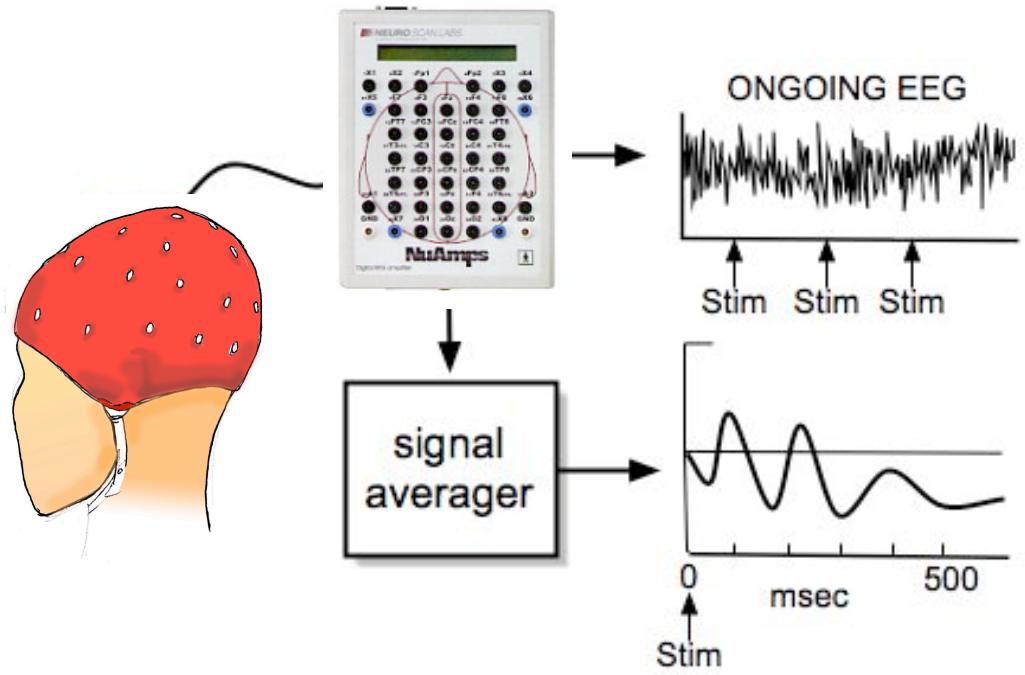
ERP Studies of Semantic Processing

LIGN 170, Lecture 17

Non-invasive methods - Electrical
Event-related brain potentials



Prelude to language ERPs: P300

- Increase in positive amplitude at 300 milliseconds after stimulus onset over the crown of the head
  - Elicited by rare or unexpected stimuli

Early ERP language studies

- What ERP response is elicited when a word at the end of a sentence is printed in an unexpectedly large font?

Kutas & Hillyard (1980a)

- Example stimulus:

Kutas & Hillyard (1980a)

- Unexpectedly large fonts lead to increase in P300 amplitude, like other unexpected stimuli

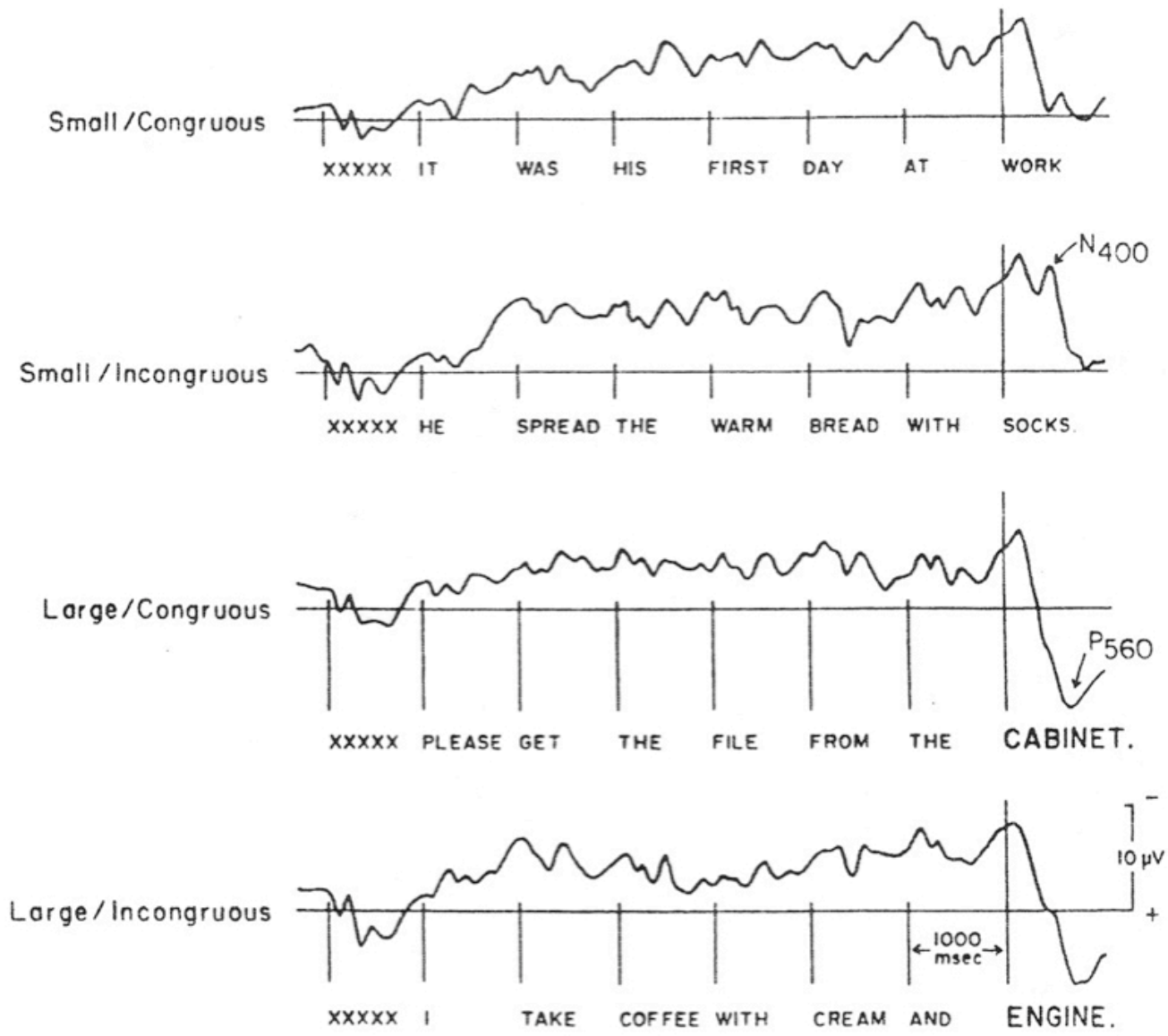
CABINET

Obvious question

- Is the P300 elicited with other kinds of unexpected linguistic stimuli?
- What happens with sentences like:
  - The pizza was too hot to drink?

Kutas & Hillyard (1980b)

- Combined physical and semantic incongruities in single experiment
  - Physical: oversized, bold font
  - Semantic: “absurd, semantically inappropriate words in otherwise meaningful sentences”


Small / Congruous
XXXXX IT WAS HIS FIRST DAY AT WORK
Small / Incongruous
N400
XXXXX HE SPREAD THE WARM BREAD WITH SOCKS.
Large / Congruous
P560
XXXXX PLEASE GET THE FILE FROM THE CABINET.
Large / Incongruous
10 μV
1000 msec
XXXXX I TAKE COFFEE WITH CREAM AND ENGINE.

Introducing the N400

- Semantic anomalies elicit an increase in negative amplitude from 300-500 milliseconds that peaks 400msec after the onset of the anomaly
- This negativity is usually largest over centrał parietal area of the scalp

Basic questions about the N400

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Susan ate a statue for breakfast.

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N400s to spoken and signed language

- Similar N400 effects have been found for violations in both spoken and signed modalities
- N400 is not limited to written language processing
- In fact, when pitch has linguistic properties (e.g. tone in tonal languages), incorrect pitch can trigger N400 effects

Mandarin Chinese

- Word meaning is in part determined by lexical tone
  - Two words that differ only by tone can mean two distinct things
    - /dan/: eggs, gall bladder

Brown-Schmidt & Canseco-Gonzales (2004)

Example

- My mother's chicken is very ill, she doesn't lay any
  - (1) eggs (dàn)
  - (2) gallbladder (dǎn)
  - (3) moat (qiàn)
  - (4) footpath (qiān)
- Results: N400 effects to (2),(3) & (4) compared to (1)

Brown-Schmidt & Canseco-Gonzales (2004)

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- Is the effect tied to sentence meaning or lexical meaning?

Fischler et al. (1983)

- N400 Effect for
  - A robin is a vehicle.

    (A robin is a bird.)
- But also N400 effect for
  - A robin is not a vehicle.

    (A robin is not a bird.)
- So false sentence gets bigger N400 than true!

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- Is the effect tied to sentence meaning or lexical meaning?
  - Lexical meaning
- Can N400 effects be elicited by pictures?

Ganis et al. (1996)

- Will images depicting anomalous concepts elicit an N400 effect?

- I take my coffee with cream and

Answer: Yes

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- Is the effect tied to sentence meaning or lexical meaning?
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- Can N400 effects be elicited by pictures?
  - Yes

Summary so far

- The N400 is elicited by semantic anomalies
  - At the end and middle of sentences
  - Regardless of speed of presentation
  - Regardless of modality of presentation
  - At the level of lexical meaning
  - Even represented in pictures

Summary so far

- This evidence suggests that the N400 is an index of lexical semantic processing - probably with access to conceptual knowledge

Scope of the N400

- Thus far: very strange semantic anomalies
  - The pizza was too hot to drink.
- Interesting, but if the N400 is limited to only these kinds of violations, then there's only so much it can help us understand.

- What else is the N400 sensitive to?

Beyond semantic anomalies

- What counts as a "semantic anomaly"?
  - Impossible
  - Strange, but possible
  - Plausible but unexpected

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  - **Plausible but unexpected**

Expected: Cloze probability

(1) Bob mailed the letter without a _____.

(2) Julie sat down on the _____.

(3) There was something wrong with the _____.

Contextual constraints

- Sentences can constrain the identity of upcoming words
  - High close probability
  - Low cloze probability
- More context = more constraint
- So, is the N400 sensitive to violations to cloze probability (not just violations of (common-) sense)?

Kutas & Hillyard (1984)

A

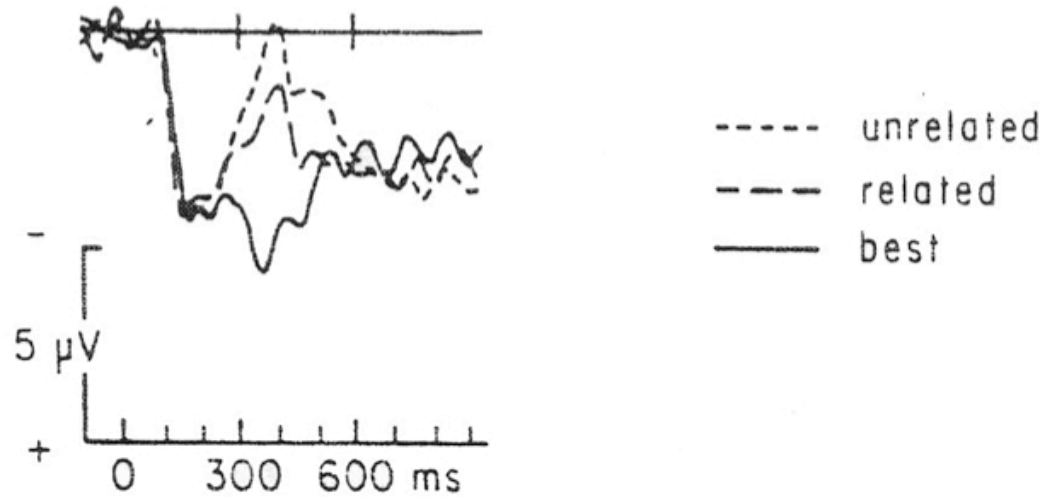
(best) Don't touch the wet paint.

(unrelated) Don't touch the wet dog.

(best) He liked lemon and sugar in his tea.

(related) He liked lemon and sugar in his coffee.

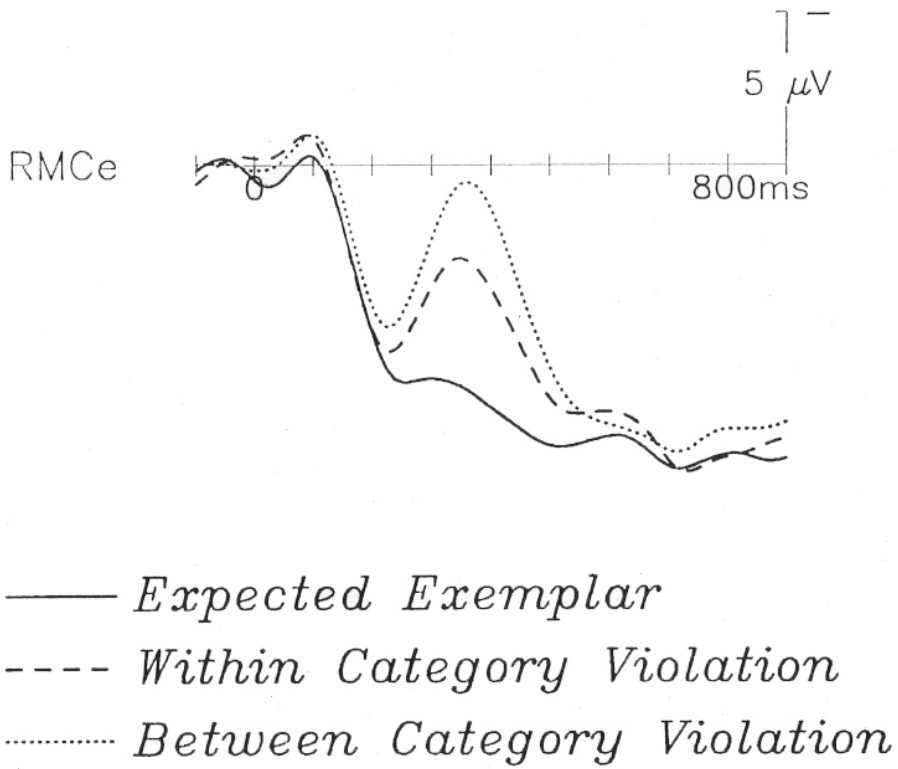
B



Beyond semantic anomalies

- What counts as a "semantic anomaly"?
  - Impossible
  - Strange, but possible
  - **Plausible but unexpected**
  - N400 sensitive to contextual constraints on word identity - not simply semantic violations

Related to expected word



- At the dinner party, I wondered why my mother wasn't eating her soup. Then I noticed that she didn't have a
- Expected: spoon
- Same category: knife
- Different category: bowl

More than just anomalies

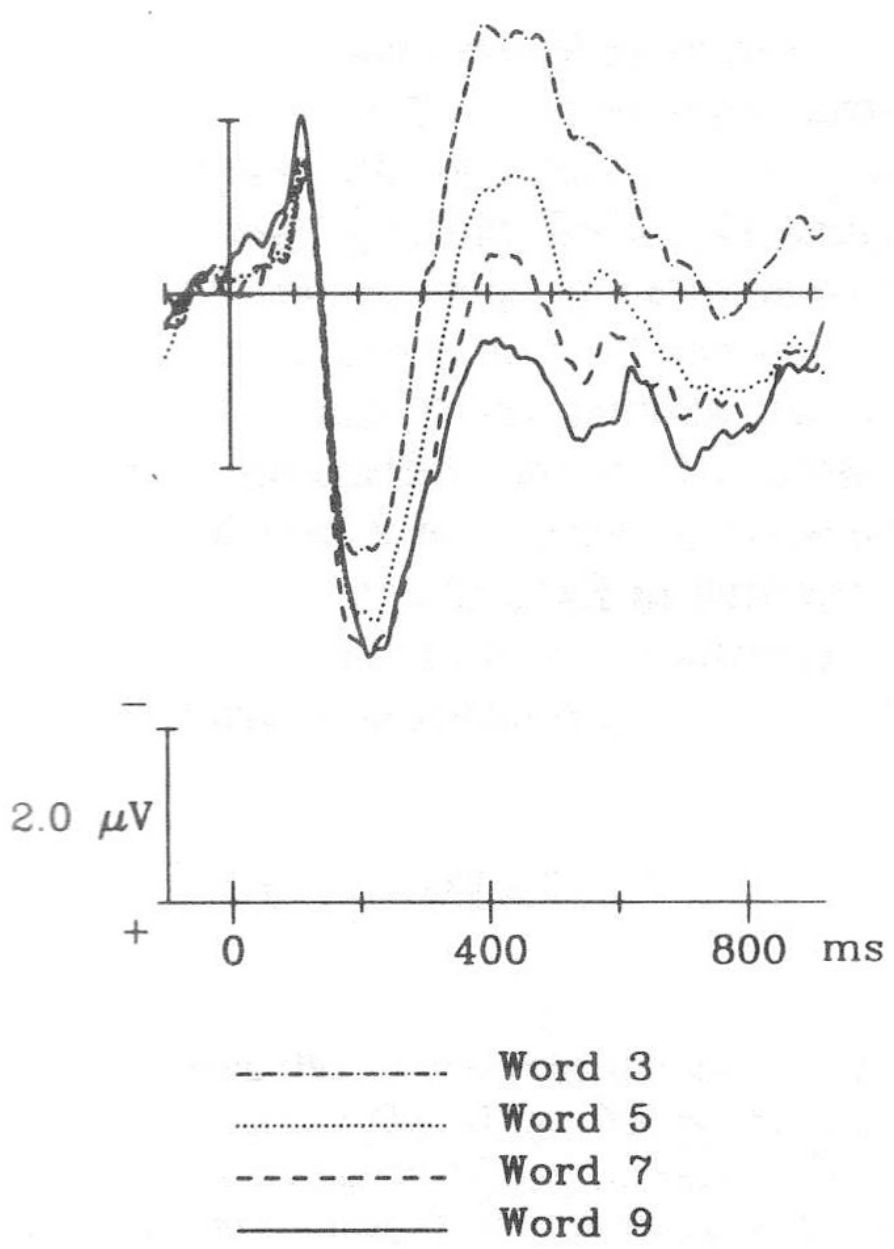
- N400 amplitude appears to reflect processes related to word expectancy and relatedness
  - Smallest amplitudes to high-constraining contexts with high probability words
  - Largest amplitudes to semantic anomalies

Beyond anomalies: Expectation

- Suggests a model of lexical processing in which comprehenders use context to develop expectations about the identity of the next word
  - But, what about when there isńt a lot of context to go by?

Van Petten & Kutas (1990)

- Increased N400 to early words compared to later words



A more complete view of the N400

- Present to every word in a sentence
- More predictable words elicit smaller N400 than less predictable words
  - N400 amplitude decreases for each word over the course of a sentence
- Frequency has an influence only when context doesn't allow prediction

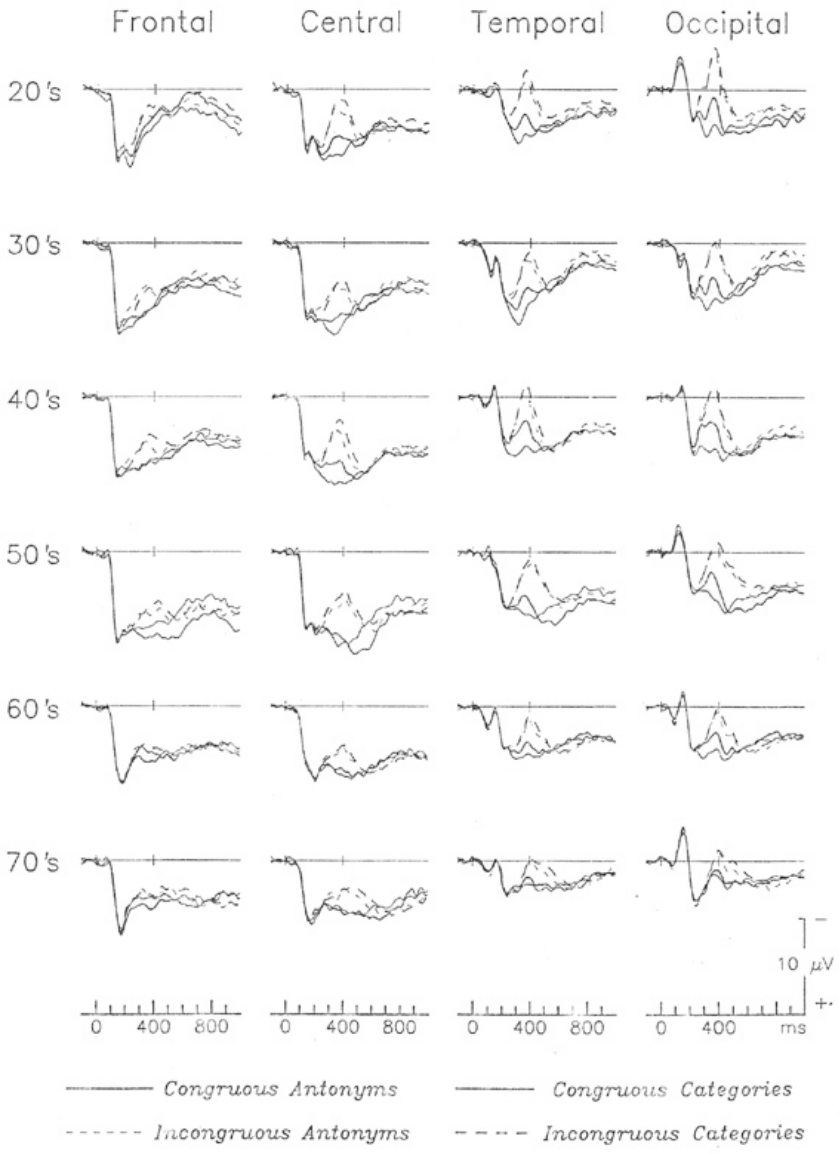
Sentence initial?

- Sentence-initial N400 amplitude is lost when the sentence is itself part of a larger discourse

Wrapping up: Semantic processes

- For each word, there is neural response starting roughly 200msec after the onset of the word and peaking at 400msec
  - Labelled N400
  - The strength (i.e. amplitude) of this response appears to be sensitive to number of factors related to the context in which the word appears

Growing Old…



from Kutas & Iragui (1998)

Syntactic violations

- The children runs to the ice cream truck every afternoon.
- The children run the to ice cream truck every afternoon.
- The children gave the ice cream to she.

Syntactic violations

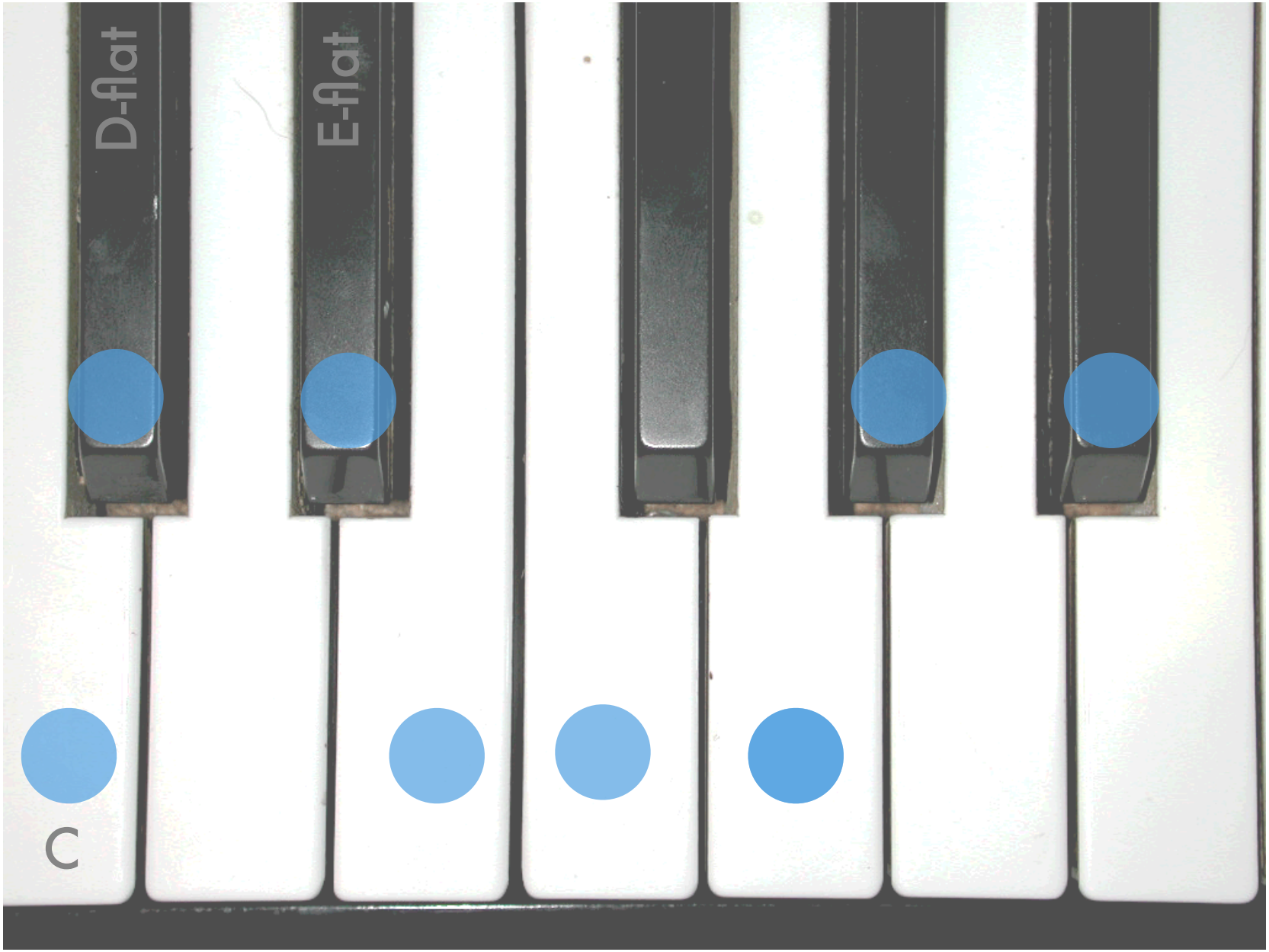
- Two ERP responses are generally elicited
  - Left Anterior Negativity
    - Same latency as N400, but different scalp distribution
  - P600/Late Positivity/Late Positive Component (LPC)/Syntactic Positive Shift
    - Can start as early as 200msec

The P600 and probability

- Sensitive to local probability
  - Can be found in response to grammatical sentences compared to ungrammatical sentences
    - When 80% of experimental trials have similar ungrammaticalities

The P600 and musical syntax

- Western European "Tonal" music
  - Has certain norms for how music is constructed
  - Musical "keys" determine which notes are sharp, which are flat
  - Key of C-major: No sharps or flats

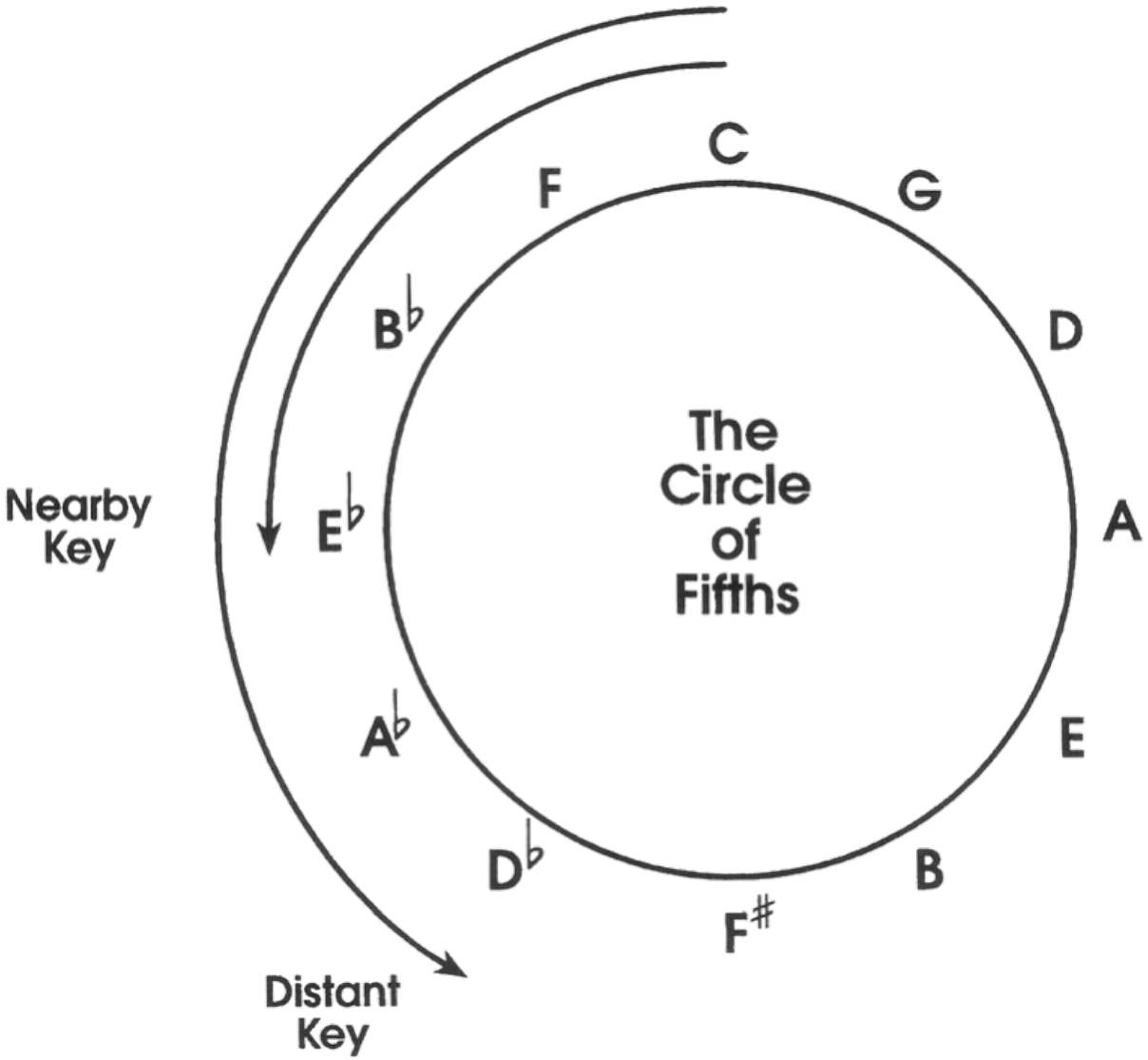

D-flat
E-flat
C

Theoretical construct

Distance between "keys"

Measured in number of flats/ sharps

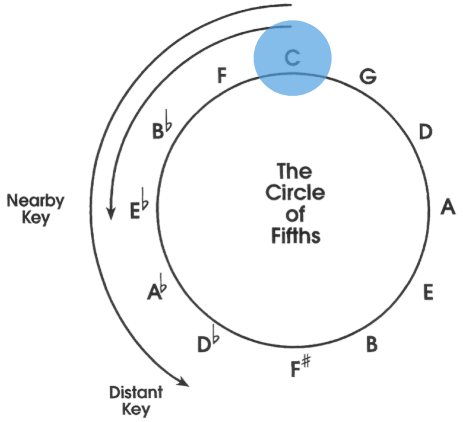
Adjacent keys differ by only one flat/sharp

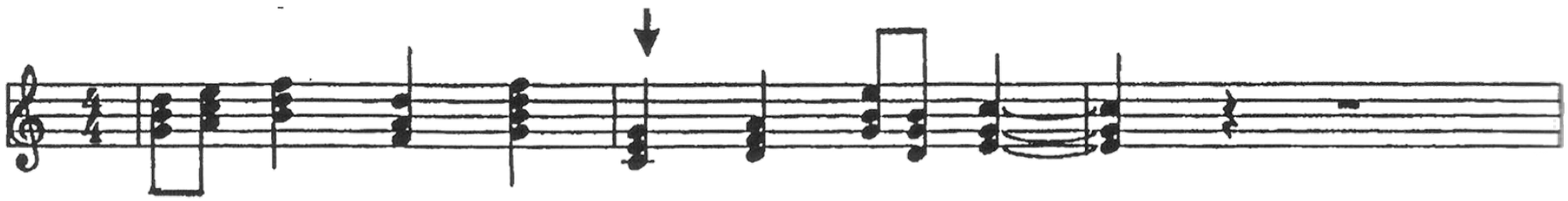


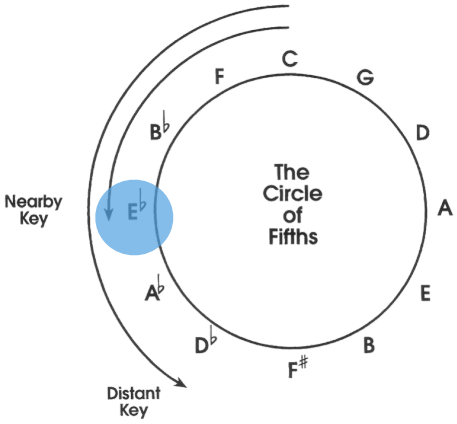
Psychologically real for musicians

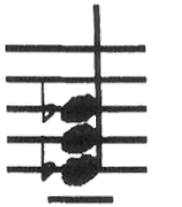
Constructing musical materials

Target key



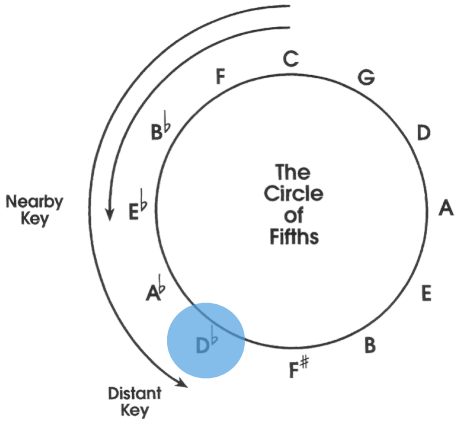






Nearby Key

Distant Key



Predictions

- Nearby key is a “syntactic” anomaly, but not too different from the expected key
- Distant key also an anomaly and is more different from expected
  - N400?
  - P600?

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- Distant key also an anomaly and is more different from expected
  - N400?
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P600 to musical syntax

- At least part of the processes used for syntactic processing of language are not unique to language.
- Are involved in other kinds of “syntactic” structural processing

Similar effect in math

- Nunez-Pena & Honrubia-Serrano (2004)
- Number sequences
  - 4, 7, 10, 13, 16, 19, X
  - Where X was correct, close or very far off
  - 22, 24, 46
- Largest P600 effect to “46”

Code switching

- Production: Could simply be a change in language form - same meaning produced with whatever word form is most available
- Comprehension?
  - Mixed results: Some studies show increase in processing difficulty, others do not

Moreno et al. (2002)

- ERP study of English-Spanish Bilinguals
  - Will code switches cause problems with lexical processing similar to those found for unexpected within-language words?
    - N400
  - Will code switches be treated as an unexpected change in form, not meaning?
    - Late positivity

Materials

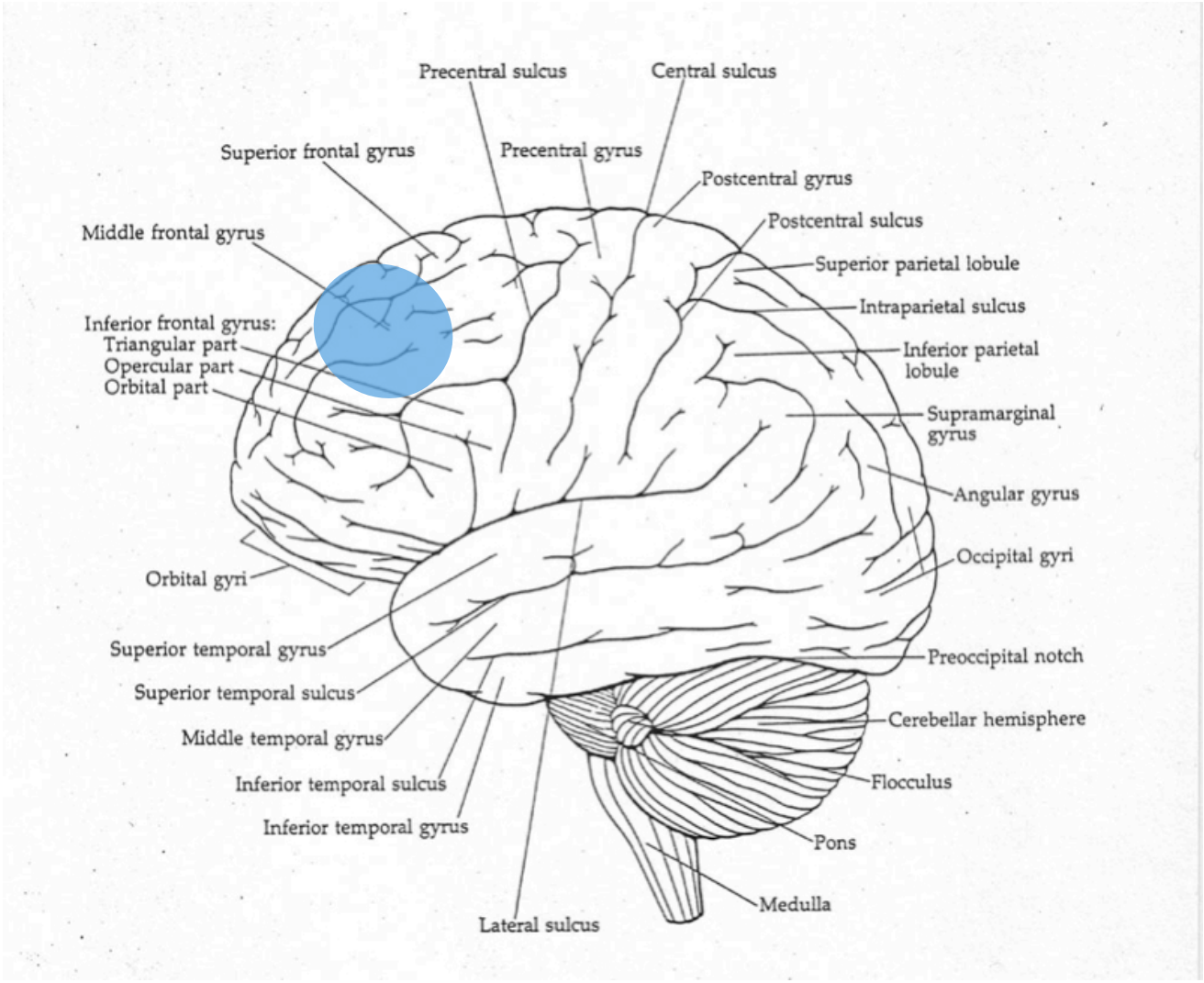
- Regular contexts:
  - Each night the campers built a
    - fire, fuego, blaze

Results Summary

- For lexical switches
  - N400 response
- For code switches
  - Large P600 response
  - Small N400-like negativity

Discussion

- Code switches appear to not pose greater difficulty for lexical processing
- Instead, they appear to be processed as something structurally unexpected
  - Same response as that seen to improbable and ungrammatical stimuli
- Goes well with other findings suggesting that code switching doesn't affect language areas, but parts of the brain associated with executive control


Precentral sulcus
Central sulcus
Superior frontal gyrus
Precentral gyrus
Postcentral gyrus
Middle frontal gyrus
Postcentral sulcus
Superior parietal lobule
Intraparietal sulcus
Inferior frontal gyrus:
Triangular part
Opercular part
Orbital part
Inferior parietal lobule
Supramarginal gyrus
Angular gyrus
Occipital gyri
Orbital gyri
Superior temporal gyrus
Preoccipital notch
Superior temporal sulcus
Cerebellar hemisphere
Middle temporal gyrus
Flocculus
Inferior temporal sulcus
Inferior temporal gyrus
Pons
Medulla
Lateral sulcus

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    - Linked to other structural processes