Announcements 3/18/19

Paper/Proposal <u>Guidelines</u> available on course webpage (link in D2L too)

➤Two paragraph prospectus due no later than Monday April 8

≻3x5 time

A few Applications

Today:

A wee bit of EMG and then....

The Electroencephalogram

- ➢ Startle Probe
- ➤ Subtle affect
 - ➤ Mere Exposure
 - ➤ Subliminal effects
 - ➤ Mortality Salience
 - Biofeedback of EEG -- outcome measure
 - Emotion Regulation outcome measure
 - Empathy individual difference measure



Dimberg et al Psychological Science 2000



PSYCHOLOGICAL SCIENCE

A few Applications

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Another loose translation: Arndt, J., Allen, J.J.B., & Greenberg, J. (2001). Traces of terror: Subliminal death primes and facial electromyographic indices of affect. *Motivation and Emotion*, 25, 253-277.

A few Applications

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From Allen, Harmon-Jones, and Cavender (2001) Allen, Cavender, Harmon-Jones, *Psychophysiology* 2001



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Figure 1. Self-reported negative affect on a 7-point Likert scale, where 0 = "not negative at all" and "7" = "strongly negative."

Ray, McRae, Ochsner, & Gross, Emotion, 2010



Ray, McRae, Ochsner, & Gross, Emotion, 2010

A few Applications

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Dimberg & Thunberg (2012) PsyCh Journal

The Electroencephalogram

Basics in Recording EEG, Frequency Domain Analysis and its Applications



Electroencephalogram (EEG)

- The EEG--an oscillating voltage recorded on scalp surface
 - Reflects Large # Neurons
 - Is small voltage
- Bands of activity and behavioral correlates
 - ➢ Gamma 30-50 Hz
 - ➢ Beta 13-30 Hz
 - ➢ Alpha 8-13 Hz
 - ➤ Theta 4-8 Hz
 - Delta 0.5-4 Hz
- Event-related activity (voltage: ERP; time-frequency)



Utility of EEG

- Relatively noninvasive
- Excellent time resolution

Sources of scalp potentials

- Glial Cells minimal, some DC steady potentials
- Neurons
 - Action Potentials NO, brain tissue has strong capacitance effects, acting as Low Pass filter
 - ➤ <u>Slow waves</u>
 - Synaptic potentials YES, both IPSPs and EPSPs from functional synaptic units are major contributors
 - > Afterpotentials May contribute to a lesser extent



Brief history of EEG

≻Hans Berger, 1929



Brief history of EEG

- ≻Hans Berger, 1929
- ➢ 1930s Signal processing: capture on chart paper and analyze by visual inspection
- Alpha waves were first identified and anything higher was called beta!
 - ➤ Then frequencies described in the 1930s
 - ≻ Hoagland, Rubin, & Cameron (1936) delta waves
 - Jasper & Andrews (1936) claimed to have seen frequencies higher than 30 Hz and called them gamma waves but this was met with skepticism initially

Brief history of EEG

- Mechanical Analyzers (Grey, 1935)
 - ≻William Walter Grey (Roboticist)
 - >Oscillators that functioned as mechanical band-pass filters
 - ➢ First model (1935) had four frequencies
 - ≻By 1944, 10 frequencies!
 - Not till 1960s, with mainframe computers were computational approaches tractable
 - ≻Cooley & Tukey (1965): Fast Fourier Transform (FFT)



Alpha and Synchronization

- ➤ Why Alpha?
 - > It is obvious and hard to miss!
 - > Accounts for ~70% of EEG activity in adult human brain
- ≻ From where, Alpha?
 - > Historically, thought to be thalamocortial looping
 - Adrian (1935) demolished that theory
 - Recorded EEG simultaneously in cortex and thalamus
 Damage to cortex did not disrupt thalamic alpha rhythmicity

 - > Damage to thalamus DID disrupt cortical alpha rhythmicity
 - > Thalamic rhythmicity remains even in decorticate preparations (Adrian, 1941)
 - > Removal of 1/2 thalamus results in ipsilateral loss of cortical alpha

Next



Alpha and Synchronization

➤ Andersen and Andersen (1968)

> Cooling of Cortex resulted in change in amplitude but not frequency of Alpha



Alpha and Synchronization

- Andersen and Andersen (1968)
 - > Cooling of Thalamus resulted in change in amplitude and frequency of Alpha at both thalamus and cortex



Alpha and Synchronization

- > In sum, Thalamus drives the alpha rhythmicity of the EEG
 - > Cortex certainly does feedback to thalamus, but thalamus is responsible for driving the EEG
 - > Particularly the Reticularis nucleus (Steriade et al. 1985)
- > What causes change from rhythmicity to desynchronization?
 - Afferent input to thalamic relay nuclei
 - > Mode-specific enhancement observed





Recording EEG







Systems are surface-based, not anatomically-based



Automated cortical projection of EEG sensors: Anatomical correlation via the international 10–10 system L. Koessler^{3,b}, L. Maillard³, A. Benhadid⁴, J.P. Vignal^b, J. Felblinger⁴, H. Vespignani^b, M. Braun^{A,CA,B} ⁴ KORD (MR, New Denking), *International Systems*, New ⁴ ⁴ Nonvalidad programs, University International Systems, New ⁴

Electrodes, Electrolyte, Preparation

- Ag-AgCl preferred, Gold OK if slowest frequencies not of interest
 - > Polarizing electrodes act as capacitors in series with signal
- ➢ Electrolyte: ionic, conductive
- ➤ Affixing
 - Subcutaneous needle electrodes (OUCH)
 - Collodion (YUCK)
 - EC-2 paste; lesser of the evils
 - ➢ Electrocap

Recording References

- Measure voltage potential differences
 Difference between what and what else?
- ≻"Monopolar" versus Bipolar
 - > No truly inactive site, so monopolar is a relative term
 - Relatively monopolar options
 - ➢ Body BAD IDEA
 - ≻ Head
 - Linked Ears or Mastoids
 - ➤ Tip of Nose
- Reference choice nontrivial as it will change your ability to observe certain signals

Recording References

➢ Bipolar recording

- ➤Multiple active sites
 - Sensitive to differences between electrodes
 - With proper array, sensitive to local fluctuations (e.g. spike localization)

Off-line derivations

- Averaged Mastoids
- Average Reference (of EEG Leads)
 - With sufficient # electrodes and surface coverage, approximates inactive site (signals cancel out)
 Artifacts "surgers in"
 - Artifacts "average in"
- Current Source Density (more in advanced topics)



Electrode Placement



Dreaded Artifacts

Three sources

- ➢ 60-cycle noise
 - ➢ Ground subject
 - ≻ 60 Hz Notch filter
- ➤ Muscle artifact
 - ≻ No gum!
 - ≻ Use headrest
 - Measure EMG and reject/correct for influence
- ➢ Eye Movements
 - ➤ Eyes are dipoles
 - Reject ocular deflections including blinks
 - > Use correction procedure (more in advanced lecture)

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P4	ininin	minin	infrining	min BI	ink and
02	minim	minnin	mmin	min Di	
H2	minim	minim	monin	Ing Ing	ole Blink
ETC1	minim	minim	mproming		h
ETC2		minim	minimi	minin	inim
TCP1	minimin	himin	minin		
TCP2	minim	minim	interview	minin	minim
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	204				
	. : 204:	1 2 3 3			

AC Signal Recording Options

Time Constant/HP filter
 Low frequency cutoff is related to TC by:

 $\mathbf{F} = \frac{1}{(2\pi(TC))}$

Where F = frequency in Hz, TC = Time Constant in Seconds

 Applying formula:

 <u>Time Constant (sec)</u>
 Free

 10.00
 5.00

 5.00
 .00

 .30
 .10

 .01
 .01

quency (Hz)
.016
.032
.159
.531
1.592
15.915



Hi Frequency/LP Settings

- Do not eliminate frequencies of interest
- Analog systems have broad roll-off characteristics
- Be mindful of digitization rate (more info soon!)



Digital Signal Acquisition

- > Analog Vs Digital Signals
 - ➤ Analog
 - > Continuously varying voltage as fxn of time
 - ➢ Discrete Time
 - > Discrete points on time axis, but full range in amplitude
 - ➤ Digital
 - > Discrete time points on x axis represented as a limited range of values (usally 2^x , e.g $2^{12} = 4096$)

A/D converters

- Schmidt Trigger as simple example
- ⊳ The A/D converter (Schematic diagram)
 - > Multiplexing (several channels); A/D converter is serial processor Result is a vector [1 x n samples] of digital values for each channel ([x(t0), x(t1), x(t2),...,x(tn-1)]
 - ➤ 12 bit converters allow 212 = 4096 values
 - ▶ 16 bit converters allow 216 = 65536 values
- > 12 bit is usually adequate for EEG
 - ▶ 4096 values allow 1 value for each ~0.02 µvolts of scalp voltage (depending upon sensitivity of amplifier, which will amplify signal ~20,000 times before polygraph output)
 - > c.g.,
 > 2.1130 μvolts => 2481 D.U.'s (2480.74)
 > 2.1131 μ volts => 2481 D.U.'s (2420.76)

 - $> 2.1250 \,\mu \text{ volts} => 2483 \text{ D.U.'s} (2483.20)$



Figure 5: A signal sampled at 20 Hz. Discrete-time sampling (left panel) sampled signals (right panel) must use a limited number of y-axis values for 2¹=8 distinct values, providing only a course approximation of the sig value (red circle) and the 3-bit diotal equivalent (red line), and the discrelues. The three e (right panel) alle bit c right pa From: Curham & Allen (submitted)



ing rates (20, 40, 100 Hz) and using three different t uV values. Low bit-resolution was used here for Figure 6: A compa ison of a signal (black line) sampled (red line) at three samp ns (4-bit, 5-bit, and 8-bit) that allow for 16, 32, and 128 distin ically 12-bit (4096 s) or 16-bit (65536 val

From: Curham & Allen (submitted)

The Problem of Aliasing

- Definition
- To properly represent a signal, you must sample at a fast enough rate.
- ➤ Nyquist's (1928) theorem a sample rate twice as fast as the highest signal frequency will capture that signal perfectly
 Stated differently, the highest frequency which can be accurately represented is one-half of the campling rate.
- sampling rate This frequency has come to be known as the Nyquist frequency and equals ^{1/2} the sampling rate
- ≻Comments Wave itself looks distorted, but frequency is captured
- Wave itself looks distorted, but nequency is super-adequately.
 Frequencies faster than the Nyquist frequency will not be adequately represented
 Minimum sampling rate required for a given frequency signal is known as Nyquist sampling rate



Harry Nyquist

Aliasing and the Nyquist Frequency

- ► In fact, frequencies above Nyquist frequency represented as frequencies lower than Nyquist frequency
 - ightarrow F_{Ny} + x Hz will be seen as F_{Ny} x Hz
 - ➤ "folding back"
 - ➤ frequency 2F_{Ny} seen as 0,
 - ≻ frequency 3F_{Nv} will be seen as F_{Nv}
 - ➤accordion-like folding of frequency axis



Fig. 3.1. A cosine wave of frequency F (solid line) sampled at its Nyquist rate. A higher frequency (dotted) wave, frequency F + a, is shown sampled at the same rate. At the sample times it is indistinguishable from a lower frequency (dashed) wave, frequency F - a.



Fig. 3.2. The accordionlike folding of the frequency (or n) axis due to sampling of a continuous signal. Frequency components of the original signal marked with x's on the f axis are interpreted in the sampled version as belonging to the lowest frequency, an encircled x.

1.2 0.8 0.4 0 -0.4 -0.8 -1.2 -1.2 -1.25 hz +1.0 hz +1.0 hz +1.5 Hz -1.5 Hz

Aliasing Demo (Part 1, 10 Hz Sampling Rate)

Aliasing Demo (Part 2, 2.5 Hz Sampling Rate)



Matlab Demo of Aliasing



Solutions to Aliasing

- ➤ Sample very fast
- ➤ Use anti-aliasing filters
- ≻ KNOW YOUR SIGNAL!

Time Domain Vs 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!

≻<u>Web Applet</u>



➢ 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.
- Psychophysiologists often interested in amplitude component:
 Power spectrum; for each frequency n/T

 $|\text{Amp}_{\cos}^2 + \text{Amp}_{\sin}^2|$

Amplitude Spectrum (may conform better to assumptions of statistical procedures); for each frequency n/T

 $|\text{Amp}_{\text{cos}}^2 + \text{Amp}_{\text{sin}}^2|^{1/2}$





Lingering details

- In absence of phase information, it is impossible to reconstruct the original signal
 - Infinite number of signals that could produce the same amplitude or power spectrum
- Spectra most often derived via a Fast Fourier transform (FFT); a fourier transform of a discretely sampled band-limited signal with a power of 2 samples
- Sometimes autocovariance function is used (a signal covaries with itself at various phase lags; greater covariation at fundamental frequencies)
- ➢ Windowing: the Hamming Taper

Preventing Spectral Leakage

≻Use windows

- ≻not Micro\$oft Windows
- ≻Hamming
- ≻Hanning
- ≻Cosine
- ≻Etc.







Fig. 3.3. Top, a periodicized segment of a cosine wave. T is the observation time and 3T/8 the period of the wave. Note the discontinuities at 0 and T. Bottom, a continuous and periodic band-limited wave drawn through the sample points $\Delta = T/16$ see apart.

Matlab Demo of Hamming Window



Pragmatic Concerns

- Sample fast enough so no frequencies exceed Nyquist ▶ signal bandwidth must be limited to less than Nyquist
 - Violation = ERROR
- Sample a long enough epoch so that lowest frequency will go through at least one period ➤ Violation = ERROR
- Sample a periodic signal
 - if subject engaging in task, make sure that subject is engaged during entire epoch
 - Violation = ??, probably introduce some additional frequencies to account for change



Demo of EEG Data

> CNT Data to Frequency Domain Representation

Frequency-domain EEG applications and methodological considerations

Applications

≻Emotion Asymmetries

≻Lesion findings

- Catastrophic reaction (LH)
- ≻RH damage show a belle indifference
- ≻EEG studies
 - ≻ Trait (100+ studies)
 - State (oodles more studies)

Types of Studies

≻ Trait

- ➤ Resting EEG asymmetry related to other traits (e.g. BAS) > Resting EEG asymmetry related to psychopathology (e.g. depression)
- Resting EEG asymmetry predicts subsequent emotional responses (e.g. infant/mom separation)

➤ State

> State EEG asymmetry covaries with current emotional state (e.g., self report, spontaneous emotional expressions)

Trait, Occasion, and State variance

- > Three sources of reliable variance for EEG Asymmetry
 - > Stable trait consistency across multiple assessments
 - ➢ Occasion-specific variance \succ reliable variations in frontal asymmetry across multiple sessions of measurement
 - may reflect systematic but unmeasured sources such as current mood, recent life events and/or factors in the testing situation.
 - ➤ State-specific variance
 - > changes within a single assessment that characterize
 - > the difference between two experimental conditions > the difference between baseline resting levels and an experimental
 - condition.
 - conceptualized as proximal effects in response to specific experimental manipulations
 should be reversible and of relatively short duration
- > Unreliability of Measurement (small)

Allen, Coan, & Nazarian 2004



Alpha Vs Activity Assumption (AAA)



Oakes et al, 2004, Human Brain Mapping

Alpha and Activity

- May be more apt to think of alpha as regulating network activity
- ≻ High alpha has inhibitory function on network activity (more in advanced topics)

EEG Asymmetry, Emotion, and Psychopathology





Left Hypofrontality in Depression



Henriques & Davidson (1991); see also, Allen et al. (1993), Gotlib et al. (1998); Henriques & Davidson (1990); Reid Duke and Allen (1998); Shaffer et al (1983)



Valence Vs Motivation

- Valence hypothesis
 Left frontal is positive
 - ➢Right frontal is negative
- Motivation hypothesisLeft frontal is Approach

 - ➢Right frontal is Withdrawal
- Hypotheses are confoundedWith possible exception of Anger



Correlation with alpha asymmetry (ln[right]-ln[left]) and trait anger. Positive correlations reflect greater left activity (less left alpha) is related to greater anger.

After Harmon-Jones and Allen (1998).

State Anger and Frontal Asymmetry

> Would situationally-induced anger relate to relative left frontal activity?

Harmon-Jones & Sigelman, JPSP, 2001

Method

- Cover story: two perception tasks person perception & taste perception
- Person perception task participant writes essay on important social issue; another ostensible participant gives written feedback on essay
- Feedback is neutral or insulting
 - regative ratings + "I can't believe an educated person would think like this. I hope this person learns something while at UW."

Harmon-Jones & Sigelman, JPSP, 2001

- Record EEG immediately after feedback
- Then, taste perception task, where participant selects beverage for other participant, "so that experimenter can remain blind to type of beverage."
- 6 beverages; range from pleasant-tasting (sweetened water) to unpleasant-tasting (water with hot sauce)
 - ➤Aggression measure

Harmon-Jones & Sigelman, JPSP, 2001



Harmon-Jones & Sigelman, JPSP, 2001

Relative Left Frontal, Anger, & Aggression as a Function of Condition



Frontal EEG asymmetry predicts Anger and Agression

- ➢ Not in Neutral condition
 - ... no relationship
- Strongly in Insult condition
 - > r = .57 for anger
 - > r = .60 for aggression
 - > Note: partial r adjusting
 - for baseline indiv diffs in asymmetry and affect



Harmon-Jones & Sigelman, JPSP, 2001

Manipulation of EEG

Peterson, Shackman, Harmon-Jones (2008)

- Hand contractions to activate contralateral premotor cortex
- Insult about essay (similar to Harmon-Jones & Sigelman, JPSP, 2001) followed by chance to give aversive noise blasts to the person who insulted them
- Hand contractions:
 - altered frontal asymmetry as predictedAltered subsequent aggression (noise blasts)
- Asymmetry duruing hand contractions predicted aggression



Figure 1. Relation between noise length and frontal-central asymmetry during right-hand contractions. Higher asymmetry scores indicate greater relative left than right activation.

Peterson, Shackman, Harmon-Jones (2008)