Commentary

Scorepochs: A computer-aided scoring tool for M/EEG epochs in the resting state

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ABSTRACT

In order to select which epochs to include in the later steps of M/EEG resting-state analysis, the epoch length and criteria must typically be defined. However, the impacts of epoch selection are rarely studied, and the technique for inspecting, labelling, and removing problematic epochs is frequently not documented, making the published results difficult to replicate. Scorepochs is a simple and free programme for automatically evaluating resting-state M/EEG epochs. Its goal is to give an objective way to assist M/EEG professionals throughout the epoch selection stage. We used the BCI2000 64 channel equipment to evaluate our method on a publicly available EEG dataset containing recordings from 109 people.

INTRODUCTION

One of the most commonly used experimental paradigms to study the baseline level of brain activity in healthy participants and pa--ients is task-free resting-state M/EEG (magneto electroencephalogram) recordings. The resting-state condition, on the other hand, is a nebulous concept influenced by various stages of attentiveness that are usually outside the control of the experimenter. During an M/EEG resting-state analysis, the first steps are typically I segmenting the raw and filtered EEG traces into a collection of non-overlapping epochs and (ii) selecting a number of artifact-free epochs to be used during the pipeline's subsequent phases. These procedures necessitate the definition of the epoch duration as well as criteria for selecting which epochs to include in the subsequent analysis. The effects of epoch length have been studied before, but the effects of epoch selection, which is produced by inter-observer variability and ambiguous criteria employed for this task, have received little attention. Epoch selection is often done by one or more specialists at the individual level (independently for each subject). Before this stage, some form of process for detecting and mitigating EEG artefacts may be used.

The exact process used to (visually) analyse, label, and eliminate problematic epochs, on the other hand, is frequently not documented, limiting the reproducibility of the stated results. Most importantly, it would be vital to ensure that homogeneous criteria were utilised, especially if the selection procedure is carried out by different specialists. In this context, most research that use restingstate paradigms assume that EEG signals are stationary and use averaging of individual features (extracted at the subject level) to draw group-level judgments. Subjective visual scoring and inter-observer variability may jeopardise the validity of these assumptions, though some studies have found that when a sufficient number of epochs is chosen, subjective influence may result in minimal changes; however, it is still unclear how to quantify this sufficient number of epochs. In this context, the prospect of producing some form of semi-automated analysis with the goal of assisting physicians and researchers throughout these critical processes would play a critical role. The majority of these methods are based on independent component analysis (ICA), which necessitates a large amount of EEG data (at least 20 time points per channel) to achieve adequate decomposition. In this paper, we introduce Scorepochs, a simple and open-source application for automatically evaluating resting-state M/EEG epochs, with the goal of providing an objective way to assist M/EEG professionals in epoch selection. Our subject-level technique assigns a score to each epoch inside a single M/EEG recording in an attempt to make this critical operation less ambiguous, objective, and repeatable. Neural oscillations are well known for their function in defining behavioural and cognitive states, as well as their involvement in the majority of brain illnesses. Until now, spectral analysis has been the most essential and widely used tool for analysing neurophysiological signals. Scorepochs is based on the EEG's entire power spectrum, does not require any specific assumptions about the underlying frequency content, and may maintain all of the crucial spectral information in the unfiltered raw signal.

METHODS

Scorepochs

The suggested method is based on a simple and quick algorithm that accepts as inputs I a series of M/EEG recordings and (ii) the desired epoch duration. Following that, the programme generates a score for each individual M/EEG epoch.

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Furthermore, all of the MATLAB and Python programmes used in the analysis are freely available. The methodology computes the power spectral density (PSD) into a given frequency range for each subject, epoch, and channel using the Welch method. At the channel level, a similarity score is generated between the PSD values retrieved from all the epochs using the Spearman correlation coefficient, resulting in a correlation matrix with a dimension of number of epochs x number of epochs. To create a score vector with a length equal to the number of epochs, the average is computed over the rows (columns) of the symmetric matrix, where the entries indicate the mean similarity score of the relevant epoch. Furthermore, the first session increased patient compliance, and after one week, all participants with a Frankl score of 4 decreased their score (T1). A second appointment (T1) was scheduled after a week, with the purpose of the patient becoming more closely acquainted with the dental instruments using the "Tell, Show, Do" module. Other behavioural approach approaches included voice control (changing voice level), distraction technique (distracting the patient's attention away from what may be viewed as a painful treatment), and boosting control (raising a hand to interrupt the dental operation).

Statistical analysis

The relative alpha power (calculated between 8 and 13 Hz) was the ideal selection for contrasting the two circumstances, as this attribute is a common yet effective trait capable of detecting macroscopic variations between EO and EC settings. Because some of the 109 patients were removed due to discrepancies in recording parameters or general low quality, the analysis was performed on 99 of them. We used a five-second epoch duration and divided the one-minute recordings into twelve non-overlapping epochs (the results were successively replicated using two different epoch lengths of 2 and 8 s). By selecting a sample of items (the four specified epochs) from a wider set, 495 potential combinations can be obtained. The results were then evaluated in terms of effect size magnitude by contrasting the two conditions (EO vs. EC) on a group level. We ran 495 t-tests (assuming normality distribution, which is a limitation in this case: see Supplementary Material), selecting four epochs for each subject in sequential order (i.e., for all subjects; for the first test, the epochs selected were, for the second test, the epochs selected were, and so on) up to the last test, where the selected epochs were.

ICLabel Algorithm

Finally, we compared Scorepochs to another potential method based on independent component classification (the number of components recognised as neural is typically regarded a credible measure of EEG signal quality). We employed the ICLabel algorithm for this, which calculates the probability of each component having a cortical generator or belonging to an artifactual class (muscular, ocular, or other artifacts). A "brain" class was allocated to each component with a likelihood of having a neural source greater than 20%. During the eyes open condition, the number of "brain" components was correlated—at the single-subject level—with the scores averaged over all epochs (in this case, 30 epochs of 2 s in the 1–40 Hz spectrum) as computed by Scorepochs. This comparison was carried out for two different preprocessing settings. The first scenario (pipeline 01) included the use of "cleanrawdata," a badchannel rejection method, as well as an artefact detection and repair method. For the artefact identification technique, the second scenario (pipeline 02) combined the usage of >3 standard deviations for problematic channel rejection with wavelength-enhanced ICA. We then used down-weighting to obtain a robust statistical measure of connection between the two parameters.

RESULTS

The magnitude of the paired Cohen's d effect size obtained using Scorepochs' suggested selection against the distribution of Cohen's d effect size based on sequential random selection, which show the comparison, in terms of Cohen's d effect size values, between the described sequential random selection and the selection suggested by our approach. The green dashed line represents the 'impact size time course' utilising this random selection and the result generated from the application of our approach. In terms of effect size values, there is a downward tendency. The vertical green dashed line represents the value of the effect size obtained using the epochs suggested by our approach. The distribution of effect size values (independent of the sequential order), where the vertical green dashed line represents the value of the effect size obtained using the epochs suggested by our approach. The Scorepochs algorithm has a Cohen's d value of 1.4512, which is close to the 75th percentile of the random epoch selection distribution. The minimal effect size is more than one, indicating that the difference is mainly independent of the epoch selection approach (i.e., the difference between the two conditions EO and EC is reliably detectable). The final section of the research, provides an indirect validation of Scorepochs' ability to choose epochs while maintaining brain activity. Scorepochs and the number of independent components classified as "brain" are compared at the single subject level, and the scatter plots and bivariate histograms (for both pipelines) show a dense distribution in the upper-right portions, with higher scores corresponding to a larger number of brain components.

DISCUSSION

We suggested an automated method to aid M/EEG professionals during the epoch selection procedure in resting-state analysis in this study. When compared to the potential arbitrariness introduced by human observers and the lack of clear and common criteria utilised to achieve this vital work, our method represents an objective (or less subjective) approach to performing epochs selection. We demonstrated that the effect magnitude varied greatly depending on the epochs included in the analysis in a typical situation of a group comparison between two resting-state circumstances (EO vs. EC). Different states of attentiveness related to exhaustion or drowsiness that are represented in the recorded signals may alter this pattern. The magnitude of the effect size produced utilising our proposed epoch selection was near to the mean effect size (which should reflect the best estimate of the population impact size), and it was also based on a quantifiable, objective, and repeatable technique (i.e., PSD scores). It's also worth noting that our findings were successfully duplicated using different time frame sizes. Furthermore, the Scorepochs approach is not computationally expensive due to the modest number of prerequisites (i.e., PSD computation). Despite its simplicity, this approach has a strong physiological foundation. In fact, it has been demonstrated that using the PSD to compute simple statistics reflects inherent features of excitatory or inhibitory levels in neuronal populations. Furthermore, the PSD can record distinct dynamics that are modified by external stimuli and offers information about sensory neural representation. Finally, it has recently been published on how various behavioural states are represented in distinct PSD features.Different spectral analysis methodologies (e.g., Fourier, Hilbert, and wavelet transform approaches).