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REVIEW OF THE DOCTORAL THESIS

"Application of Independent Component Analysis to EEG and fMRI dara in separating distinct neural processes"

submitted by Ewa Beldzik, MSc

Ms Beldzik has submitted a cumulative doctoral thesis in the field of biophysics which is based on three studies successfully published in scientific journals with peer review. The thesis addresses the use of independent component analysis (ICA) to data reflecting human brain activity, specifically electroencephalography (EEG) and functional magnetic resonance imaging (fMRI).

In an introductory chapter, Ms. Beldzik provides the reader with background information on blind source separation methods, specifically ICA. She gives a concise historical overview of the development of ICA and its use in systemic and cognitive neurosciences. Furthermore, she discusses the advantages and limitations of the method of ICA and suggests approaches to overcome the limitations. After short summaries of the three empirical studies she ends the chapter with an outlook on future developments with a specific focus on multimodal imaging (e.g., simultaneous EEG and fMRI) and joint ICA.

Study 1, published in the renowned journal Clinical Neurophysiology, addresses the sources of event-related EEG activity associated with solving a numerical Stroop task. Dense-array (256-channel) EEG was recorded from 20 participants and subjected to temporal ICA at the individual subject's level. ICA was used to remove artifacts and to extract EEG activity related to functional processes assumed to underlie the solution of the task at hand. At the group level, independent components were subjected to a cluster analysis. The N450 event-related potential (ERP), previously found associated with response conflict in Stroop-like paradigms, was explained to a large extent by two sources: a midparietal cluster presumably originating in the posterior cingulate cortex (PCC) and a frontocentral cluster most likely generated in the anterior cingulate cortex. The integration of stimulus- and response-locked analyses suggested that the PCC source was associated with stimulus processing while the ACC seemed to be more engaged by performance monitoring functions. These findings are in line with current theories of cognitive control. In sum, the study confirmed that ICA of EEG data not only yield reliable and reasonable results but provides more information than conventional ERP analyses.

Study 2 addresses the brain networks underlying pro- and anti-saccadic eye movements. This study was published in the high-ranking journal Neuroimage. In this study, fMRI data was recorded from 15 participants while performing antisaccades and prosaccades in a blockwise fashion. Spatial group ICA was applied to the fMRI data, revealing a number of brain networks showing task-related activity variations, specifically the eye-field network, parieto-medial temporal network , an executive control network, and the default-mode network. The study provides novel insights into the neuronal implementation of processes involved in volitional eye-movement control, particularly inhibition and vector inversion. This study nicely demonstrates the utility of ICA for fMRI data. Yet, some inconsistencies with previous studies were found that required further analyses.

These issues were addressed in Study 3, which was also published in Neuroimage. In particular, some findings from the data-driven ICA approach seemed not to match the findings with the conventional, model-based general linear model (GLM) analysis. A new supplemental analysis method, contributive sources analysis (CSA) was developed and applied to shed light on network interactions that can result in contradictory or at least inconsistent findings of GLM and ICA. CSA

provides an estimate of the number and strengths of the neural networks detected with ICA that significantly contribute to the results of the GLM. It can verify cancellation effects due to interactions of different networks.

This is an excellent thesis that, in my view, fulfills all criteria for a dissertation. Ms. Beldzik has demonstrated her deep insights into the methodology of ICA and its use for analysis of electrophysiological and hemodynamic brain data. Her thesis makes a significant contribution to biophysics and neurosciences in several ways. On the one hand, there it clearly advances the analytical approaches. In particular, the novel method of CSA appears to be an important step forward. On the other hand, her work has revealed in insights into cognitive processes. A common theme is executive control, which is needed for successful, flexible and goal-directed behavior. Critically one could mention that Ms. Beldzik could have linked study 1 to the two other studies (2 and 3) more in the introductory chapter or a short final discussion.

In sum, this is an excellent work demonstrating Ms. Beldzik's ability to conduct scientific research on the highest methodological level. I thus strongly and without any hesitation recommend to approve the thesis and its release to the public defense.

Sincerely,

Prof. Dr. Markus Ullsperger

Magdeburg, January 5, 2015