

Specific and accurate quantitative EEG predictions are largely missing from the literature. We sought to make accurate quantitative predictions based on a new information-theoretic approach to electroencephalography. Traditionally, the measurement of information in the EEG is unusually difficult due to the fact that the physical encoding of informational symbols is unknown. Stated mathematically, the domain of the information random variable is not known. To solve this problem, we invented a method to estimate the Tsallis information in EEGs despite this missing knowledge.

This method is based on two results. The first result is that the physical instantiation of an informational symbol must begin and end at a critical point (maximum, minimum, saddle point) or discontinuity in the physical data. For example, this piece of paper contains information which is instantiated by black ink on white paper. There is a discontinuity in luminance from the white of the paper to the black of the ink. Similarly, neural “spikes” occur at discontinuities (actually maxima) in the voltage output of a neuron. This result indicates that EEG informational events begin and end at each maxima/minima of the EEG waveform. Thus, EEG events are identified by partitioning the data of the EEG waveform into intervals which begin at one maxima/minima and end at the next maxima/minima. This partitioning of the data separates it into individual occurrences of informational events.

Our second result is based on an optimality assumption. We assumed that the probability of an EEG informational event is inversely proportional to its power. We have shown that the probability of this event is (to a good approximation) directly proportional to the variance within of the time-varying voltage contained in this informational event. Together, these two results allowed us to estimate the Tsallis information (a non-extensive generalization of the Shannon information) in the EEG.

We used this method to measure the information in the EEGs of subjects who were either normal aging or had very early Alzheimer’s Disease (AD), often called Mild Cognitive Impairment. Subjects’ EEGs were recorded while they performed a memory task (delayed recognition). We compared the information in their EEG recorded in the frontal part of the brain to that in the posterior. This comparison was made by computing the ratio of the frontal information to the posterior information. A cohort of 48 subjects was tested. This resulted in a disease/no disease classification accuracy of 92%. We also performed a matched sample analysis. This analysis accounted for the possible confounds of medication treatment (cholinesterase inhibitor) and age. It was performed on a cohort of 20 individuals. The specificity, sensitivity and total accuracy of this analysis was 100%. These results are the most accurate in the literature. On the other hand, when the same method was applied to the same subjects engaged in a non-memory task, the perception of structure-from-motion, our detection accuracy was no better than chance; 58%. Interestingly, the information in the EEG recorded from the frontal part of the brain was always higher than that in the posterior part of the brain for the healthy subjects in this matched sample analysis. However, it was always lower for the AD subjects. To the extent that this EEG information corresponds to the neural information processing during recognition memory, it suggests that a healthy brain will have more frontal information than posterior information during a recognition memory task.