The impact of electroencephalogram (EEG) reference selection on information-theoretic complexity and integration measures of EEG signals

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Bieber K. The impact of electroencephalogram (EEG) reference selection on information-theoretic complexity and integration measures of EEG signals. J Behav Neurosci Res. 2021;4(5):22.

PERSPECTIVE

According to accumulating evidence, human cognition and behaviour are the results of brain networks interacting on local and global sizes. The functional segregation (specialized information processing within regional groups of brain areas) and integration (the combination of that specialized information across scattered brain regions) of the brain networks are reflected in these different scales of neural activity. Furthermore, due to the dynamic interplay between segregation and integration, the architecture of these brain networks is extremely complicated. The term neural complexity refers to a high number of coordinated interactions between brain parts at various levels of subordination that are neither completely regular nor completely random. Information theory is used to characterize neural activity in terms of deviations from statistical independence among components of a neural system, which is one way to measure segregation, integration, and complexity in the brain. In this study, we look at two information-theoretic measures that have been used to analyze Electroencephalographic (EEG) data. The first metric known as integration, is a multivariate measurement of the overall divergence from statistical independence of specific system constituents. The second criterion is interaction complexity. Confidence intervals are a statistical measure of a system's information content derived from interactions between its constituents. The link between complexity and integration is non-monotonic and follows an "inverted-U" shape. When system components are fully statistically independent, complexity is low at low integration values, when there is heterogeneous statistical dependence among system components, complexity is high at intermediate integration values and when system components are fully statistically dependent, complexity is low at high integration values. These tests were forerunners to the segregation and integration tests that are now employed in the integrated information theory of consciousness and brain function. It's crucial to understand how the various parameters of Electroencephalographic (EEG) measurements influence confidence intervals and integration for them to provide useful insight into the brain networks controlling cognition and behavior. This makes it possible to test the reliability and validity of confidence intervals and integration in a variety of measurement settings. The reference scheme or montage is an important Electroencephalographic (EEG) measuring parameter. The Electroencephalographic (EEG) signal is the difference between two voltages, one at the electrode site of interest and the other as electrically neutral as feasible concerning the signal of interest. Because different reference choices may or may not be electrically neutral depending on location, participant activity, and the neurocognitive function under examination, the choice of Electroencephalographic (EEG) reference is well-known to alter signal quality. The dependability of the signal statistics from which these confidence intervals and integration measurements are calculated should be affected by the impact of Electroencephalographic (EEG) reference on signal quality. Furthermore, confidence intervals and integration index the interaction between various brain signal elements, interdependencies that can be artificially exaggerated at the scalp level due to the impacts of cortical Electroencephalographic (EEG) source signal volume conduction across the head. Volume conduction may alter scale Electroencephalographic (EEG) measurements done concerning different reference schemes to varying degrees, which should affect the degree to which these complexity measures reflect true or artefactual complexity and integration. If such complexity and integration metrics are to be effective when applied to scalp-recorded Electroencephalographic (EEG) data, it must first be established that they are reliable and stable when compared to other Electroencephalographic (EEG) references. Unfortunately, there isn't any research like this in the current literature. Van Putten and Stam analyzed scalp recorded Electroencephalographic (EEG) signals gathered during a resting state task using integration and another Electroencephalographic (EEG) complexity measure called neural complexity (which is related but not identical to interaction complexity) (eyes-closed and eyes-open condition). To decrease idiosyncratic reference effects and volume conduction effects, the Electroencephalographic (EEG) data were referenced to an average reference and a source reference (computed as the voltage difference between the recording site and the mean voltage of 3-4 nearby recording sites). Although the overall between-condition pattern was the same for both references (higher integration and confidence intervals for eyes closed than eyes open), the magnitude of integration and complexity for the source reference was lower than the average reference. The purpose of this study was to look into the effect of electroencephalographic reference on the quantification of electroencephalographic integration and complexity in greater depth. Human participants sat in a wakeful resting condition and had their scalp electroencephalographic recorded in 72 channels (interleaved counterbalanced eyes-open and eyes-closed blocks). To compare and check data integrity and quality, we computed confidence intervals and integration of the electroencephalographic signals, as well as a traditional electroencephalographic measure of resting-state activity Fourier-based Power Spectral Density (PSD). We used four distinct electroencephalographic reference methods to calculate the information-theoretic and spectral power metrics. The first was the Linked-Mastoids (LM) reference, which is made up of the mathematical average of signals from electrodes on each ear's mastoid bones. The Average (AVG) reference, which was calculated by averaging the signals from all electrodes and then removing the averaged signal from each electrode individually, was the second scheme. The third technique involved transforming raw electroencephalographic potentials into a measure of radial current density at the scalp using a Laplacian (LAP) reference-free transformation. Finally, an Infinity (INF) reference was developed, which employs the Reference Electrode Standardization Technique to approximation translate a scalp point reference (or average reference) to a reference point at infinity. Rest accomplishes this by computing the actual or similar brain sources for a set of electroencephalographic signals and then computing the obtained sources ahead to infinity. We used a concentric 4 shell spherical head forward volume-conduction model to replicate oscillatory resting-state electroencephalographic data at the scalp to aid interpretation of the observed electroencephalographic complexity and integration. These simulations used oscillating intracranial dipole sources with predetermined complexity and integration. Given the known mixing effects of volume conduction, this allowed us to test how accurately electroencephalographic source complexity and integration patterns might be approximated at the scalp.

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Received: September 02, 2021; Accepted: September 16, 2021; Published: September 28, 2021