Causal Relationship Analysis of Heart Rate Variability and Power Spectral Density Time Series of Electroencephalographic Signals

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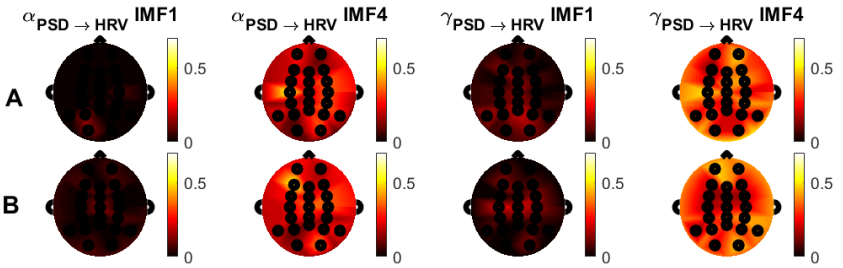
Aims: This study aimed to find whether there is G-causality between the power spectral density time series ($\mathbf{PSD}_{ts}$) of alpha, beta and gamma brainwaves and components of the heart rate variability (HRV), in order to determine the connectivity underlying the autonomic nervous system.

Methods: 21 EEG channels and one ECG derivation of 14 subjects were recorded during idle state and a controlled breathing task. The EEG signals were separated into alpha, beta and gamma frequency ranges and their $\mathbf{PSD}_{ts}$ were estimated. The RR intervals from the ECG were used to obtain the HRV signal, which was decomposed into intrinsic mode functions (IMFs). Granger causality tests were run for the $\mathbf{PSD}_{ts}$ of the brainwaves described and the HRV signals IMFs.

Results: A G-causal relation was found between the $\mathbf{PSD}_{ts}$ of alpha, beta and gamma waves and the HRV IMFs. As seen on the figure below, G-causality increased significantly for slower IMFs (IMF4). Also, gamma's $\mathbf{PSD}_{ts}$ G-caused HRV for a larger number of subjects and channels than the other frequency bands. Row A on the figure corresponds to idle state and B to the breathing control task, showing there was a larger incidence on the number of channels that G-caused HRV during the breathing control task.

Conclusion: There is a causal influence from the $\mathbf{PSD}_{ts}$ of EEG signals to the HRV IMFs, leading to believe there is an indirect or unobserved interaction between instantaneous changes on EEG power spectral density and components of HRV.



G-causality from each channel of alpha's and gamma's $\mathbf{PSD}_{ts}$ to the HRV IMFs 1 and 4. Row A shows idle state and row B the breathing control task.