Inferences 2

http://www.cogsci.ucsd.edu/~coulson/cogs179/
Announcements

• Homework due Thursday (not today)
• Course Reader available Thursday
• Library Reserves (not currently available, but hopefully soon)
Inferential Limitations

- Null Results
- Scalp Distribution
- Polarity
- Intracerebral Sources
- Amplitude
- Time Course
- Correlation vs. Causation
- Interdomain Mapping
Amplitude

- Typically interpreted as reflecting strength of activity
- But amplitude differences can also arise when violations of assumptions behind averaging occur
- Assume temporal invariance of signal
  - But latency jitter can introduce apparent amplitude differences between two conditions that differ only in the degree of latency variability
- Assume signal identical across trials
  - Possible signal present on some trials but not others
  - Amplitude differences across conditions would then indicate the probability of the engagement of a particular process rather than the degree of engagement of a particular process
Fig. 11. Woody filtering. The tracings in the upper left of this figure are the 16 single-trial waveforms from Fig. 9. When averaging these waveforms together provides the waveform in the lower left of the figure. In the upper right of the figure the single-trial waveforms have been adjusted in their timing so as to have the greatest correlation with a template waveform. For the initial iteration the template waveform is the average waveform shown in the lower left of the figure. After the single-trial waveforms have been latency-compensated, they are then averaged together to form a new average waveform. This waveform then becomes the template for another cycle of correlations and latency compensations. The latency compensations and the resultant averaged waveform shown on the right of this figure are from the 7th iteration. The latency compensation process is dominated by the P3 wave which is the largest wave in the single-trial waveforms. By aligning the single-trial waveforms around this P3 wave, the final compensated average waveform shows a larger P3 wave (arrow) than the simple average.
Woody (1967)

1. Calculate a traditional time-locked average (template).
2. Perform cross-correlation between this template and each individual EEG sweep.
3. The shift amount where there’s maximum correlation between the EEG sweep and the time-locked average is the jitter estimate.
4. Shift each EEG sweep by its jitter estimate, and re-average the latency-adjusted trials.
5. Repeat the process, now cross-correlating each single trial with the latency-adjusted average.
6. Perform no more than 3 iterations.
The diagram illustrates the concept of correlation in time series analysis. It shows a plot of amplitude against time, with a specified time window for analysis. The graph also highlights a maximum correlation point, indicating the lag shift at which the correlation is at its highest.
Inferential Limitations

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Time Course

• Is onset of ERP effect onset of divergent processing in the brain?

• Neural activity could differ before effect onset, but not be detectable at the scalp
  – Onset latency best construed as upper bound on divergence

• Adequate interpretation of time course of ERP effects requires understanding of functional significance of differences in e.g. peak latency, rise time, and duration of effect
Correlation vs. Causation

• Experimental modulation of ERPs via cognitive manipulations reveal correlations between neural activity and cognitive processes

• Does not necessarily imply the brain activity measured is:
  – essential for cognitive processes of interest
    • Incidentally associated processes
  – direct manifestation of those processes
    • Downstream processes

• Need to interfere w/relevant neural activity and see whether it impacts cognitive function
  – Lesions, TMS, drug studies
Interdomain Mapping: The Mind-Body Problem

- Logic of ERPs typically assumes 1-to-1 mapping between brain states and cognitive states.
- Differential brain activity less meaningful if the same cognitive process could be achieved via multiple different neural instantiations.
- Differential brain activity doesn’t always reveal distinct cognitive processes:
  - Early hemispheric differences in visual processing.
  - How big of difference is a meaningful difference? (2 adjacent neurons?)
Exploiting ERP Components

- Assume positivity at X (relative to X') is known ERP component associated with a specific cognitive process $P$
- Inference about the time course of $P$ in conditions 1 and 2
  - Onset
  - Peak latency
  - Rise time
  - Duration
- Inferences about the degree of engagement of $P$ in conditions 1 and 2
  - Amplitude
- Rely on well-designed experiments
  - Motivate initial connection between amplitude modulations and engagement of $P$
  - Motivate initial connection between latency modulations and engagement of $P$
  - Interpret observed modulations in terms of $P$
Case Studies: Mental Chronometry

• In 1960s and 1970s timing of cognitive tasks probed entirely by reaction time tasks
• But RTs conflate several stages of processing
  – Perceptual Processing
  – Identification and Categorization
  – Response Generation
• Use P300 as more specific index?
  – Kutas, McCarthy & Donchin (1977) study
P300 peak latency: Stimulus Evaluation vs. Response Selection

- If P300 indexes Stimulus Evaluation
  - Peak latency modulated by experimental manipulations that affect stimulus evaluation
- If P300 indexes Response Selection
  - Peak latency modulated by experimental manipulations that affect response selection

- Is P300 latency more correlated with the time it takes people to
  - evaluate the stimulus
  - generate the response
- When RT variance is determined by stimulus evaluation demands, P300 latency and RTs should be highly correlated
- When RT variance is determined by response selection demands, P300 latency and RTs should be less correlated
Experimental Paradigm

- Oddball Paradigm
  - Standard (Probable Stimulus)
  - Target (Rare Stimulus)
  - Task: identify target in some way
- Fixed Names
  - Standard (80%): David
  - Target (20%): Nancy
- Variable Names
  - Standard (80%): Male Names
  - Target (20%): Female Names
- Synonyms
  - Standard (80%): words
  - Target (20%): word “prod” and its synonyms
- Tasks
  - Count Targets
  - Press Button – be as accurate as possible
  - Press Button – be as fast as possible
Results

- Raw Averages (Latencies)
  - Count & Accurate: FN < VN < SYN
  - Speed: FN < VN=SYN
- Latency Adjustment
  - Allows for more valid comparison of amplitudes
  - Also allows for evaluation of P3 latency on individual trials
  - (see next slide)
- Amplitudes
  - Differ before Correction
  - Not after Correction
  - Amplitude differences artifact of latency jitter
P3 latencies & RT

- **Correlation**
  - Accuracy Condition: $r = .61$
  - Speeded Condition: $r = .26$

- **Inaccurate responses**
  - Marked w/X’s
  - More in Speeded
  - Correlation goes up when they are removed

- **Relative timing**
  - Accurate trials P3 peak *earlier* than RT
  - Inaccurate trials P3 peaks *later* than RT
Proposed Interpretation

• P300 indexes stimulus evaluation
• RT indexes response generation

• Accuracy Instructions
  – Stimulus Evaluation then Response Generation
  – Correlation between processes indexed by correlation between P300 and RT

• Speed Instructions
  – Response Generation begins before Stimulus Evaluation has been completed
  – Dissociation of processes indexed by lower correlation between P300 and RT
  – Inaccurate responses result when Response Generation proceeds without adequate input from Stimulus Evaluation
Case Studies: Attention

Numerous Sensory Inputs

attended information

Input

Sensory Memory

Selective Filter

STM

Output

Early Selection

Input

Sensory Memory

Attenuator

STM

Output

Attenuated Selection

Input

Sensory Memory

STM

Output

Late Selection

Input

STM

Output
Cuing Paradigm

- Cue tells subject which direction to attend
- Target appears either in cued or un-cued box
  - More often in cued
- Subject presses button as soon as target appears
- Compare RTs & ERPs
  - Right Side Square:
    - Attended
    - Unattended
  - Left Side Square:
    - Attended
    - Unattended

Stimulus Sequence from an Endogenous Cuing Experiment
Timing Inferences

- **Without knowledge**
  - Attention effects begin at least by 60 ms after the onset of the stimulus
  - Attention effects have ended by 300 ms after the onset of the stimulus

- **With prior knowledge**
  - P1 and N1 reflect visual processing of the stimulus
  - Attention modulates early sensory processing of stimuli
  - At least in this experimental paradigm
Reynolds et al.

- Monkey single cell recording in V2
- Ref is stimulus this cell is tuned to
- A: shows activity suppression in presence of another stimulus it’s NOT tuned to
- B: greater response to pair stimulus when monkey attends to that region of space than when region is unattended
- Increased spiking rate could be manifested (indirectly) by amplitude enhancements at scalp recording sites
Inhibition of Return

• Exogenous Cueing
  – Participants faster at cued location even when the cue is not predictive
  – Attention moves automatically

• Inhibition of Return
  – Red region in graph →

• Are effects due to changes in motor thresholds or changes in sensory responsiveness?

Fig. 1. A prototypical demonstration of IOR. (a) The sequence of events in a typical trial. A fixation display is followed by the first stimulus (S1, cue); the brightening of one of the two peripheral boxes. After varying intervals (cue–target onset asynchronies, CTOAs) from the onset of the cue, a target (S2), shown here as an asterisk, is presented at the cued (right) or uncued (left) location. The observer’s task is to make a speeded detection response as soon as the asterisk is detected. Catch trials with cues but no targets are included to discourage anticipatory responses and measure their frequency in the form of false alarms. (b) The data from such an experiment, by Posner and Cohen?: responses to cued targets, filled circles; responses to uncued targets, open circles. Faster responding to cued targets at the shorter intervals (green) reflects the facilitatory effect of reflexive orienting of attention toward the cue. IOR is reflected in the slower responding to targets at the cued location at the longer intervals (red).
ERP Study

HOPFINGER AND MANGUN

Figure 3. Event-related potentials to right visual field target stimuli (top) and left visual field target stimuli (bottom) at the short cue-to-target stimulus intervals (ISIs). Electrodes O1, and O2 are located midway between T5 and T6 and midway between T6 and F4, respectively, in the International 10-20 system of electrode placement [Jasper, 1958]. Electrodes T5 and T6 are between T6 and F4, and between T5 and P4, respectively. Shaded gray areas highlight the latency ranges over which statistics were computed for the contralateral P1 (100-190 msec), the P300 (250-350 msec), and the ipsilateral invalid negativity (IVN; 200-300 msec). At the short cue-to-target ISIs, contralateral targets (solid line) elicited significantly enhanced P3 and P300 components, relative to central-target (dashed line) untrained localization (invalid) targets elicited a significantly negative-going wave, ipsilateral to the target location (the IVN).
Questions…

• In short ISIs, why is P1 effect evident over LH channel with RVF and RH channel in LVF?
• What might be going on with the IIN since it shows the reverse pattern?
• Could you explain the null results in the Long ISI as due to power limitations?
Hopfinger & Mangun

• **P1 & P3**
  – Larger for valid trials at short ISIs (facilitation trials)
  – Not larger for valid trials at long ISIs (IOR)
  – P1: enhanced perceptual processing
  – P3: greater significance of stimulus

• **IIN (Invalid Ipsilateral Negativity)**
  – Present at short ISIs (facilitation trials)
    • Reflects disengagement of attention from cued location
  – Absent at long ISIs (where IOR occurs)
    • No need to disengage from cued location, since attention wasn’t AT cued location

• Excitatory effect at short ISIs and inhibitory effect at long ISIs both involved modulations of sensory processing
Case Study: Late Bottlenecks

• Some argue about how early attention can act
• Others argue about whether attentional bottlenecks occur later in the processing stream – Pashler
• Central processing capacity is limiting factor in dual task performance
Psychological Refractory Period

Stimulus 1

Perception

Response selection

Response production

Stimulus 2

Perception

Response selection

Response production

SOA (stimulus onset asynchrony)

PRP
Terminology

• Response Time of Task 1 = RT1

• Response Time of Task 2 = RT2

• Early (Pre-central), Central & Late (Post-central) processing for each task:
  – Task 1 includes A1, B1 & C1
  – Task 2 includes A2, B2 & C2
Typical PRP Findings

SOA (ms)

RT (ms)

Task 2

Task 1
Where’s the bottleneck?

- Pashler argues that interference in the PRP paradigm is due to limitations on *central* processing capacity rather than peripheral processing capacity
  - Central: response selection
  - Peripheral: perception
- RT data suggests interference occurs
  - Do they tell us unambiguously which stage the interference arises?
- Are there any other ways to address this issue?
ERPs!
Recall

- P300 latency is sensitive to stimulus evaluation rather than response preparation

Kutas, McCarthy & Donchin (1977)
So…

- Why not use P300 latency as index of stimulus evaluation in PRP paradigm?
  - Delayed P300 would suggest bottleneck occurs *at or before* stage of stimulus evaluation
  - No P300 latency shift would point to bottleneck in later stages of processing
• Dual Task
  – T1: Red vs. Green Square
  – T2: X vs. O

• Findings
  – RT2 affected by SOA
  – P300 amplitude affected by SOA
  – P300 latency not affected by SOA

• Which stage is the bottleneck?

• Are there any ambiguities?
Attentional Blink Paradigm

- Two tasks, e.g.
  - If you see a vowel, say it out loud
  - If you see a number, press one key if it’s odd another if it’s even
    - Or even just remember it...
- Stream of characters presented very rapidly (RSVP)
  - Push the limit on people’s discrimination abilities
  - Stream composed mostly of nontargets
- What do you suppose happens?
- Further argument for “cognitive bottleneck”
Attentional Blink Phenomenon

- 10 letters per minute
  - Mostly black, some white
- Dual task
  - T1: Say white letters out loud
  - T2: Is X present/absent?
- U-shaped accuracy curve
  - Good performance lag 1
  - Poor performance lags 2-5 (attentional blink)
  - Good performance lags 6-8
- Unless stimuli entered in working memory, they will be overwritten (due to rapid presentation)
- AB arises because T1 diverts attention needed to update working memory for T2
- How to test whether AB affects the updating of working memory?
ERPs!

- Which component?
Luck et al. (2000)

- Which ERP components modulated during AB?
- Not N1 or P1
  - What might this suggest?
  - Any reason for skepticism?
- P3 eliminated!
  - What’s the implication for explanations of AB?
Luck et al. (1996)

- Items that appear during AB are processed visually
- Are they processed to the level of meaning?
- To test
  - Use paradigm to elicit AB
  - Adapt to look at whether ERP component sensitive to semantic analysis is modulated during the AB
    - N400
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<th>Time (ms)</th>
<th>Related trial</th>
<th>Unrelated trial</th>
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<td>WHEEL</td>
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**Box 4. Isolating overlapping ERP waveforms**

(a) The stimulus on a typical trial, beginning with a T1 presentation of a context word followed by a stream of stimuli presented at a rate of 10 per second (all stimuli were presented in normal upright orientation at fixation). The targets were a number (T1) followed by a word (T2). At the end of each trial, subjects reported whether T1 was odd or even and whether T2 was semantically related or semantically unrelated to the context word. (b) The overlapping ERP components for a trial in which the T2 word matches the semantic context for that trial. (c) The activity for a semantic mismatch trial, which is equivalent to the matching trial plus the addition of mismatch-related ERP activity following T2. (d) The result of subtracting the matching trials from the mismatching trials, which isolates mismatch-related activity triggered by T2 (primarily the N400 component).
Results

FIG. 2 a, Probe-discrimination accuracy as a function of lag (lag of 1-, 3- or 7-strings) for the experimental and control conditions. These values reflect only the trials on which the first target was correctly discriminated (first-target accuracy was 96% correct overall, with no effect of lag). b, Mean N400 amplitude as a function of lag for probe words in the experimental and control conditions, measured from the unrelated – related difference waves and averaged across electrode sites. N400 amplitude was computed as the mean amplitude of electrical activity between 300 and 500 ms poststimulus, relative to a 200-ms prestimulus baseline, at the F3, Fz, F4, C3, Cz, C4, P3, Pz and P4 electrode sites.

FIG. 3 ERP difference waves at frontal, central and parietal electrode sites along the midline (Fz, Cz and Pz), averaged across the 14 subjects. These waveforms were produced from averages that included only the trials on which the first target was correctly discriminated, but were not sorted according to the accuracy of the response to the probe word. The waveforms were low-pass filtered by convolving them with a gaussian impulse-response function with a standard deviation of 10 ms and a 50% amplitude cutoff of 20 Hz. Time zero represents the onset of the probe word. Note that, by convention, negative is plotted upwards.
Integrating across studies...

- Attention can have an early effect and impact perceptual processing
  - Cuing paradigms
  - IOR paradigm
  - P1, N1, P3
- Attentional constraints relevant at post-perceptual stages such as response selection or memory updating
  - PRP paradigm
    - Not P1
    - P3 amplitude, not P3 latency
  - AB paradigm
    - Not P1, N1, N400
    - P3 eliminated
- How do these results fit together?
Integrating across methods

- Do same study w/ERP and fMRI
- Task: look for upside down T on attended side
- Alternate between attend left and attend right
- Any problems with this design?
fMRI Data
ERP Data

- C1 not attentionally modulated
- P1 larger for attended stimuli over contralateral hemisphere
- Ditto N1
Localizing ERP effects

- C1 in V1 (striate cortex)
- Early P1 near V3 and middle occipital cortex (extra-striate)
- Late P1 in fusiform gyrus
Putting it together

• fMRI attention effects in V1 suggests attention acts at the earliest stage of visual processing
• However, null effect on C1 ERP component (generated in area V1) argues to the contrary
• Spatial vs. Temporal resolution of techniques
  – V1 activation results from feedback connections from higher-level visual areas
  – V1 attention modulation occurs after the initial feedforward activation
Questions?