Seeking for a fingerprint: analysis of point processes in actigraphy recording

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I. ABSTRACT

Despite numerous studies indicating anomalous temporal statistics and scaling in spontaneous human activitity and interhuman communication, there is much on-going discussion on the origin and universality of observed statistical laws. Behavioral processes are frequently conveniently characterized in terms of stimulus-response approach[1,2], by adapting a systematically repeated, the same external sensory protocol which allows to estimate the statistics of subject's responses. In a more general attitude, in which brains are conceived as information processing output-input systems[3,4], the observed self-similar temporal patterns of non-stimulated spontaneous neuronal activity can be determined by analyzing spatio-temporal statistics of location and timing of neural signals. Similar to scale-free fluctuations detected in psychophysical time series, also dynamics of collective neuronal activity at various levels of nervous systems exhibit power-law scalings. Remarkable scale-free fluctuations and long-range correlations have been detected on long time scales (minutes and hours) in data recorded with magneto and electroencephalography and have been attributed to the underlying dynamic architecture of spontaneous brain activity discovered with functional MRI (fMRI) and defined by correlated slow fluctuations in blood oxygenation level-dependent signals.

On the other hand, negative deflections in local field potentials recorded at much shorter time scales (milliseconds) have been shown to form spatiotemporal cascades (neuronal avalanches) of activity, whose size (amplitude) and lifetime distributions are again well described by power laws. These power-law scaling behaviors and fractal properties of neuronal long-range temporal correlations and avalanches strongly suggest that the brain operates near a critical, self-organized state[3] with neuronal interactions shaping both, temporal correlation spectra and distribution of signal intensities. It seems thus plausible to further investigate timing, location and amplitudes of such cascades to gain information about underlying brain dynamics and to identify characteristics of stochastic spatial point processes which can serve as reliable models of the ruling dynamics.

Some neurological and psychopathic diseases such as Parkinson disease, vascular dementia, Alzheimer disease, schizophrenia, chronic pain and even sleep disorders and depression are related to abnormal activity symptoms. So far there are many, non-unique evaluative measures used in clinical practice to determine severity of these disorders or the effect of applied drugs. The challenge thus remain to what extent correlations during resting state (spontaneous) activity are altered in disease states and whether a set of characteristic parameters can be classified unambiguously to describe statistics of healthy versus unhealthy mind states and spatiotemporal organization of such disrupted brain dynamics.

Motor activity of humans displays complex temporal fluctuations[5,6] which can be characterized by scale-invariant statistics, thus documenting that structure and fluctuations of such kinetics remain similar over a broad range of time scales. Former studies on humans regularly deprived from sleep or suffering from sleep disorders predicted change in the invariant scale parameters with respect to those representative for healthy subjects. In these studies we investigate the signal patterns from actigraphy recordings[5] by means of characteristic measures of fractional point processes. We analyze spontaneous locomotor activity of healthy individuals recorded during a week of regular sleep and a week of chronic partial sleep deprivation. Behavioral symptoms of sleep lack can be evaluated by analyzing statistics of duration times during active and resting states, and alteration of behavioral organization can be assessed by analysis of power laws detected in the event count distribution, distribution of waiting times between consecutive movements and detrended fluctuation analysis (DFA) of recorded time series. We claim that among different measures characterizing complexity of the actigraphy recordings and their variations implied by chronic sleep distress, the exponents characterizing slopes of survival functions in resting states are most effective in determining biomarkers distinguishing between healthy and sleep-deprived groups.

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