Instantaneous Assessment of Depressive State in Bipolar Patients by Point-Process Nonlinear Models of Heartbeat Dynamics.

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Abstract—Within the conceptual framework of the European funded project PSYCHE, we present a novel experimental/methodological approach for the assessment of autonomic patterns of depression in bipolar patients. A novel Point-Process-based Nonlinear Autoregressive Integrative model is applied to analyze heartbeat data, demonstrating that the inclusion of instantaneous nonlinear features significantly improve mood discrimination accuracy.

Introduction: Bipolar disorder is a psychiatric condition in which patients experience episodes of mood swing, such as oscillations between depressive states and euthymic states (i.e., relatively good affective balance). Despite its prevalence, this illness may go undetected for years. Moreover, the patient’s diagnosis is mainly performed by clinician-administered rating scales and no biological markers nor physiological signals highlighted in research studies are used for clinical purposes. The goal of our research is to be able to accurately recognize depressive states in bipolar patients from the analysis of the heartbeat dynamics. Data were gathered within the European project PSYCHE (Personalised monitoring SYstems for Care in mental HElth) using wearable systems such as textile-based sensorized t-shirt.

Methods: We propose a novel methodological approach based on a point-process nonlinear derivative model. This powerful, fully-parametric statistical tool accounts for the probabilistic generative mechanism of the heartbeat, further considering a quadratic Wiener-Volterra representation of the first order moment of a physiological plausible inverse-gaussian statistics and allowing the estimation of the instantaneous autospectrum and bispectrum even in short recordings and under nonstationary conditions. As the framework is defined in continuous time, it is possible to estimate instantaneous heart rate and heart rate variability indices without using any interpolation method. Kolmogorov-Smirnov (KS) test and quantiles’ autocorrelation plots are used to evaluate the model goodness-of-fit and to test independence of the model-transformed intervals, respectively. By integrating the obtained instantaneous spectrum, it is possible to compute the HRV index within the LF (0.04-0.15 Hz) and HF (0.15-0.5 Hz) ranges along with their ratio, which has been taken as index of sympatho-vagal balance. Similarly, the double integration performed on the bispectral plane in the appropriate frequency bands can be interpreted as an index of nonlinear interactions within the sympathetic system (LL index), nonlinear interactions within the parasympathetic system (HH index), and nonlinear interactions between the sympathetic and parasympathetic systems (LH index).

Experimental Protocol: The point process was applied to data coming from three bipolar patients having a "mood label" ("euthymia" or "depression") undergoing a dedicated affective elicitation protocol. The dedicated affective elicitation protocol started with two five minutes lasting phases of resting state, with eyes closed and open respectively. Subsequently, a passive emotional elicitation by images gathered from the International Affective Picture System and the Thematic Apperception was performed.

Results: The optimal model order was chosen by means of the Akaike Information Criterion applied to the first 5-min RR recordings. Three out of the four KS plots were inside the confidence intervals and all the KS distances were < 0.0375. No less than 97% of the autocorrelation points were inside the boundaries. An inter-subject analysis was performed to reveal the common mood pattern among patients using the well-known Multilayer Perceptron Neural Network. A first feature set, \( \alpha \), was composed by only the standard HRV feature set (mean, standard deviation, LF, HF, LF/HF), whereas the nonlinear indices (LL, LH, and HH) were added to the \( \alpha \) set to create the second set, \( \beta \). A classification accuracy of 93.26% for the \( \alpha \) set, and 99.33 % for the \( \beta \) set was achieved. Therefore, a common pattern of heartbeat features was found despite the inter-subject variability. Results clearly demonstrate the importance of the inclusion of the nonlinear indices in improving the discrimination. Moreover, the inclusion of the nonlinear indices gives smaller variance with respect to the classification performed by using only \( \alpha \) sets (i.e. the standard features). Given their preliminary nature, these results are very promising. The proposed point-process nonlinear analysis represents a pioneering study in the field of mood assessment in bipolar patients.

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