Cichocki A., Cincotti F., Babiloni F., Mattia D., Marciani M.G., Fallani F.D.V., Bakardjian H., Yamaguchi Y., Astolfi L., Estimate of causality between cortical spatial patterns during voluntary movements in normal subjects, Proceedings of the 12th annual Meeting of the Organization for Human Brain Mapping, Florence, Italy, June 11-15, 2006.

Estimate of causality between cortical spatial patterns during voluntary movements in normal subjects

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Different non-invasive brain imaging techniques are presently available to provide images of the human functional cortical activity, based on hemodynamic metabolic or electromagnetic measurements. However, static images of brain regions activated during particular tasks do not convey the information of how these regions communicate to each other. Cortical connectivity estimation aims at describing these interactions as connectivity patterns which hold the direction and strength of the information flow between cortical areas. To achieve this, several methods have been already applied on data gathered from both hemodynamic and electromagnetic techniques. So far, the causality between brain signals have been assessed by using the time varying information derived from hemodynamic or electromagnetic signals recorded at the scalp or cortical level. However, the causality estimation from these brain functional waveforms will depict a single pattern of connectivity involving several brain areas, for each time segment or in every frequency band analyzed. Since it is well know that the brain does not produce any "single waveform" but rather engages several distributed cortical areas in order to process information, a question arose about the appropriateness of the estimation of the functional connectivity between waveforms . In particular, the question is whether instead to estimate the causality between single waveforms derived from the different cortical or scalp areas it is possible estimate the causality between "spatial patterns of brain cortical activations". In fact, it is reasonable to pose the question if it could be more interesting to estimate the causality (in the sense of the Granger) between the activation of distributed cortical systems or just observe the causality between isolated waveforms.

In this report we attempted to estimate the causality between distributed cortical systems during the execution of simple movements in a group of normal healthy subjects. To estimate the causality between the spatial distributed patterns of cortical activity in the frequency domains we applied a series of processing to the recorded EEG data. From the high resolution EEG recordings it was estimated the cortical waveforms in the ROIs selected for all the group population. The solution of the linear inverse problem returned a series of cortical waveforms for each ROI considered and for each trial analyzed. In each subject, the cortical waveforms were then subjected to the Independent Component Analysis. The independent components obtained by the application of the ThinICA algorithms were then processed by the Partial Directed Coherence (PDC) algorithm, in order to extract the causality between the spatial cortical patterns of the estimated data. Such couples of cortical patterns were obtained for each one of the four frequency bands employed here; theta (4-7 Hz), alpha (8-12 Hz), beta (12-30 Hz) and gamma (above 30 Hz). Cortical patterns estimated suggest the involvement of a large network of parietal and premotor areas in the beta band. These results are the first that demonstrates the involvement of a group of cortical areas that "causes" the activation of a second group of cortical areas for a simple motor task.