PSYC597L:  
Analyzing Neural Time-series Data

Spring, 2020  
Mondays, 1:00-3:45 p.m.  
Room 323 Psychology

Course Resources Online:  
jallen.faculty.arizona.edu

Follow link to Courses
Available from:
Amazon:
http://www.amazon.com/gp/product/0262019876/ref=ox_ya_os_product
MIT Press:
UA Library Online
But first...

SYLLABUS AND WEBSITE
Roadmap

- Classic (Time or Frequency) vs. Newer (Time-Frequency) Approaches
  - Time Approaches
  - Frequency Approaches
  - Time-Frequency Approaches
- Brief discussion of Neural Sources and interpretation
- Guidelines for writing good code
- Code workshop part 1!
Previous Matlab Experience

- None
- Minimal
- Some
- Considerable
- Extensive
- Matlab Fears Me
Time Approaches: ERPs

- What/how
- Advantages
- Disadvantages
Overview

Event-related potentials are patterned voltage changes embedded in the ongoing EEG that reflect a process in response to a particular event: e.g., a visual or auditory stimulus, a response, an internal event
Ongoing EEG

Stimuli ★ ★ ★ ★ ★ ★

Visual Event-related Potential (ERP)

Latency (msec)
Figure 4.2. A schematic representation of ERP components elicited by auditory, infrequent target stimuli. The three panels represent three different voltage × time functions: the left bottom panel shows the very early sensory components (with a latency of less than 10 ms); the left top panel shows the middle latency sensory components (with a latency of between 10 and 50 ms); and the right panel shows late components (latency exceeding 50 ms). Note the different voltage and time scales used in the three panels, as well as the different nomenclatures used to label the peaks (components). (Adapted with permission of the author from Donchin, 1979, with kind permission of Springer Science and Business media.)
Time-locked activity and extraction by averaging
Matlab Demo!

Plus-Minus averaging to show impact of noise:
PlusMinus.m

Welcome to the Matlab Environment!
The Classic View:
Time-locked activity and extraction by signal averaging

- Ongoing activity reflects "noise"
- Activity that reflects processing of a given stimulus "signal"
- The signal-related activity can be extracted because it is **time-locked** to the presentation of the stimulus
- Signal Averaging is most common method of extracting the signal
  - Sample EEG for ~1 second after each stimulus presentation & average together across like stimuli
  - Time-locked signal emerges; noise averages to zero
  - Signal to noise ratio increases as a function of the square root of the number of trials in the average
What does the ERP reflect?

- May reflect sensory, motor, and/or cognitive events in the brain
- Reflect the synchronous and phase-locked activities of large neuronal populations engaged in information processing
Component is a "bump" or "trough"

Figure 4.2. A schematic representation of ERP components elicited by auditory, infrequent target stimuli. The three panels represent three different voltage × time functions: the left bottom panel shows the very early sensory components (with a latency of less than 10 ms); the left top panel shows the middle latency sensory components (with a latency of between 10 and 50 ms); and the right panel shows late components (latency exceeding 50 ms). Note the different voltage and time scales used in the three panels, as well as the different nomenclatures used to label the peaks (components). (Adapted with permission of the author from Donchin, 1979, with kind permission of Springer Science and Business media.)
Making
Meaning from
the bumps

Pores o'er the Cranial map with learned eyes,
Each rising hill and bumpy knoll decries
Here secret fires, and there deep mines of sense
His touch detects beneath each prominence.
Time Approaches: ERPs

- What/how
- Advantages
- Disadvantages
ERPs Advantages

- Simple, easy to derive
- Exquisite temporal resolution
  - Time-freq approaches will blur temporal precision
  - Although ... time precision seldom realized with ERPs
- Extensive literature spanning decades
- Because of ease to compute, can provide check on single-subject data
ERPs Disadvantages

- ERPs blind to non-phase-locked activity
ERPs can be “blind” to activity

Cohen, 2014
ERPs Disadvantages

- ERPs blind to non-phase-locked activity
- Limited basis for linking to physiological mechanisms
  - Time-frequency approaches assess oscillations
  - Neurophysiological mechanisms that produce ERPs are less well understood than the neurophysiological mechanisms that produce oscillations
Frequency Approaches: FFT etc

- What/how
- Advantages
- Disadvantages
Frequency Domain Analysis

- Frequency Domain Analysis involves characterizing the signal in terms of its component frequencies
  - Assumes periodic signals

Periodic signals (definition):
- Repetitive
- Repetitive
- Repetition occurs at uniformly spaced intervals of time

- Periodic signal is assumed to persist from infinite past to infinite future
Fourier Series Representation

- If a signal is periodic, the signal can be expressed as the sum of sine and cosine waves of different amplitudes and frequencies.
- This is known as the Fourier Series Representation of a signal.
Interactive Fourier!

- Web Applet
- www.falstad.com/fourier/
Fourier Series Representation

Pragmatic Details
- Lowest Fundamental Frequency is $1/T$
- Resolution is $1/T$

Phase and Power
- There exist a phase component and an amplitude component to the Fourier series representation
  - Using both, it is possible to completely reconstruct the waveform.
Averaging Multiple Epochs improves ability to resolve signal

Note noise is twice amplitude of the signal
Matlab Demo!

Advanced Coding Challenge:
- Find two snippets of the same song with different frequency characteristics
- Use Audacity to create two wav files
- Alter m code to plot spectra of these two snippets
Frequency Approaches: FFT etc

- What/how
- Advantages
- Disadvantages
Advantages of Frequency Approaches

- Sensitive to all frequencies below Nyquist
- Sensitive to phase-locked and non-phase-locked signals
Frequency Approaches: FFT etc

- What/how
- Advantages
- Disadvantages
DisAdvantages of Frequency Approaches

- Temporally nonspecific
- Power interpretation is ambiguous:
  - More is more?
  - More is more often?
Time-Frequency Approaches

- What/how
- Advantages
- Disadvantages
Time-Frequency Representation:
Power

Cavanagh, Cohen, & Allen, 2009
Time-Frequency Representation: Power

Inter-Channel Phase Synchrony Change

Cavanagh, Cohen, & Allen, 2009
Time-Frequency Approaches

- What/how
- Advantages
- Disadvantages
Time-Frequency Advantages

- Results can be interpreted in terms of neurophysiological mechanisms of neural oscillations.
  - Oscillations are a fundamental neural mechanism that supports aspects of synaptic, cellular, and systems-level brain function across multiple spatial and temporal scales (Cohen, 2014)

- Oscillations studied across multiple species and levels of analysis (single cell, LFP, intra-cranial, scalp)

- Captures more of brain dynamics than ERPs
Power increase in the absence of any phase locking

FIGURE 3 | Simulated data showing how information contained in raw EEG data (A,B; single “trials”) is not apparent in the event-related potential (C) but is readily observable in the time–frequency representation (D). Matlab code to run this simulation is available from the author.
Time-Frequency Approaches

- What/how
- Advantages
- Disadvantages
Time-Frequency Disadvantages

- Decreased temporal precision vs ERPs
  - Must observe a full oscillation to capture it
  - Greater loss of temporal precision at lower frequencies
  - BUT NOTE (Time-frequency proponents take heart!)

Cohen, 2014
Time-Frequency Disadvantages

- Decreased temporal precision vs ERPs
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  - BUT NOTE (Time-frequency proponents take heart!)

- Diverse range of analysis possibilities leads combinatorial explosion of possible ways to screw up!
  - Running analyses improperly
  - Running improper analyses
  - Rendering inappropriate interpretations
  - Multiple comparisons problem
    - Time-frequency space is large
    - Multiplied by many electrodes!
  - The “paralysis of analysis” (Cohen, 2014)

- TF approaches are relatively new, but growth in use is exponential!
How to view Time-Frequency Results

Cohen, 2014
How to view Time-Frequency Results

Figure 3.4
A screen-shot of the data-cube-viewing utility tviewex, which is available online with the Matlab code. Mouse clicks on the time-frequency plot update the topographical map to show the scalp distribution at that time-frequency point, and mouse clicks on the topographical map update the time-frequency plot to show the time-frequency dynamics at the nearest electrode. Multiple tviewex windows can be opened (e.g., to view results from different conditions) and can be synchronized to show the same time-frequency-electrode point across plots. Type “help tviewex” in Matlab to learn about how to use this utility.

Cohen, 2014
Matlab Demo!

・ tfviewerx

A Non-coding Challenge:
・ Explore the time-frequency-topography space using the preloaded data in tfviewerx
Be suspect: Time-Frequency Results

Figure 3.5
Some features of time-frequency results that should arouse suspicion, although they are not necessarily artifacts. In panels B and C, the offending single trial (out of 99 otherwise good-data trials) is superimposed on the time-frequency plot (EEG trace amplitude is arbitrarily scaled). The topographical map in panel E was produced by randomly swapping electrode label-location mappings.

Cohen, 2014
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Brief comment on Neural Sources of EEG

EEG blind to many signals

- Insufficient number of neurons synchronously active
- Electrical field geometry
Electrical Field Geometry

Figure 5.1
Illustration of dipoles in different orientations with respect to the skull. The dipoles illustrated in (a) will contribute the strongest signal to EEG, whereas the dipoles illustrated in (b) will contribute the strongest signal to MEG. The dipoles illustrated in (c) are unlikely to be measured because the dipoles on opposing sides of the sulcus produce electrical fields that are likely to cancel each other. The dipole illustrated in (d) will make a smaller contribution to EEG than dipole (a) because it is further away from the electrode. (This figure is inspired by figure 1 of Scherg 1990.)
Brief comment on Neural Sources of EEG

- EEG blind to many signals
  - Insufficient number of neurons synchronously active
  - Electrical field geometry
  - Cortical Sources predominate for electrodes on the scalp (deep sources “buried”)
    - Field strength decreases exponentially from source
Brief comment on Causation

- EEG is only direct noninvasive measure of neural activity
- BUT... is the measured activity causal to the psychological process of interest?
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Writing Matlab Code

- Write Clean and Efficient Code
- Comment your code!
  - One comment per three lines of code
- Use Meaningful File and Variable Names
- Make Regular Backups of Your Code
  - Keep Original Copies of Modified Code
- Initialize Variables; pre-allocate matrices/cells
- Make functions!
- Test small segments and built outward
  - Use cells within code
- Read (and critique) other people’s code
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Let’s Code!
How to access Self-study Materials or Additional Training if you wish

Workshops for Matlab, EEGLab, and R are available from my website resources and downloads page.

The link for Matlab and R Tutorials from Summer 2011 will prompt you for a password, and you can access the page with this password: U2CanzBeGeekz

Full instructions and links to all resources are available on that page.

Lessons 1-3 most relevant for basic coding mastery; Lesson 4 for EEG-specific coding

Mike Cohen’s very accessible book on Matlab (FunTF) is just $9.99 on Kindle