolbox: A new approach to Granger-causal inference. Journal of Neuroscience Methods, 223:50-68, 2014.

 Published by Verlag der Technischen Universität Graz