Vigilance-state dependent differences in Lempel-Ziv complexities obtained with different signal coarse-graining techniques.

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Abstract:

Different behavioural states are associated with changes in neuronal network function and characterised by specific spatiotemporal patterns of cortical activity, although their functional significance for information processing during waking and sleep is not entirely clear. Non-linear analysis of electroencephalogram (EEG) or local field potential (LFP) signals with Lempel-Ziv complexity (LZC), a measure of complexity based on coarse-graining of the signal, can provide valuable insights into understanding brain activity.

LFP recordings and single- and multi-neuron activity were collected with microwire arrays implanted in the frontal cortex of 7 adult male Wistar-Kyoto rats in undisturbed waking and sleep. The amount of vigilance states was 476.57±67.5, 709.71±158.4 and 194.67±19.5 s for waking (W), NREM sleep (N) and REM sleep (R), respectively. LZC was computed with two coarse-graining methods, k-means (LZCkm) and median (LZCm), over consecutive 4-s epochs. Results were lower in NREM sleep but almost identical between LZCkm (W: 0.46±0.046, N: 0.25±0.031, R: 0.47±0.027) and LZCm (W: 0.46±0.046, N: 0.25±0.030, R: 0.47±0.026). LZC values in NREM sleep correlated negatively with LFP slow-wave activity (SWA, spectral power between 0.5-4 Hz). While on average LZCkm and LZCm results were similar, they deviated in a subset of 4-s epochs. The average proportion of epochs where absolute difference between LZCkm and LZCm values exceeded 10% was 2.7±2.4% (W), 16.8±4.3% (N) and 1.3±1.2% (R). For NREM sleep the average absolute firing rates were lower in epochs where the difference between LZCkm and LZCm values exceeded 10% (5.9±0.7 Hz vs 6.54±0.7 Hz, p=0.0461, paired t-test). The LFP signal variance and SWA showed higher values in epochs where LZCkm and LZCm were different (variance: 81.8±16.9 vs 58.3±13.9 uV, p=0.0351, paired t-test; relative SWA: 121.5±2.6 vs 95.1±1.5 % of mean SWA over all epochs, p= 7.3030e-004, paired t-test).

Different coarse-graining approaches have only marginal overall influence on the resulting LZC values. However, when there was an effect, signals also differed in terms of temporal structure, spectral content and underlying neuronal activity. Thus, interpreting LZC results should take into account the coarse-graining algorithm.

Keywords: Lempel-Ziv complexity, k-means, local field potential, sleep