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Commentry

Automated Pipeline for Infants Continuous EEG

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Electroencephalography (EEG) provides a non-invasive, direct, and low-cost measure of neural activity with a high temporal resolution, making EEG a valuable tool for developmental cognitive studies. Two problems are encountered with this technic. First, the EEG signal is unavoidably contaminated by many artifacts from different sources, such as environmental factors (e.g., line noise), physiological phenomena (e.g., ocular artifacts, heartbeats, muscle activity), and motion artifacts, whose amplitude is often much larger than the neural signal. Second, the neural signal of specific cognitive processes is lost among many other computations occurring at the same time, which furthermore spatially overlaps due to the wide diffusion of the electrical fields. One successful solution to isolate a cognitive process is to average across many trials to recover a reproducible neural activity time-locked to the stimulus presentation, i.e., the event-related potential (ERP). For the averaging method to be successful, many trials are needed, and those trials should not be contaminated by high amplitude changes, whose impact on the average could not be eliminated without thousands of trials. Other EEG analysis techniques (e.g., decoding, time-frequency analyses) have similar constraints on a high number of trials, without large amplitude changes. However, these requirements are at odds with the usual testing circumstances in infants, which are short and often heavily contaminated by motion, thus calling for a different approach to obtain a sufficiently good signal despite these challenging conditions. While simple steps as filtering can remove some artifacts as line noise, the correction of physiological artifacts requires more sophisticated methods. Fortunately, the high redundancy of the signal in time and space due to the diffusion of the electric field enables the implementation of different signal reconstruction techniques.

Several pipelines and artifact removal algorithms have been developed for adult EEG (e.g., PREP, Automagic, FASTER, ADJUST, MARA. However, they are not adapted to infants challenging data. The correction methods currently available for physiological artifacts require long recordings without high amplitude artifacts; thus, they are not directly applicable to infant data. Second, the power spectrum of the EEG signal and the properties of the evoked responses evolve throughout development due to maturational changes. More specifically, the background activity is rich and ample in low frequencies, and the signal variability between trials is higher in infants than in adults. Third, exogenous artifacts vary according to infants' age (e.g., fewer blinks and less motion in younger infants). Lastly, most infant datasets do not include electrocardiogram (ECG) and electromyogram (EMG) recordings used in adults' pipelines to identify non-neural artifacts.

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Because of all the factors mentioned in the previous paragraph, the methods developed for adult EEG are ill-suited for infant studies, and no agreement has been reached on the most appropriate preprocessing procedures for infant EEG. Traditional preprocessing usually relies on the manual identification of non-functional channels and data segments contaminated by motion artifacts, which are subsequently discarded. However, high-density recording systems (64, 128, 256 electrodes) and longer recording sessions make this approach time-consuming and inefficient, revealing the need for automated pipelines. These are usually based on fixed thresholds below which the voltage must remain. Non-functional channels are either rejected or interpolated, but no additional correction of non-neural artifacts is applied

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