Nonlinearity of the visual system assessed by cross-frequency phase coupling

Perenboom, MJL; Yang, Yuan; van der Helm, Frans; Ferrari, MD; Schouten, Alfred; Tolner, EA

DOI
10.1186/s40810-016-0021-4

Publication date
2016

Document Version
Final published version

Citation (APA)
Perenboom, MJL., Yang, Y., van der Helm, F., Ferrari, MD., Schouten, A., & Tolner, EA. (2016). *Nonlinearity of the visual system assessed by cross-frequency phase coupling*. 86-87. Abstract from 19th Biennial Conference of the International Pharmaco-EEG Society, Nijmegen, Netherlands. https://doi.org/10.1186/s40810-016-0021-4

Nonlinearity of the visual system assessed by cross-frequency phase coupling

Matthijs JL Perenboom[1*], Yuan Yang[3], Frans CT van der Helm[3], Michel D Ferrari[1], Alfred C Schouten[3,4], Else A Tolner[1,2]

[1]Department of Neurology, Leiden University Medical Centre, Leiden, The Netherlands; [2]Department of Human Genetics, Leiden University Medical Centre, Leiden, The Netherlands; [3]Department of Biomechanical Engineering, Delft University of Technology, Delft, The Netherlands; [4]MIRA Institute for Biomedical Technology and Technical Medicine, University of Twente, Enschede, The Netherlands

* M.J.L.Perenboom@lumc.nl

Background

Processing of visual input by the brain is a highly nonlinear operation, involving complex interactions among neuronal networks. Nonlinear visual system activity includes harmonic interactions, thought to reflect resonance of neural processing, whereas intermodulation, being the contribution of multiple input frequencies to one output frequency, relates to functional integration [1]. Using a sum-of-sinusoid signal as visual input [2], it is possible to elicit a richer class of nonlinear responses than the classic pulse train stimulus, thereby providing a more complete description of nonlinearity. Here, we will use nonlinear EEG analyses to quantify higher-order nonlinearities in visual processing.

Methods

Ten healthy participants were subjected to bi-sinusoidal light stimulation of 13 and 23 Hz for 320 1s-epochs, while scalp EEG (8 electrodes) was recorded at the occipital, parietal and frontal lobes. The frequencies of light stimulus were chosen to guarantee no overlap of their harmonic and intermodulation frequencies for different orders of nonlinearity. Nonlinear interactions and time delay from stimulus to cortex were analyzed in the frequency domain using novel phase synchronization measures [3] and amplitude spectrum.

Results

Higher harmonic and intermodulation interactions were detected between visual input and cortical responses. First to fourth order phase coupling interactions were enhanced in the visual cortex compared to parietal and frontal responses. Spectral amplitude differences were less pronounced between cortical regions. Time delay estimation showed a delay between light stimulus and visual cortex of 118±21ms, significantly higher than the delay between stimulus and frontal or parietal lobes.

Discussion

This study demonstrates the potential of using sum-of-sinusoid light stimulation and quantitative nonlinear EEG analysis to identify higher-order nonlinear dynamics of visual processing. We foresee that application of the described frequency interaction analyses

can further our insight in the nonlinear dynamics of visual processing not only in healthy subjects, but also with respect to the pathophysiology of neurological diseases with visual manifestations that relate to cortical hyperexcitability, like migraine and epilepsy.

References

1. Friston KJ. Book review: Brain function, nonlinear coupling, and neuronal transients. Neuroscientist. 2001 Oct 1;7(5):406-18.
2. Victor J, Shapley R. A method of nonlinear analysis in the frequency domain. Biophys J. 1980 Mar;29(3):459.
3. Yang Y, Solis-Escalante T, Yao J, Daffertshofer A, Schouten AC, van der Helm FC. A General Approach for Quantifying Nonlinear Connectivity in the Nervous System Based on Phase Coupling. Int J Neural Syst. 2016 Feb;26(01):1550031.