Methodology for EEG data analysis using FieldTrip ToolBox

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**Introduction**

- EEG: neuroimaging technique which records brain cortical activity through small metal electrodes placed on the scalp
  - Non-invasive and cheap, EEG is used to diagnose seizures, epilepsy, head injuries, brain tumors, and more
  - The EEG waveform is divided into five main frequency bands, from low to high: Delta (\(\delta\)), Theta (\(\theta\)), Alpha (\(\alpha\)), Beta (\(\beta\)), and Gamma (\(\gamma\))
- Inexpensive, dry-electrode consumer EEG devices now present the possibility to take this technology outside of the lab and into real-world environments
  - The benefits of consumer EEG devices are their relative affordability and usability

**FieldTrip ToolBox**

- FieldTrip: MATLAB toolbox for advanced analysis of electrophysiological data including EEG
- Advantages
  - has reproducible analysis protocols
  - is able to identify and remove artifacts
  - contains a variety of methods to visualize analysis results
- Our Usage
  - Specify the time windows for EEG data preprocessing and analysis
  - Remove artifacts from cortical activity using the Independent Component Analysis (ICA) approach
  - Separate into frequency bands using power spectrum analysis in the frequency domain

**Artifact Removal**

In addition to neuronal activity, raw EEG recordings is contaminated by eyeball movements, blinks, heartbeats, and so on. Simply rejecting contaminated epochs would cause a huge loss of information. Independent Component Analysis (ICA) presents a way to remove a wide variety of artifacts from multichannel EEG recordings by first identifying the sources of activity and then removing artifactual contributions from raw data.

**Power Analysis**

- Time series EEG data are transformed into the frequency domain using the discrete Fourier transform
- Transformation displays the signal based on the amount of power at a given frequency.
- Patterns that repeat at specific frequencies can be seen in the frequency domain
- A band pass filter is used to separate this frequency transformed signal into discrete bands
- Bands are summed to find the total power in each band, which can be correlated with various behaviors
- Ex. theta power associated with sleep, alpha with alertness

**Limitations of Consumer EEG**

- Emotiv Insight consists of only 5 channels, significantly fewer than clinical EEG systems which typically consist of 21 or more channels
  - More channels correlate to greater accuracy
- The placement of electrodes on the scalp is fixed due to the Insight’s compact build and the quality of a consumer EEG device cannot be expected to match that of medical-grade EEG

**Conclusions**

- EEG analysis methods generally revolve around cleaning data and extracting information from cleaned data
- Artifact removal and power analysis are standard steps in EEG processing pipeline, but every experiment will have its own limitations and requirements
- FieldTrip is a powerful tool that can be used to cater EEG analysis to specific needs

**Artifact Removal**

**Power Analysis**

**Limitations of Consumer EEG**

**Conclusions**

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**References**


**Figure 1:** This image shows an EEG signal transformed into the frequency domain. The x-axis is segmented into the various bands\(^2\)