Chapter 18: Time-Frequency Power and Baseline Normalizations

ANALYZING NEURAL TIME SERIES DATA
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Up to Now:

- We know how to extract estimates of time-varying frequency-band-specific power using:
  - wavelet convolution
  - filter-Hilbert
  - short-window FFT
  - multitaper
  - etc.

*NOW What?!
Purpose:

To discuss methods for converting time-frequency power data into a form which is qualitatively and quantitatively accessible for inspection and statistical analyses.
Many signals with a frequency and power component, including EEG data, show decreasing power at increasing frequencies.

Power = $c/f^x$

EEG data simply takes on $1/f$ form

This characteristic causes the visualization of activity from multiple frequency bands difficult to do simultaneously.
Limitations born from 1/f relationships

- Can not visualize power across frequency bands.
- Quantitative comparisons are difficult across frequency bands.
- Comparing across subjects is difficult with raw power values due to individual differences in subjects.
- Difficult to disentangle signal power from background activity.
- Raw power is not normally distributed, hence, parametric statistics are limited.
Baseline Normalizations circumvent these problems

- Decibel Conversion
- Percentage Change
- Z-transform
Decibel Conversion

- A bel is the base unit of the logarithm of a ratio of numbers.
- A decibel is simply ten bels, and we use this unit when comparing the strength of one signal relative to another signal.
- \( \text{dB} = 10 \times \log_{10} \left( \frac{\text{signal}}{\text{baseline}} \right) \)
- The signal and baseline are equally effected by 1/f scaling, therefore conversion to dB will remove any activity in the signal that was constant over time (i.e., in the baseline).
Considerations for Decibel Conversions

- What is baseline?
- Apply to trial-average power
- Symmetric color scaling should be used when possible.

![Color limit of -12 to +12 dB](image)
Same Data!
Percentage Change and Baseline division

- Similar to decibels
- The results are interpreted as the change in power relative to a baseline.
- \( \% \text{change} = 100 \times \frac{(\text{signal} - \text{baseline})}{\text{baseline}} \)
Z-transform

- The Z-transform scales power data from the signal to standard deviation units relative to power from the baseline.

- $Z = (\text{signal} - \text{baseline}_{\text{ave}})/ (n^{-1} \sum (\text{baseline}_{\text{time}} - \text{baseline}_{\text{ave}}))$

- The variability of the baseline data is accounted for here. Thus noisy trials, or trial with too few data can be problematic.
Comparing Transforms

Figure 18.6
Comparing Transforms

- dB change from baseline
- Percent change from baseline
- Divide by baseline
When to use what transformation

Thoughts?
Mean vs Median

- Mean is predominantly used if many trials were collected the data is sufficiently clean.
- Disadvantage of mean is its sensitivity to outliers.
- If outliers exist, and cannot be removed, it may be advantageous to use the median to find the central tendency of a data set.
- Single-trial baseline normalizations can help mitigate the effects of an outlier.
What is baseline?

- Since baseline normalizations rescale data relative to an arbitrary baseline, the choice of this baseline can change the interpretation of data.

  - Choose the baseline carefully!
Questions to ask when setting a baseline period:

- What happened prior to time 0?
- Where in time is the signal of interest?
- Where does your experimental design allow an unbiased baseline period?
- How big of a time window will yield the best results?
- Condition-specific baseline or conditioned-averaged baseline?
Where in time is the signal of interest?

Wang et al., Neuron 2013
Final words on Baseline-Normalized Power

- Main advantage: data from all conditions, electrodes, frequencies, and subjects can be quantitatively compared since they are on the same scale.

- Main disadvantage: the activity become relative to a baseline, consequently this baseline can be reflected in the task-related activity.
Signal to noise ratio (SNR)

- Helpful in determining the quality of data.
- Useful in testing hypotheses concerning within-subject, cross-trial variability.
- Must be able to dissociate signal from noise, which is not possible with EEG data.
  - Therefore SNR can be estimated by the ratio of the mean signal to the standard deviation of the signal.
Reliability analysis

- It is important to design experiments that provide enough trials to reliably detect whatever effect is occurring. Also, minimizing the number of trials to the necessary amount is crucial for practical, and possibly scientific purposes.

- Correlate the power time course averaged over a subset of the trials chosen at random with the power derived from the entire data set.

- Repeat this procedure for any number of trials between one and the total number of trials in the data set.

- In general, trial counts that yield a correlation of 0.7 provide a reasonable number of trials per condition.
Each line is a frequency band

not dB normalized

Frequency (Hz)

Number of trials

Number of trials
Choose your baseline wisely!

Thank you