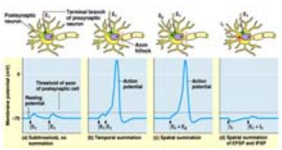
How to Study for COGS 179 Final

- Final will be in the same format as the problem sets
  - Some questions will be from problem sets
  - Ergo, review all old problem sets
- Go through your lecture notes
  - Be sure you understand basic technical concepts related to EEG recording
  - Be sure you understand basic aspects of neural generation of scalp-recorded activity
  - Understand how ERP data is/are interpreted
  - Be sure you're familiar with well-known ERP components (auditory N1, Nd, MMN, P3, N400, LRP, N200, N280/LPC, N400-700, N300, pictureN400, etc.)
  - Pay special attention to studies we both read and talked about
- FYI
  - Exam is Friday March 24 from 3-6pm in CSB 003
  - Coulson's office hours Thursday March 23, 3pm-4pm CSB 161

Greatest Hits from COGS 179

- A variety of slides to remind you about important concepts from COGS 179

Summation of Post-Synaptic Potentials

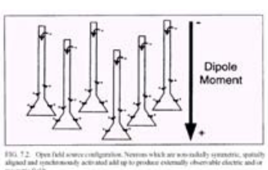


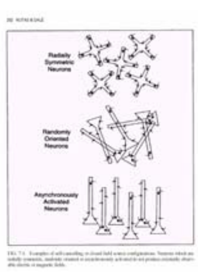
- Temporal Summation
  - If PSPs occur close in time, they summate
- Spatial Summation
  - If PSPs occur in close proximity, they summate
- EPSPs and IPSPs summate (and cancel)

Preconditions

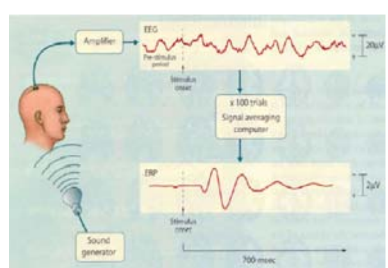
- What conditions are needed to record electrical brain potentials at the scalp?
  - Very sensitive voltmeter (bioamplifier)
  - Possibility of spatial summation
  - Possibility of temporal summation

Summates / Cancels out

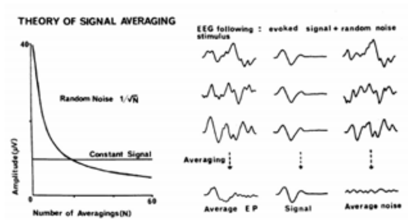




EEG and ERPs



Why averaging works…



What do ERPs reflect?

- Sensory, motor, and/or cognitive events in the brain
- Synchronous activity of large populations of neurons engaged in information processing

Characteristics of ERP components

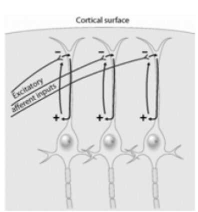
- Polarity
  - Is it a positive wave or a negative one?
- Latency
  - How long after stimulus presentation does it peak?
- Functional Significance
  - What cognitive (or perceptual) activity is it sensitive to?
  - What makes it bigger or smaller?

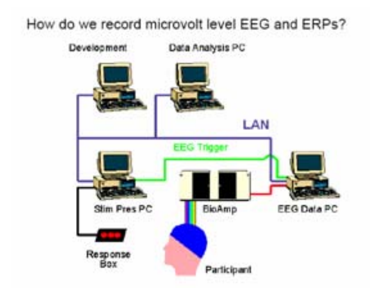
Review Questions

- What conditions must obtain for electrical brain activity to be recorded at the scalp?
- What sort of brain activity is recorded in the EEG?
- What sorts of non-brain activity is recorded in the EEG?
- Is there a correspondence between inhibitory activity and the polarity of voltage recorded at the scalp?
- What is the difference between the forward problem and the inverse problem?
- What is the difference between the EEG and the ERP?
- What is an ERP component?

Questions

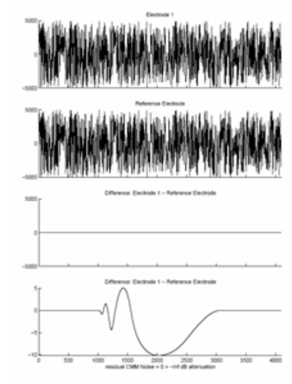
- If input to the cell is excitatory, why are there negative signs near the dendrites?
- What polarity would the signal be if the electrode was on the cortical surface?
- Assuming the scalp was directly over the cortical surface, what polarity would the scalp-recorded signal be?
- Why isn't it easy to infer whether activity is excitatory or inhibitory from the polarity of EEG activity?





Differential Amplification

- Permits extraction (and amplification) of difference between 2 sites
- Requires 2 signal electrodes
  - 1 at scalp location of interest
  - 1 at reference site
    - Same noise as scalp site, little or no brain activity
    - E.g. Mastoid bone, earlobe, nose tip
- Conceptually 2 pairs of electrodes
  - Pair 1: scalp site and ground
  - Pair 2: reference site and ground
- In practice, use same ground (3 electrodes)
  - E1: scalp location of interest
  - E2: reference electrode
  - G: ground electrode



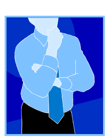
Amplification

- Brain signals very small at the scalp
  - Non-brain sources 50-500 microvolts
  - EEG 10-100 microvolts
  - ERP effects 1-10 microvolts
    - 10^-6 Volts=1 microvolt
- Amplifiers change data in 2 important ways
  - How much amplification?
  - What kind of frequency filtering?

How much amplification?

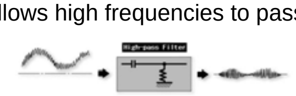
- Amplifiers increase the magnitude of input by a factor of up to 500,000x
- After amplification, signal should be on the order of +/- 1 V to be compatible with A/D converter on computer
- Gain depends on size of signal
  - ECG: 1 millivolt need 1000X
  - EEG: 50 microvolts need 20K
- Don't want to saturate amplifier and cause blocking
  - Channels close to eyes might be better with slightly smaller gain

What kind of frequency filtering?



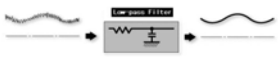
High Pass Filter

- Attenuates frequencies *below* chosen frequency
  - Allows high frequencies to pass through



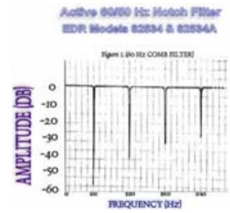
Low Pass Filter

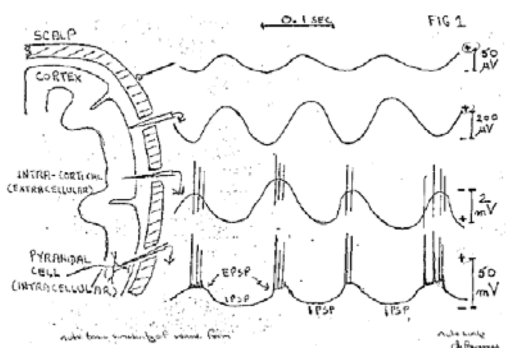
- Attenuates frequencies *above* chosen frequency
  - Allows low frequencies to pass through



Notch Filter

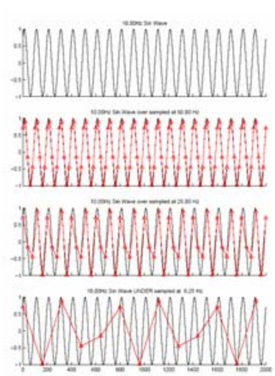
- Attenuates activity at a particular frequency
- Line frequency
  - 60 Hz USA
  - 50 Hz Europe





What sampling rate?

- How many samples per second?
- To properly represent a signal you must sample at a fast enough rate
  - else Aliasing
- Aliasing – when high frequency aspects of the waveform look slower due to undersampling



Nyquist

- Nyquist's theorem
  - Sample rate 2x as fast as highest signal frequency will capture signal perfectly
  - The highest frequency that can accurately be represented is ½ the sampling rate
  - This is known as the Nyquist frequency

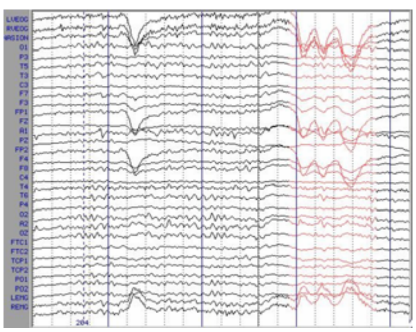
Time Domain Vs Frequency Domain Analysis

- 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

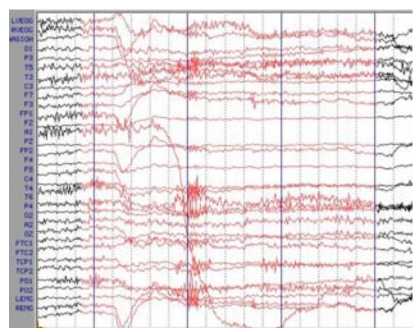
Dealing with Artifacts

- 60 cycle noise
  - Ground subject
  - 60 Hz Notch filter
- Muscle artifact
  - No gum
  - Use headrest
  - Measure EMG and correct for it
- Eye movements
  - Eyes are dipoles
  - Reject ocular deflections including blinks
  - Algorithms for blink and eye movement corrections

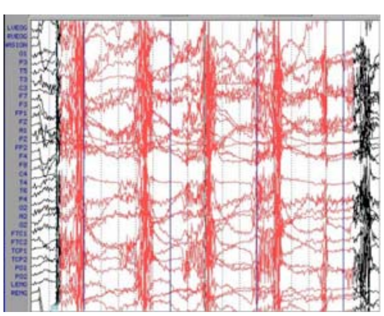
Name that artifact!



Name that artifact



Name that Artifact



Assumptions of Averaging

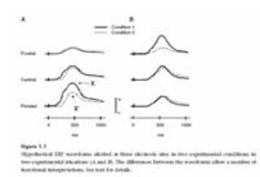
- Signal and noise (in each epoch) sum linearly together to produce the recorded waveform for each epoch (not some peculiar interaction)
  - Safe assumption
  - Helmholz Law (additivity)
- The evoked signal waveshape attributable solely to the stimulus is the same for each presentation
  - *No latency jitter*
  - (unlikely for cognitive tasks)
- The noise contributions can be considered to constitute statistically independent samples of a random process
  - Not always true…
  - Systematic blinking
  - Time-locked alpha (though this probably not “noise”)

Benefit of Averaging

- $S/N_{\text{ave N}} = \text{sqrt}(N) * S/N_{\text{single trial}}$
- P3 = 20 microvolts
- EEG = 50 microvolts
- S/N = 20/50
- If have thirty trials then
- S/N = (20 * 5.5)/50 = 110/50

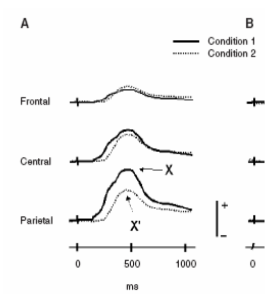
Simplest Inference

- ERPs to condition 1 differ from those to condition 2
- Cognitive processes associated with the two conditions differ in some respect
- Come on! Would that ever be useful information?

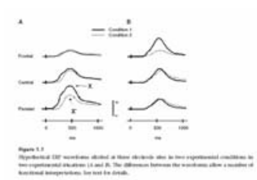


Timing Inferences

- Conditions 1 & 2 begin to differ at 250 ms post-event
- Cognitive/neural processes that differentiate the two conditions began by 250 ms
- When (pardon the pun) would we care about this sort of issue?



Dissociative Inferences



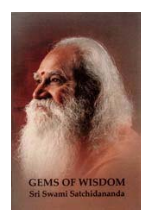
- Scalp distribution (topography) differs in A and B
  - Largest effect over Parietal site in A
  - Largest effect over Frontal site in B
- Different scalp distributions imply different patterns of underlying neural activity
- May support functional distinction between the conditions
  - Assumes neurophysiological distinction → functional distinction

Quantitative vs. Qualitative Differences

- What if the scalp distribution is the same for ERPs in 2 conditions, but the amplitude is greater for one than the other?
- Understood as quantitative (not qualitative) processing difference
- But null effects always tricky
  - Hard to draw too firm of conclusions from the absence of a difference
  - More on this later

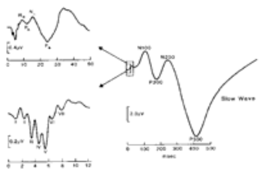
Inferences Based on Prior Knowledge

- Build on research by older (sometimes wiser) scientists
- Relies on the elicitation of an ERP component whose functional significance is agreed upon by cognitive neuroscientists



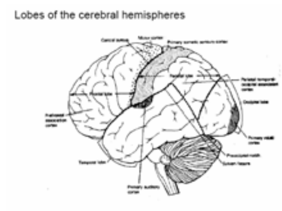
What is an ERP component?

- Portion of the ERP waveform that has been experimentally linked to a given neurocognitive process
- Physiological identification
  - Naatanen
  - Component defined in terms of its anatomical source/s
- Functional identification
  - Donchin
  - Component identified by functional process associated with its elicitation



Causes of Scalp Distribution Differences

- Totally different brain areas active in the two conditions
  - Visual vs. Auditory Cortex
- Difference in relative contribution of areas in a network
  - Frontal & Motor cortex both active in A & B
  - Frontal stronger in A
  - Motor stronger in B
  - Qualitative or Quantitative?
- Difference in time course of engagement of areas in a network
  - Frontal & Motor cortex both active in both A & B
  - Increased frontal activity begins earlier in A than it does in B
  - Quantitative or Qualitative?

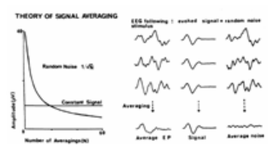


Polarity

- Polarity of ERP effect depends on many factors
  - Location and orientation of intracerebral sources
  - Location of reference electrode
  - Baseline against which it is compared

Amplitude

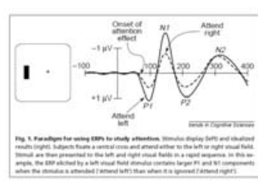
- Typically interpreted as reflecting strength of activity
- But amplitude differences can also arise when violations of assumptions behind averaging occur
- Assume temporal invariance of signal
  - But latency jitter can introduce apparent amplitude differences between two conditions that differ only 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



Time Course

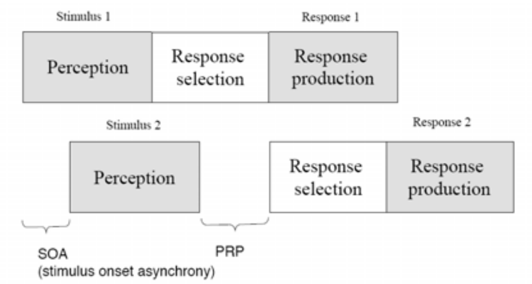
- Is onset of ERP effect onset of divergent processing in the brain?
- Neural activity could differ *before* effect onset, but not be detectable at the scalp
  - Onset latency best construed as upper bound on divergence
- Adequate interpretation of time course of ERP effects requires understanding of functional significance of differences in e.g. peak latency, rise time, and duration of effect

Timing Inferences

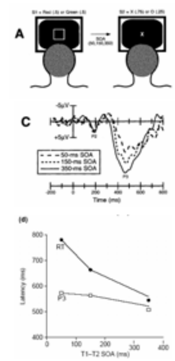


- Without knowledge
  - Attention effects begin at least by 60 ms after the onset of the stimulus
  - Attention effects have ended by 300 ms after the onset of the stimulus
- With prior knowledge
  - P1 and N1 reflect visual processing of the stimulus
  - Attention modulates early sensory processing of stimuli
  - At least in this experimental paradigm

Psychological Refractory Period



Luck (1998)

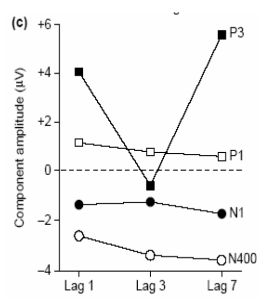


- Dual Task
  - T1: Red vs. Green Square
  - T2: X vs. O
- Findings
  - RT2 affected by SOA
  - P300 amplitude affected by SOA
  - P300 latency not affected by SOA
- Which stage is the bottleneck?
- Are there any ambiguities?

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"

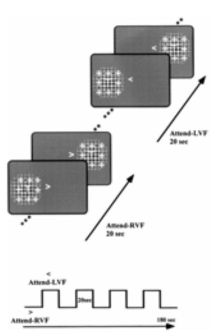
Luck et al. (2000)



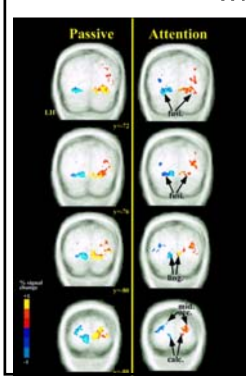
- Which ERP components modulated during AB?
- Not N1 or P1
  - What might this suggest?
  - Any reason for skepticism?
- P3 eliminated!
  - What's the implication for explanations of AB?

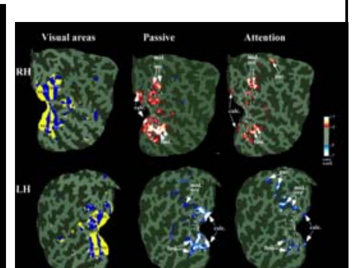
Integrating across methods

- 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?

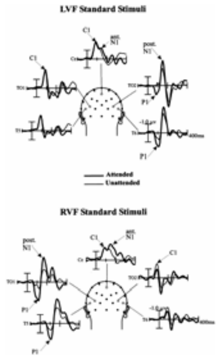


fMRI Data





ERP Data

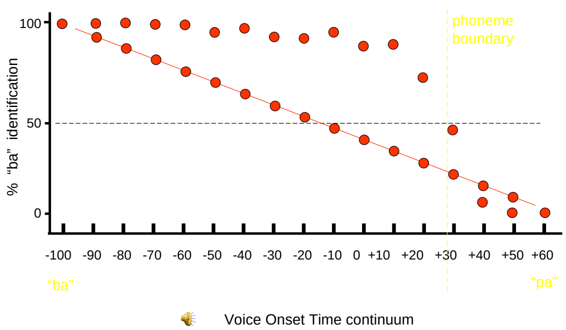


- C1 not attentionally modulated
- P1 larger for attended stimuli over contra-lateral hemisphere
- Ditto N1

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

Categorical Perception

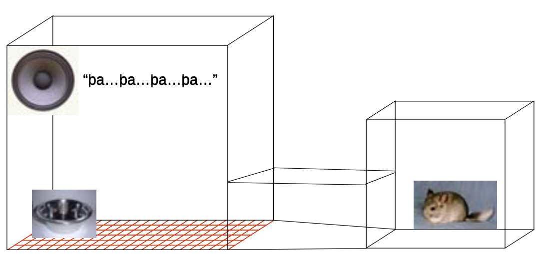


Why speech perception is a challenge

- Something we do without effort
- Something machines do very poorly
- Characteristics:
  - Extremely rapid
  - No "white space"
  - "Lack of invariance"
    - Within a speaker
    - Across speakers

Chinchilla experiment

(Kuhl & Miller experiment)



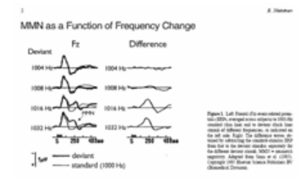
Studying Speech Perception w/ERPs

- Is there an ERP component that could serve as an objective record of perceptual discriminations people make when comprehending speech?

Mismatch Negativity (MMN)

- Frontocentral negative ERP component
- Peaks 100-250 ms post-stimulus onset
- Change in repetitive aspect of on-going auditory stimulation

Mismatch Negativity

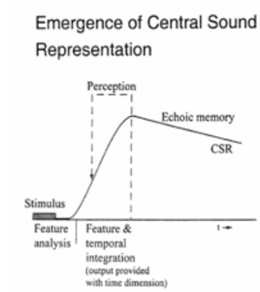


Reflects Automatic Processing

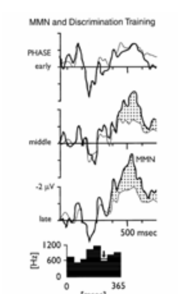
- Occurs with or without attention to auditory stimuli
- Sleep
  - Stage 2
  - REM
- Coma
- MMN signal more "pure" without attention
  - Without: subtraction yields only MMN
  - With: subtraction yields MMN, N2, P3

MMN & Echoic Memory

- Seems to reflect unified sound percepts (not acoustic features)
  - Simple tones
  - Complex stimuli (phonemes)
  - "complex spectrotemporal pattern"
- Does not arise unless "standard" is repeated a few times
- Does not arise if 5-10 s intervenes between stimuli
  - Matches estimated length of echoic memory

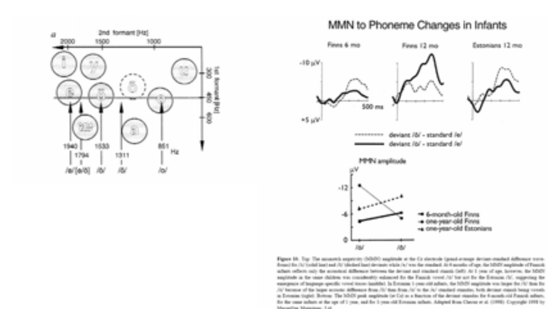


MMN and Experience



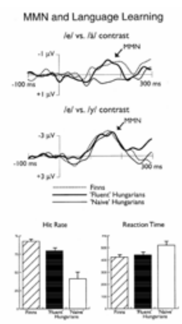
- Subjects read a book while tones played in background
- Tested periodically in their ability to discriminate between tones
  - Increased over course of study
- MMN increases in amplitude as function of experience

Language Experience: Infants

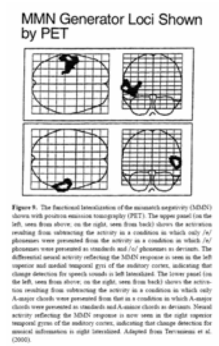


Language Experience: Adults

- /a/ embedded in /e/
  - Relevant in Finnish
  - Not relevant in Hungarian
- /y/ embedded in /e/
  - Relevant in Finnish
  - Relevant in Hungarian



Speech Stimuli (Left Temporal)



Musical Stimuli (Right Temporal)

Voltage Maps

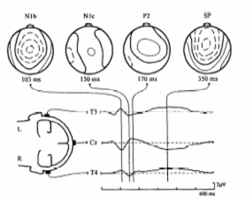


Fig. 19. Scalp distribution maps for the auditory evoked potential. These maps present the scalp distributions at selected latencies during the waveforms plotted in Fig. 4. The maps are based upon the average reference recordings and are plotted using an azimuthal equidistance projection extending down below the Fpz-T7-Oz-T8 equator to about the level of the mastoid electrodes. The thick line in the maps represents zero voltage. The dashed lines represent contours for negative voltages and the thin lines represent contours for positive voltages, both plotted at intervals of 1 μV. At 105 ms there is negative wave (N1b) recorded maximally at the vertex whereas a later negative (N1c) occurs maximally in the left temporal region. The P2 wave is maximally recorded from the vertex. The sustained potential (SP) is maximally recorded from frontocentral regions with a scalp distribution somewhat more anterior than that of the N1b wave.

$$V_x = \sum_{i=1}^{N} (d_i^{-m} V_i) \Big/ \sum_{i=1}^{N} d_i^{-m}$$

- Nearest Neighbor
  - di: distance to electrode i
  - N: number of neighbor electrodes
  - Vi: voltage at electrode i
- Alternative
  - Spline interpolation

Current Source Density

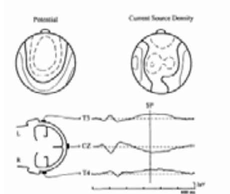


Fig. 22. Current source densities. The upper left of this figure illustrates the scalp distribution of the sustained potential recorded at a latency of 350 ms for the same data as shown in Fig. 19. As in previous maps, contours in region of negative polarity are plotted with dashed lines and contours in the region of positive polarity are plotted with thin lines. Sample waveforms (referred to an average reference) are shown in the lower half of the figure. The current source density is plotted in the upper right of the figure. The distribution of the current source density over the scalp suggests dipole fields originating in the Sylvian fissures, particularly on the left. The stimulus was presented to the right ear.

- 2nd spatial derivative
  - How voltage changes at each point on the scalp differ w/respect to changes at other points
- Estimates sources and sinks of radial current
  - Net current outflow: source
  - Net current inflow: sink
- Highlights activity focused on limited scalp area
- Tends to remove deep sources that show up at many electrodes

Scalp Distribution of Dipole Fields

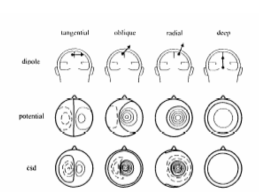
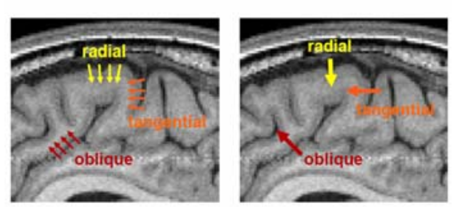


Fig. 21. Scalp distribution of dipole fields. At the top of this figure are shown dipoles located in various regions of the brain. All dipoles are oriented within the coronal plane. The second line of the figure shows the distribution of the scalp potentials associated with these dipoles. The bottom line of the figure estimates the current source density (csd) at the surface of the scalp. Note the similarity between the middle two potential maps and the dissimilarity of the csd maps. Note also the absence of any clear csd map when the dipole is located at the center of the head (rightmost column).

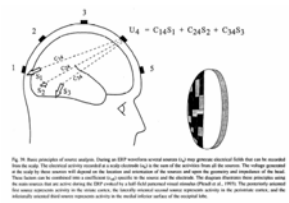
- Oblique & Radial sources yield
  - similar scalp maps
  - different CSDs
- For deep source
  - No clear CSD
  - Deep sources equally distant from all sites
  - Look similar at all sites
  - Hard to detect with derivative measure

Neuronal current flows perpendicular to the cortex and creates dipole fields

net current density * area = equivalent dipole moment



Source Analysis

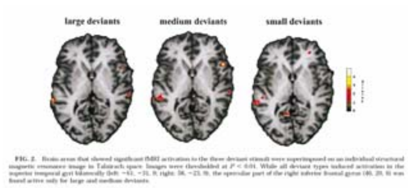


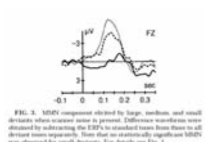
- Activity at each site linear combination of sources
- C here is coefficient that determines value of source at electrode u based on
  - Source Location
  - Source Orientation
  - Conductivity of brain, skull, and scalp

General Idea

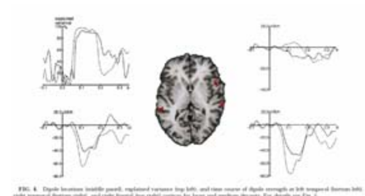
- Forward Model
  - Postulate N dipolar sources with particular locations and orientations
  - Coefficient matrix C: N sources x K electrodes (values based on head model)
  - Run source magnitudes through C to yield predicted scalp voltage at each electrode: Vector U'
- Inverse Model
  - Invert matrix C
  - Multiply by actual scalp voltage matrix U
  - Yields S
- Reduce Residual Variance
  - Difference between U and U'
  - Change dipoles so as to minimize difference between U and U'
- Rinse and Repeat

Opitz et al.





Conclusions?

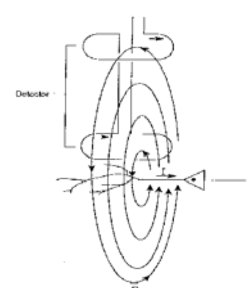


- Their claim: early MMN temporal lobe sources, late MMN frontal source
  - Plausible a priori
- BUT: Model explains variance from .1 to .2 seconds
- Frontal source most active *after* that period
- Authors making big claims about the least solid aspect of their data…

Magnetoencephalography (MEG)

- Records the *magnetic flux* or the *magnetic fields* that arise from the source current
- A current is always associated with a magnetic field perpendicular to its direction
- Magnetic flux lines are not distorted as they pass through the brain tissue because all biological tissues offer practically no resistance to them

Dipole is a small current source

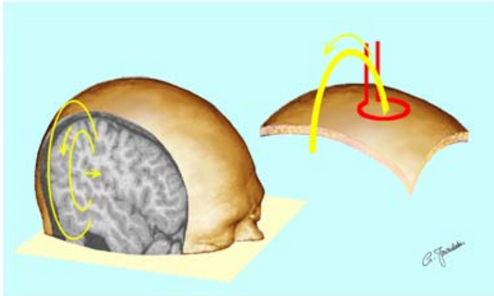


- Dipole generates a magnetic field
- At least 10,000 neurons firing “simultaneously” for MEG to detect
- Dendritic current

Recording of the Magnetic Flux

- Recorded by special sensors called *magnetometers*
- A magnetometer is a loop of wire placed parallel to the head surface
- The strength (density) of the magnetic flux at a certain point determines the strength of the current produced in the magnetometer
- If a number of magnetometers are placed at regular intervals across the head surface, the shape of the entire distribution by a brain activity source can be determined

Magnetic Flux Associated with Source Currents



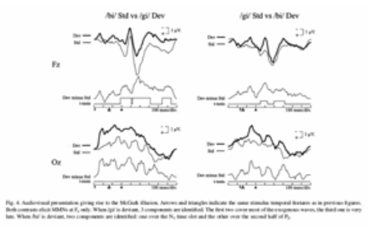
McGurk Effect

Sams, et al. (1991)

- McGurk effect reflects a stage of audiovisual integration
- What brain area does this occur in?

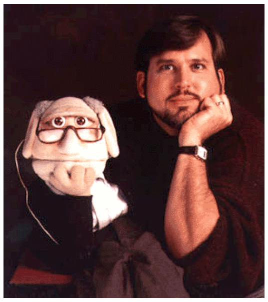
MEG Study
- McGurk Deviant
  - Hear /pa/ See /pa/ 84%
  - Hear /pa/ See /ka/ 16%
- McGurk Standard
  - Hear /pa/ See /ka/ 84%
  - Hear /pa/ See /pa/ 16%
- Control (Face Replaced by)
  - Red light 84%
  - Green light 16%

Audiovisual (McGurk Effect)



Ventriloquist Illusion

- Speech comes from man, but seems to come from puppet
- When there are synchronized auditory and visual events displaced in space, perceived auditory location shifted in space towards visual event
- Perceptual system integrates discrepant stimuli

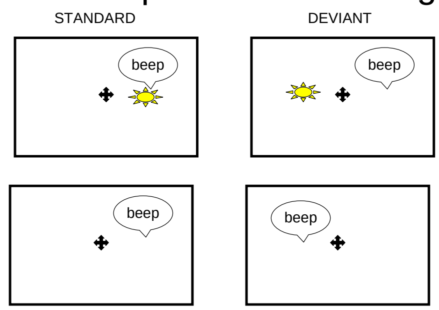


Cross-Modal Integration

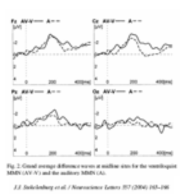
Stekelenburg, Vroomen, & de Gelder (2004)

- What is the time course of the cross modal integration in the ventriloquist illusion?
- Is it early enough to elicit a MMN?
  - Spatial displacement of a sound elicits MMN
  - Does *illusory* displacement of a sound elicit MMN?
  - If it did, what would it mean?

Ventriloquist MMN Paradigm



Results

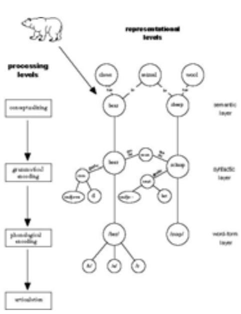


- MMN auditory condition
  (dashed line)
- MMN AV-V condition
  (solid line)
- Similar amplitude & topography
- What does it mean?

Eech Sperrors

- What can we learn from these things?
- Anticipation Errors
  - a reading list → a leading list
- Exchange Errors
  - fill the pool → fool the pill
- Phonological, lexical, syntactic
- Speech is planned in advance
  - Distance of exchange, anticipation errors suggestive of how far in advance we "plan"

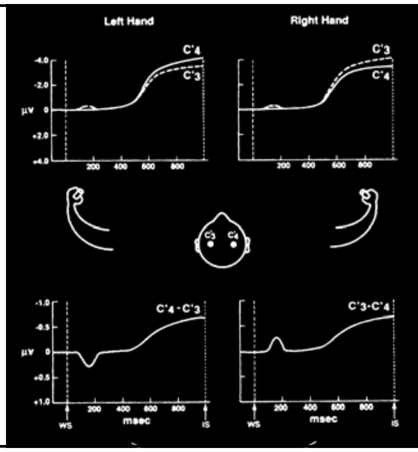
Levelt and Colleagues Model



- Image
- Lexical or Concept Level
  - Stored information about bears
  - Related concepts stored close
  - These can be co-activated by thought or image
- Lemma Level
  - Syntactic information
  - Competition among all activated items
- Lexeme Level
  - Match syntactic elements from lemma to sounds
  - Syllables, stress, rhythm, intonation
- Message goes to formulator for grammatical encoding
  - Lemmas: Semantic & Syntactic
- Phonological Encoding
  - Lexemes
- Articulator

LRP

- derivative from the Bereitschaftspotential
- button press tasks
- ramp-shape activation above the motor cortex
- planning of movement (before actual movement)
- in go and nogo responses
- maximum contra lateral to movement
- maximum at electrode sites C3' and C4'



LRP

- Real time measure of response preparation
- Response selection can begin even before complete stimulus information available
- LRP provides index of time when different aspects of stimulus available for response selection

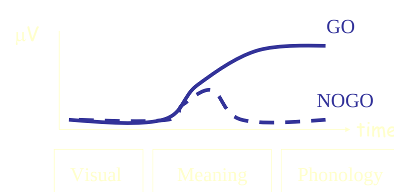
LRP in language production

- preparation to respond
- indicates when specific information becomes available
- dual choice go/nogo paradigm (Van Turennout et al., 1997, 1998)

- two decisions
- one is based on semantics
- one is based on phonology

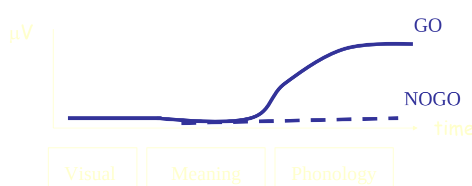
LRP Hypothesis

- hand = semantics
- if semantics precedes phonology LRP even on nogo trials



LRP Hypothesis

- hand = phonology
- if semantics precedes phonology LRP only on go trials



Second ERP component: N200

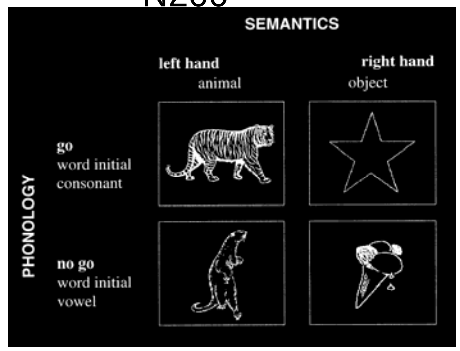
- go/nogo paradigm
- enhanced negativity for nogos compared to gos
- maximum at frontal sites
- related to response inhibition
  - Sasaki and Gemba, 1989, 1993
  - Single cell recordings in monkeys

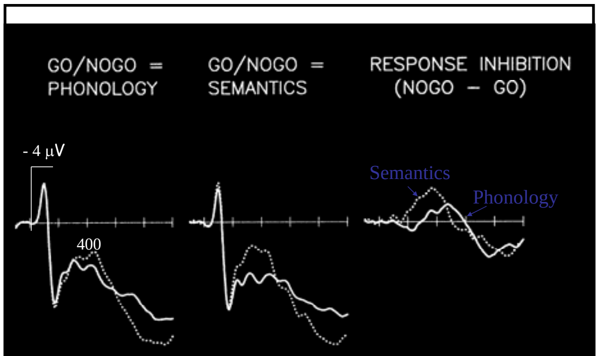
N200 in language processing

- nogo - go difference wave
- onset and peak of the effect
- moment in time when specific information is available

N200

design



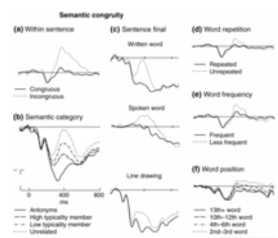


...... NOGO — GO

Difference

Functional Significance

- N400 index of difficulty retrieving conceptual knowledge associated with a word
- Depends on
  - Representation of word itself
  - Contextually activated knowledge

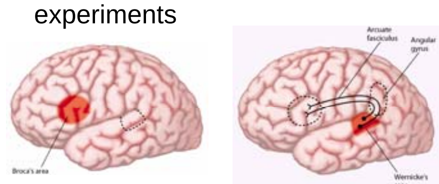


Identifying Neural Generators

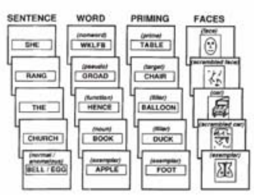
- ERPs from patients with well-characterized damage to the brain
- fMRI
- Intracranial Recording
- MEG

fMRI

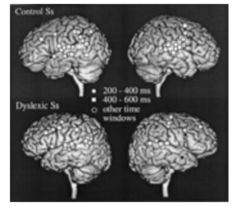
- Divergent pattern of activation due to manipulations of semantic context
- Left superior temporal gyrus in 7/12 experiments
- Left inferior frontal gyrus in 8/12 experiments



Nobre & McCarthy (1994)



Helenius & colleagues (2005)



Models of Spoken Word Identification

- The TRACE (Interactive Activation) Model
  - McClelland & Elman, 1986
- The Cohort Model
  - Marslen-Wilson & Welsh, 1978
  - Revised, Marslen-Wilson, 1989

Marslen-Wilson's Cohort Model

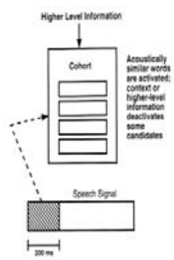


FIGURE 6-11 The Cohort Model of Word Recognition.

- Mental representations of words activated (in parallel) on the basis of bottom-up input (sounds)
- Can be de-activated by subsequent input
  - bottom-up (phonological)
  - top-down (contextual)

Word ID & Semantic Integration

- Cohort model suggests context impacts word recognition via the deactivation of some words in the cohort, but
- Doesn't say much about the relative timing of word recognition and understanding meaning of sentence
- Van Petten & colleagues raise 3 possibilities
  - Semantic processing of words begins after uniqueness point has been reached
  - Meaning of all words in cohort active early, but contextual integration does not begin until after uniqueness point has been reached
  - Semantic processing at both word and sentence levels begins early

Van Petten et al.

- Determine isolation point for a bunch of words
- Embed words in sentences where they are congruous vs. incongruous
- N400 as index of contextual integration
  - When is onset effect of N400 relative to isolation (uniqueness) point for words?
  - Are words in the same cohort ruled out by context before the uniqueness point or after it?

Open vs. Closed Class Words

- **Open Class**
  - Set of these words is continually changing as words come into and go out of fashion
- Content Words
  - Meaning bearing elements
  - Important for semantic function
- Nouns
- Verbs
- Adjectives
- (most) Adverbs
  - Formed by adding –ly to an adjective

- **Closed Class**
  - Set of these words changes very slowly
  - Remains relatively constant over time
- Function Words
  - Very abstract meaning, if any
  - Important for grammatical function
- Prepositions
- Determiners
- Conjunctions
- Pronouns
- (some) Adverbs
  - "where" "when"

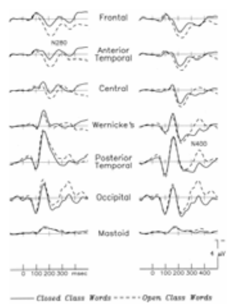
Psycholinguistics

- Bradley (1978) argues
  - closed class items processed by special system
  - operates at an early stage in comprehension
  - channels information to the parser
- Lexical decision task
  - Word/Nonword
    - CAT
    - CET
- Open Class Words
  - LDT inversely related to frequency
- Closed Class
  - LDT relatively constant, regardless of frequency

Neville, Mills, & Lawson (1992)

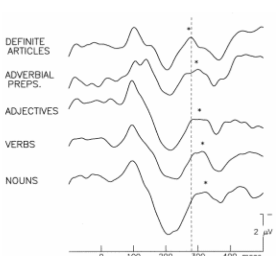
- Open Class Words
  - N400
- Closed Class Words
  - N280
  - Negativity observed at left frontal sites
- Consistent w/Bradley's proposal
  - ERPs to closed class words peak earlier than to open class words
  - ERPs to closed class words largest over left frontal sites above Broca's area

King & Kutas



- Just as N400 elicited for both OC and CC words, but *smaller* for CC
- Perhaps N280 also elicited for both OC and CC, but *later* for OC
- Differences in word length and word frequency

"N280" in different kinds of words



- Compiled ERPs to words of different syntactic categories
- Correlated measurements of ERPs with measurements of words' length and frequency in the language
- ERPs recorded at left anterior channel
  - Negative peak present for articles at 280 ms, but also adverbial prepositions, adjectives, verbs, etc. at slightly later time points
- Dubbed this component "Lexical Processing Negativity"

Consolidating

- What was Bradley's proposal about different brain systems underlying processing of OC and CC words?
- What ERP data from Neville, Mills, & Lawson seemed to support this proposal?
- Do CC words elicit N400?
- Why might N400 elicited by CC words be smaller than OC words?
- Do King & Kutas think OC words elicit N280?
- How did they digitally filter their data to better observe N280 to OC words?
- What did King & Kutas discover about the latency of the LPN and word frequency (or word scarcity)?
- What cognitive process do you think the LPN might be indexing?
- How do King & Kutas findings with respect to the LPN sit with Bradley's proposal? Do they argue for or against it?

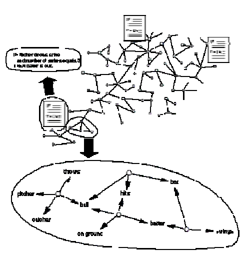
Easy Questions

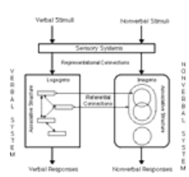
- What ERP component was originally thought to reflect processing of OC but not CC words?
- Are there differences in N400 to OC versus CC words?
- What ERP component was originally thought to reflect processing of CC but not OC words (but isn't now)?
- What characteristic of words predicts the peak latency of the N280/LPN?
- What theoretical suggestion motivates the search for ERP components specific to OC versus CC words?
- What ERP component tends to be elicited *only* by CC words?
- What ERP component associated with anticipatory processing has been related to the N400-700?

Common vs. Multiple Semantic Systems

- ERPs to words vs. pictures
- ERPs to concrete vs. abstract words

UNITARY ***MULTIPLE***





Picture N400

- Earlier onset of picture N400 (in Mixed) consistent with finding that people categorize pictures faster than they do words
- Frontal distribution may reflect generator in temporal pole

ERPs to pictures

- N300
  – Anterior distribution
  – Picture-specific semantic system
- N400
  – Fronto-central distribution
  – More general semantic system

Review Questions

- What is the main difference between the N400 elicited by words vs. pictures?
- What does this finding imply about the existence of a common semantic system?
- How does the scalp distribution of the N300 compare to that of the picture N400?
- What is the main evidence that N300 and N400 are different components?
- What has been proposed about the functional significance of the N300 vs. the N400?
- Should we be troubled by the fact that N300 congruity effects were not observed in the complex stimuli used by Ganis & Kutas (2003)?
  – If an effect is only observed in paradigms lacking ecological validity, do they reflect real brain processes?

Concreteness Effects

- Concrete words understood more quickly and accurately
- Concrete words remembered better
  - Free recall
  - Cued recall

ERP Studies of Concreteness

- Kounios & Holcomb, 1994
  - Record ERPs as people do LDT on list of concrete words, abstract words & nonwords
  - Concrete Words elicit more N400 than Abstract Words
  - Anterior Distribution, R>L
  - Bears some similarity to picture N400
  - Dual Coding Theory

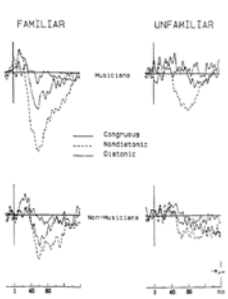
Review Questions

- How do ERPs to concrete words differ from those to abstract words during the interval the N400 is measured in?
- Does this support proposals for common or multiple semantic systems?
- Concreteness effects are evident in ERPs to words in neutral sentences
  - Are they also seen in anomalous sentence completions?
  - Are they seen in congruous sentence completions?
- Concreteness effects go away in supportive sentence contexts
  - How is this finding explained by dual coding theory?
  - How is this finding explained by context availability theory?
- Describe an ERP finding that argues against the explanation based on context availability theory

Violations of Musical Expectancies

- Besson & Faita (1995)
- Harmonic Violation
  - A note or chord from a different key than the one that has been established (non-diatonic)
- Melodic
  - A note from the same key, but not the one that's expected (diatonic)
- Rhythmic
  - Note is what is expected, but timing relative to prior notes is unexpected (e.g. 600 ms delay)

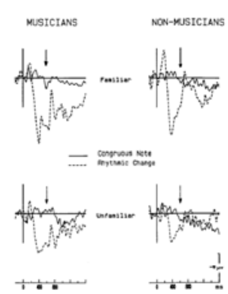
Musical Violations



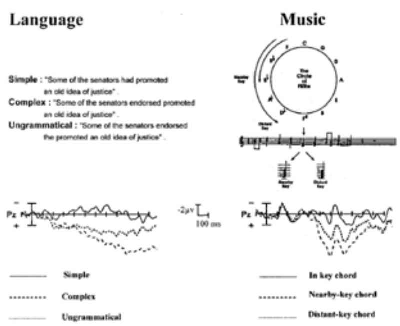
- Familiar Melodies
  - P300/LPC
  - Larger for
    - Nondiatonic (out of key) than
    - Diatonic (wrong note in same key)
  - Effects larger in musicians than non-musicians
- Unfamiliar Melodies
  - P300/LPC but smaller than for Familiar Melodies
  - Larger for Nondiatonic than Diatonic
  - Larger in musicians than non-musicians
- P300/LPC sensitive to
  - Perceived badness of note
  - Ability to perceive badness

Rhythmic Violations

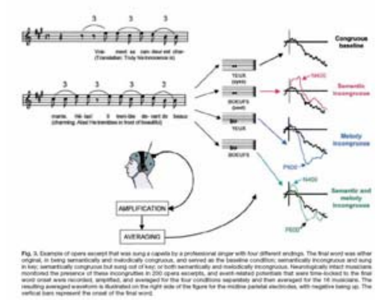
- Delayed last note elicits biphasic negative-positive complex
  - Larger for Familiar than Unfamiliar melodies
  - Similar in Musicians & Nonmusicians
- Emitted stimulus potential
  - also elicited in auditory oddball paradigms if a regular stimulus is interrupted
  - "Pause" positivity elicited in Van Petten et al. (1999) spoken sentences (dolphin/dollar/muffin) study
- Arrow marks actual presentation of note
- Actual note elicits N1-P2 complex typically evoked by tones



Syntactic vs. Harmonic Violations



Semantic vs. Harmonic Violations



Musical Meaning

- Iconic meaning
  - Musical sounds that resemble sounds or qualities of objects
- Emotional meaning
  - Suggestion of a particular mood (happiness)
- Associative meaning
  - Extramusical associations (national anthem; “our” song)
- **Musical tension**
  - **Via the combination of chords**
- **Musical resolution**
  - **Via the combination of chords**

Koelsch et al. (2003)

Figure 1. Examples of stimuli. Top: C major chord sequence exclusively consisting of in-key chords. Bottom: chord sequence modulating from C major to D major. The second chord is the pivot chord, functioning as dominant in C major, as well as subdominant in D major. The third chord of the modulating sequence (indicated by the arrow) is the dominant chord of D major, introducing one out-of-key note in respect to C major.

ERAN & N5

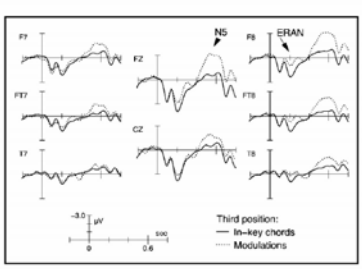
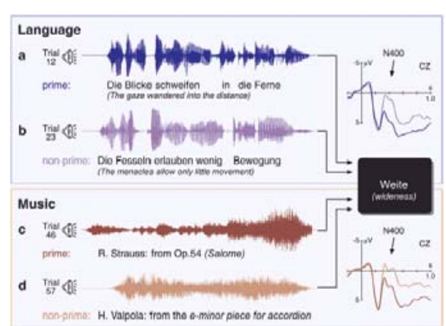


Figure 3. Grand average ERPs elicited at position 3 of the sequences, separately for modulating and in-key chords. Modulating chords elicited an early right anterior negativity (long arrow) and a late right frontal negativity (N5, short arrow).

Koelsch et al. (2004)



Environmental Sounds

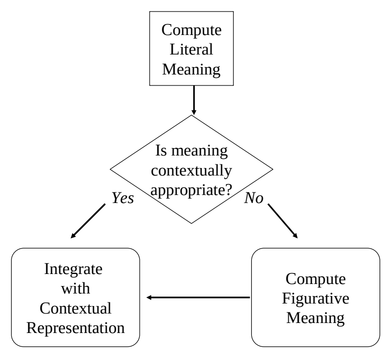
- People derive meaning from auditory information in the environment
- When asked to identify a sound, people name the source of the sound rather than describing its acoustic characteristics (Ballas & Howard, 1987)

Van Petten & Rheinfelder

- Similarities in the brain response to contextually primed words and environmental sounds
- Different topography points to hemispheric differences in the specialization for processing meaningful verbal versus nonverbal acoustic information

Metaphor & Discourse

Standard Pragmatic Model

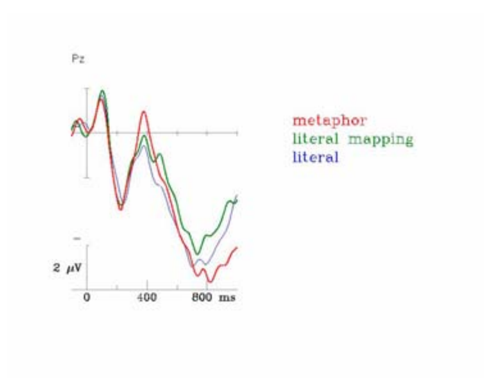


Materials

Literal: He knows that whiskey is a strong *intoxicant*.
Litmap: He has used cough syrup as an *intoxicant*.
Metaphor: He knows that power is a strong *intoxicant*.

Literal: The secret ingredient in her stew is *cayenne*.
Litmap: The chef apparently uses salt instead of *cayenne*.
Metaphor: My crazy uncle says jokes are conversation's *cayenne*.

Literal: They had a few chickens in the yard, and in the barn was a *goat*.
Litmap: On our trip to the mountains, Dad thought a bighorn sheep was a *goat*.
Metaphor: Someone had to take the fall, and unfortunately your husband was the sacrificial *goat*.



ERPs and Metaphor Processing

- Metaphoric language is harder to understand
- Graded N400 difference argues against literal/figurative dichotomy

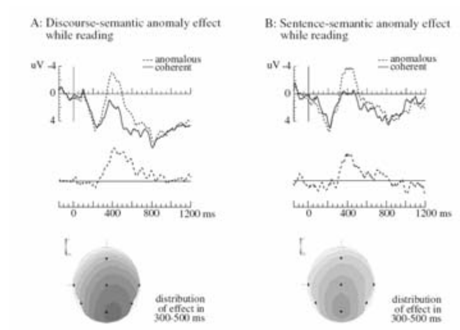
Discourse Processing

- N400 amplitude indexes congruity with sentence context
- Does it also index congruity with larger discourse context?

Discourse-level Anomaly Effects

- Locally congruent sentences elicit similar N400 presented in isolation
- Larger N400 for sentence completions not congruent with information set up in the discourse context
- Also true for words in the middle of sentences
  - need not be at end of sentence
- N400 enhancement happened even for low constraint (open-ended) contexts that did not suggest a particular word
- Suggests words are integrated with the discourse context as soon as they are processed for meaning
  - Argues against model of word processing followed by sentence processing followed by discourse processing

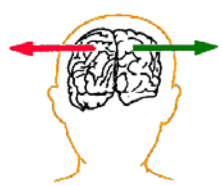
Written Materials: Discourse- versus Sentence- Level Anomalies



Hemispheric Asymmetry & Joke Comprehension

Left brain/Right brain

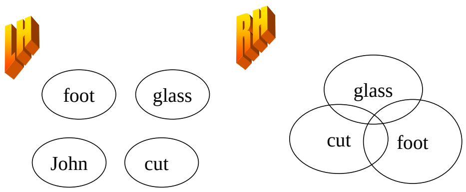
Speech
Word-finding
Grammar



Discourse
Metaphors
Jokes

Coarse Coding Hypothesis

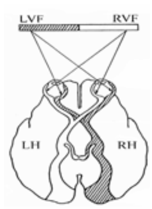
Difference in effects of LHD and RHD reflect broader semantic activations in the RH that are crucial for the interpretation of figurative language.

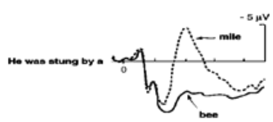


Alternative Formulation

- Beyond "broad" activation metaphor
- Semantic activation in the RH might involve alternative frames (schemas, scripts, ICMs) that represent causal and relational information important for joke comprehension

DVF ERP Priming Paradigm





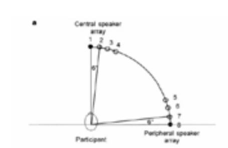
Materials

Pun	Probe Word
During branding cowboys have sore calves.	Cow (Primary Related)
During branding cowboys have sore calves.	Leg (Secondary Related)
I could have been a swimmer if I had a stroke.	Cow (Primary Unrelated)
Seven days without a pun makes one weak.	Leg (Secondary Unrelated)

Coulson & Severens, 2006

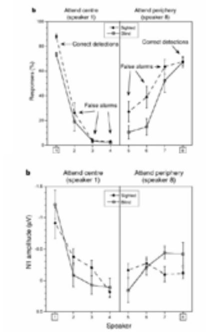
- Initially
  - Both meanings of puns active in LH
  - Only highly related meaning active in RH
- Later
  - Both meanings of puns active in both hemispheres
- Puns differ from more semantic jokes in their involvement of the RH

Experimental Paradigm



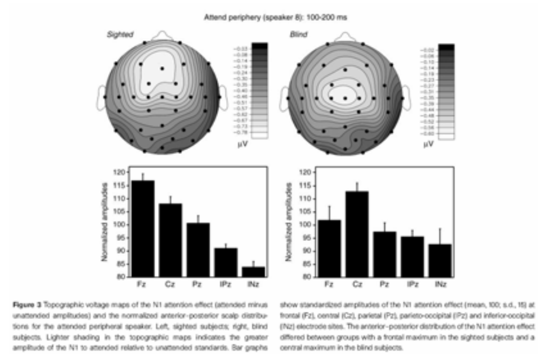
- Participants were either sighted individuals wearing blindfolds or congenitally blind
- Brief noise bursts occurred randomly from each of the 8 speakers
  - Frequent Standard
  - Rare (higher-pitched) Target
- Two Conditions
  - Attend Center (detect targets from speaker 1)
  - Attend Periphery (detect targets from speaker 8)

Spotlight of Attention



- How do behavioral data (top) map onto N1 amplitude data (bottom)?
- Are good correct detection scores associated with big or small N1 amplitude?
  - Why?
- Are low false alarm rates associated with big or small N1 amplitude?
  - Why?
- Who has a more focused attentional spotlight in the periphery?
- What about the center?

Nd: Attended minus Unattended



Conductors

- Besides sensory deprivation, experience can also alter brain organization
- Orchestra conductors have to both listen to overall sound and be able to focus on particular individuals
- Does this experience affect their ability to localize sounds in the environment
  - Relative to other musicians, e.g. pianists
  - Relative to non-musicians

Those amazing components…

- What component did Roder and colleagues examine in a similar paradigm?
  - Functional significance?
- What difference component do you get if you subtract (N1) ERPs elicited by stimuli when its location is unattended from attended?
  - Functional significance?
- When auditory stimuli are ignored, what component is derived by subtracting the standard noises from the deviant noises?
  - Is it larger when the difference between the two sorts of stimuli is *easy* to detect or *hard* to detect?
- What ERP component are the auditory deviant stimuli likely to elicit when they are the targets?

Nager et al. Discussion

- Conductors better than pianists at attentively focusing relevant auditory information in space
  - Dropoff in Nd effect at irrelevant locations in the periphery
  - Same brain regions used as pianists, though
- Conductors better at “pre-attentive registration of deviant stimuli outside the attentional focus.”
  - P3a to ignored deviants observed only in conductors

Good Luck

You’ve been an excellent class – I’m sure you’ll all ace the final exam!