Methodology for EEG data analysis using FieldTrip ToolBox

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Introduction

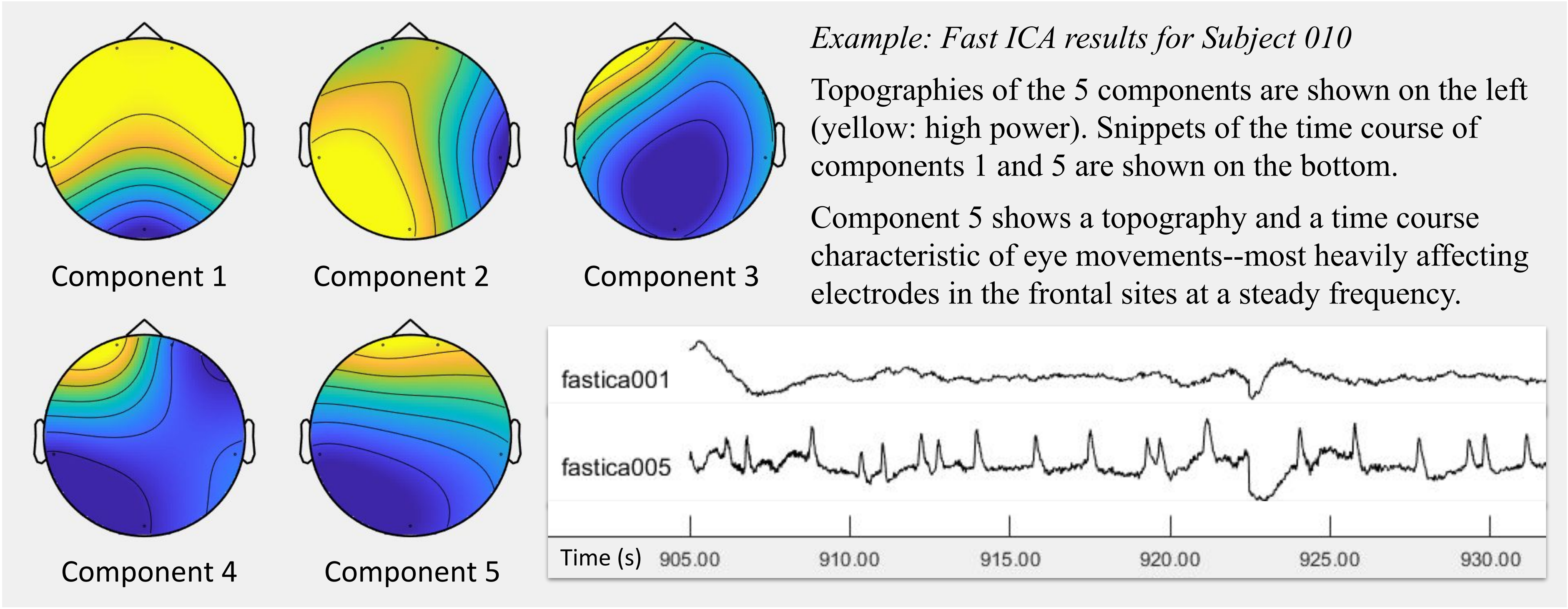
- EEG: neuroimaging technique which records brain cortical activity through small metal electrodes placed on the scalp
  - Non-invasive and cheap, EEG is used to diagnose seizures, epilepsy, head injuries, brain tumors, and more
  - The EEG waveform is divided into five main frequency bands, from low to high: Delta (δ), Theta (θ), Alpha (α), Beta (β), and Gamma (γ)
- 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.



Assumptions:

- Cortical and artifactual activities come from different, fixed locations (spatial stability)
- Cortical and artifactual time courses are not correlated (temporal independence)
- The summation of potentials arising from different sources is linear at the electrodes
- The delay in signal propagation is negligible

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

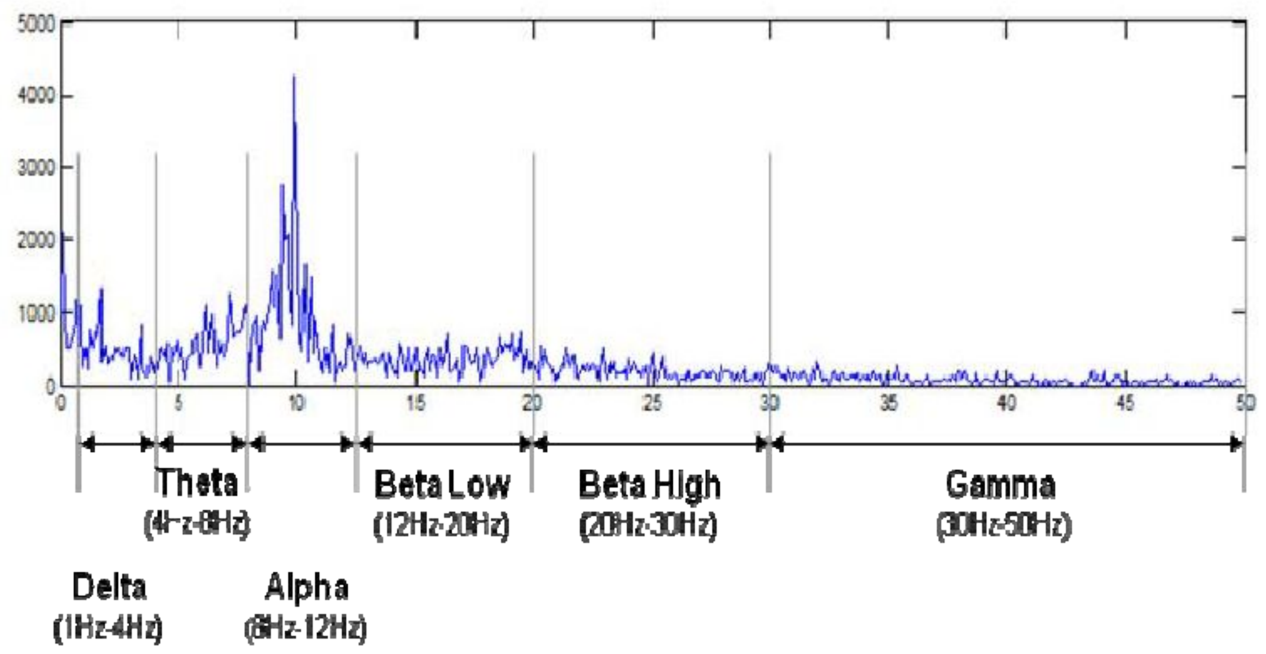


Figure 1: This image shows an EEG signal transformed into the frequency domain. The x-axis is segmented into the various bands[2]

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

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