Sleep: A single-sensor automatic sleep-stage classification based on cross-frequency coupling

S. Dimitriadis[1,2,3], C. Sallis[4], D. Linden[1,2,3,5]
[1]*Institute of Psychological Medicine and Clinical Neurosciences, Cardiff University School of Medicine, UK*
[2]*School of Psychology, Cardiff University School of Medicine, UK*
[3]*Cardiff University Brain Research Imaging Center, School of Psychology,, Cardiff University, UK*
[4]*Department of Informatics and Telecommunications Engineering,, University of Western Macedonia, Greece*
[5]*Psychology, Neuroscience and Mental Health Research Institute (NMHRI) Psychology, UK*

Clinical specialists of sleep often score manually the sleep stages by visually inspecting the characteristic waveforms of a patient's neurophysiological signals like electroencephalogram (EEG), electrooculogram (EOG), electrocardiogram (ECG) and electromyogram (EMG). The whole approach of sleep scoring the neurophysiological recordings of a patient last over eight hours is a very demanding, difficult and time consuming procedure. Complementary, the limitations of manual sleep stage scoring have forced the scientists to develop techniques based on signal processing and machine learning for a completely Automatic Sleep Stage Classification (ASSC). Our first aim was to propose a novel EEG single-sensor ASSC based on dynamic reconfiguration of cross-frequency coupling (CFC) estimates using three different algorithms for the estimation of phase-to-amplitude coupling (PAC). The dynamic PAC (dPAC) was estimated between predefined frequency pairs applied to 10 s epoch lengths. We attempted to predict sleep stages (non-REM:N1,N2,N3,N4 ,REM:R) and wake (W) condition simultaneously as a six-class classification problem applied to 10 s epoch lengths. The proposed analytic scheme was demonstrated using the PhysioNet Sleep European Data Format (EDF) Database using sleep recordings from 41 subjects. The presented methodology achieved an absolute classification sensitivity, specificity and accuracy of 90.3 ± 4.1%, 94.2 ± 4.1%, and 94.6 ± 4.2%., respectively, when multi-class Bayes Naive classifier is applied. Finally, our novel method was compared with those in recently published studies, enhancing further the high classification accuracy performance presented here.