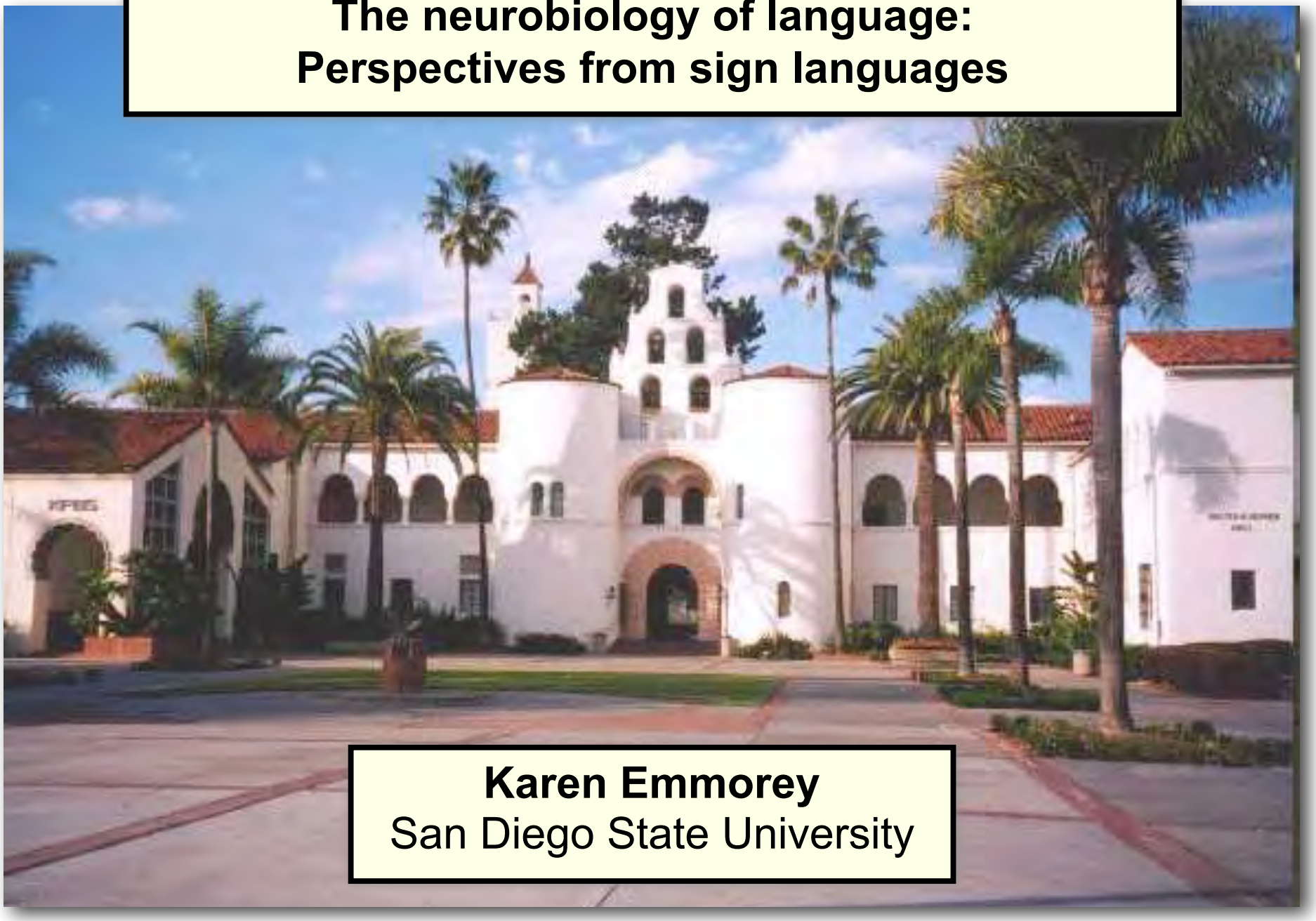
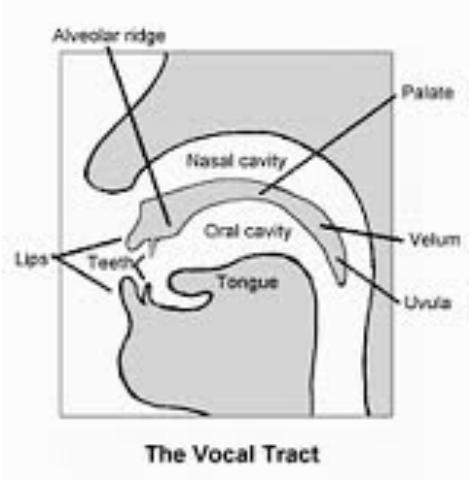
The neurobiology of language: Perspectives from sign languages

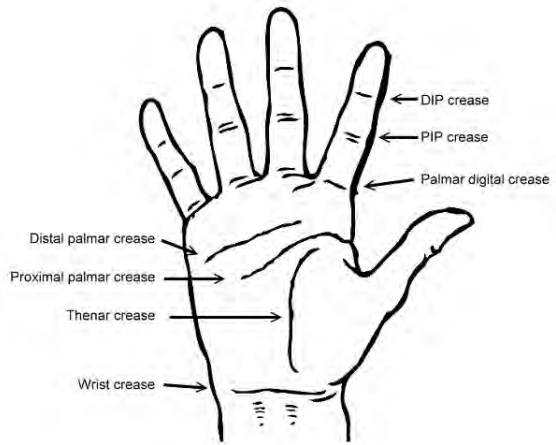


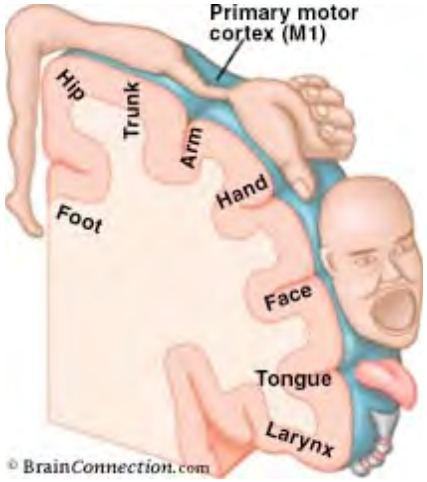
Karen Emmorey
San Diego State University

Biological differences between sign and speech

- Linguistic articulators

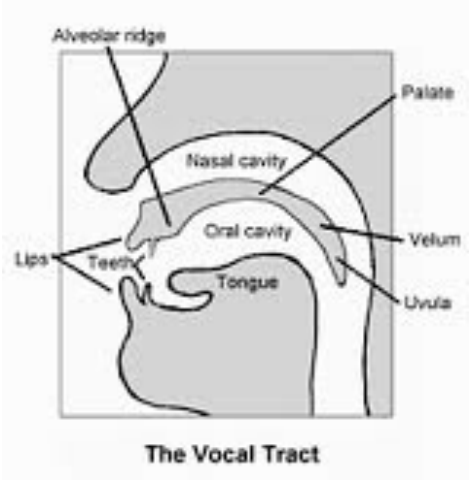


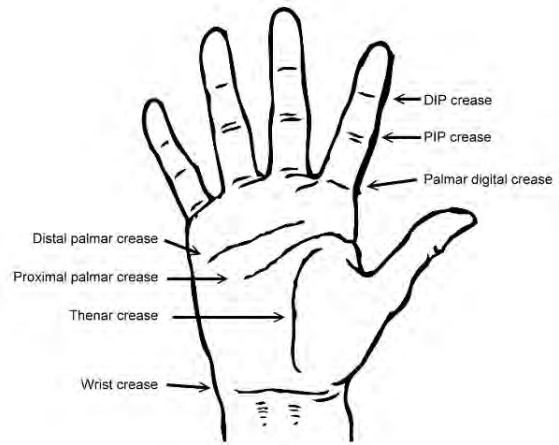


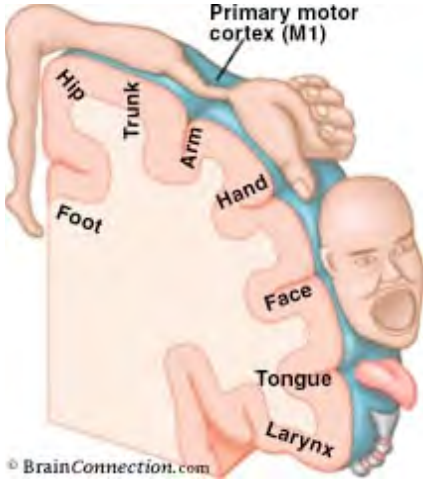


Biological differences between sign and speech

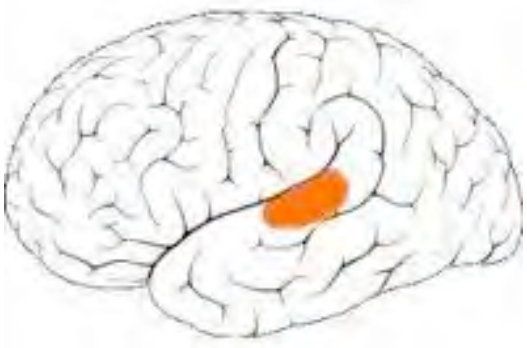
- Linguistic articulators





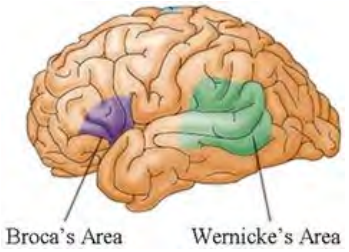


- Perceptual systems



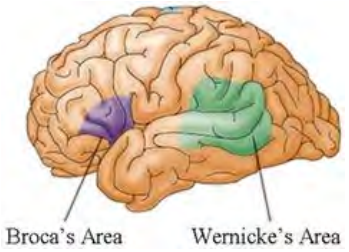
Implications for the neurobiology of language

- Are the same key brain regions engaged?



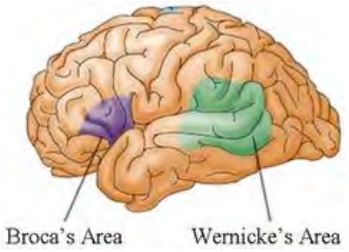
Implications for the neurobiology of language

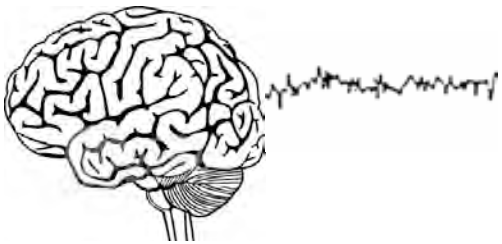
- Are the same key brain regions engaged?
- Do neural differences extend beyond sensory & motor cortices?



Implications for the neurobiology of language

- Are the same key brain regions engaged?
- Do neural differences extend beyond sensory & motor cortices?
- Impact on electrophysiological responses?

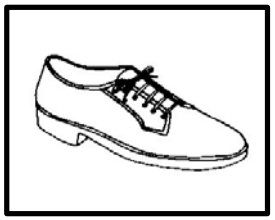




Neural conjunction: ASL and English Production

Deaf signers (N = 29) and hearing speakers (N = 64)

Picture naming



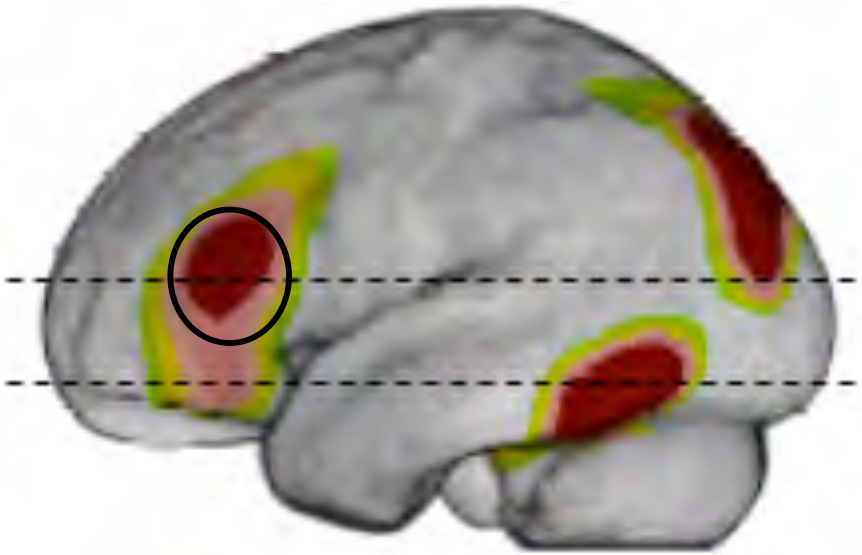
"shoe"

Common baseline task

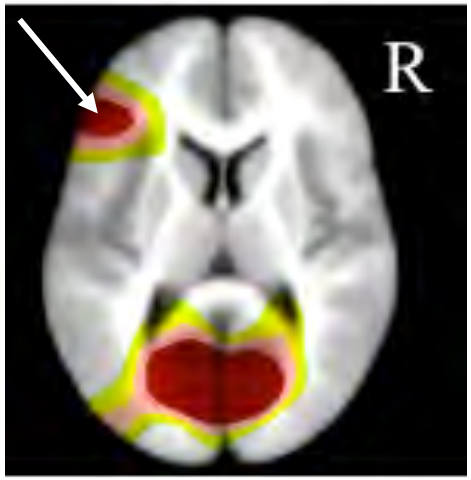
Emmorey, Mehta, & Grabowski, 2007

Neural conjunction: ASL and English Production

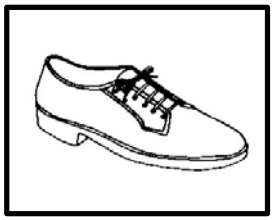
Deaf signers (N = 29) and hearing speakers (N = 64)



Broca's area



Picture naming



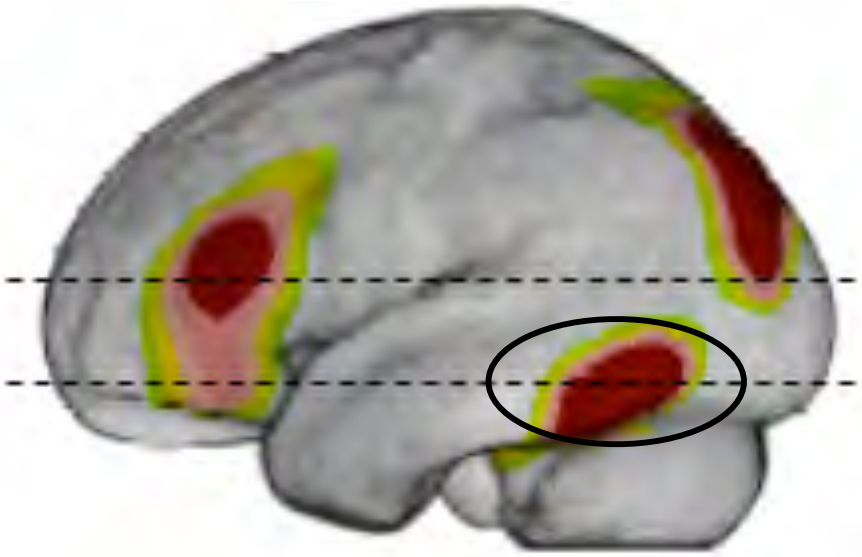
"shoe"

The function of Broca's area (left IFG) is not tied to the speech articulators

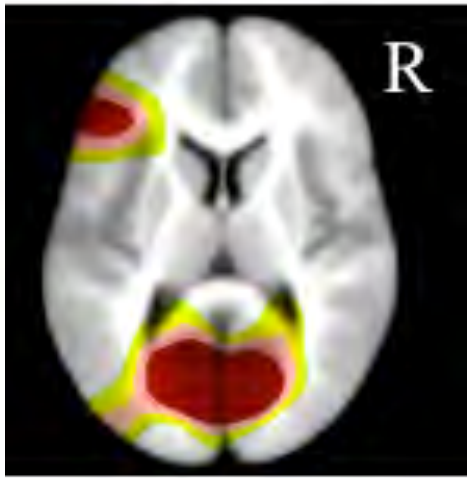
Emmorey, Mehta, & Grabowski, 2007

Neural conjunction: ASL and English Production

Deaf signers (N = 29) and hearing speakers (N = 64)



Broca's area



Inferior temporal

Lexical interface

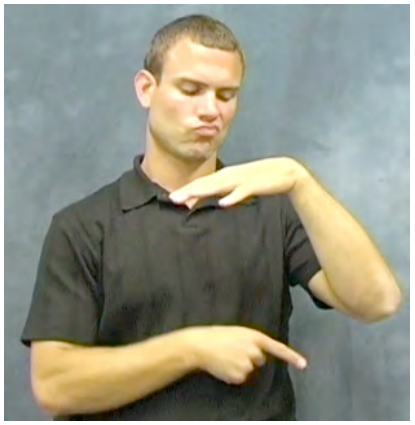
Left inferior temporal regions support conceptually driven lexical access for both words and signs

Emmorey, Mehta, & Grabowski, 2007

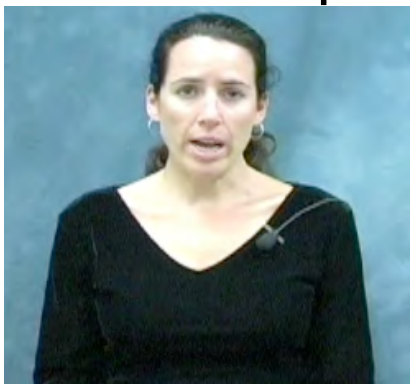
Neural conjunction: Comprehension

Conjunctions:

Signed sentences



Audio-visual speech



Task:

Sensibility judgements on occasional odd sentences

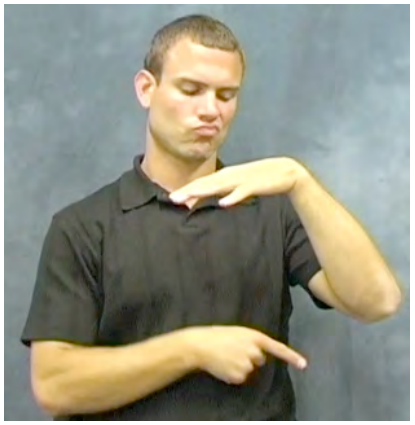
Baseline:

Still model, detect a low-level visual target (color change for dot on chin)

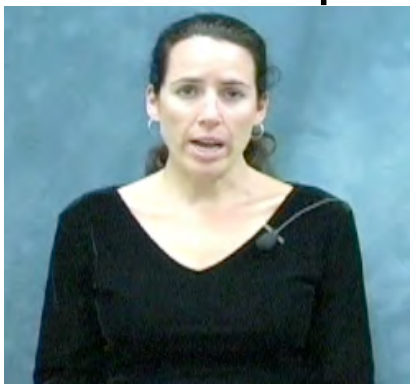
Neural conjunction: Comprehension

Conjunctions:

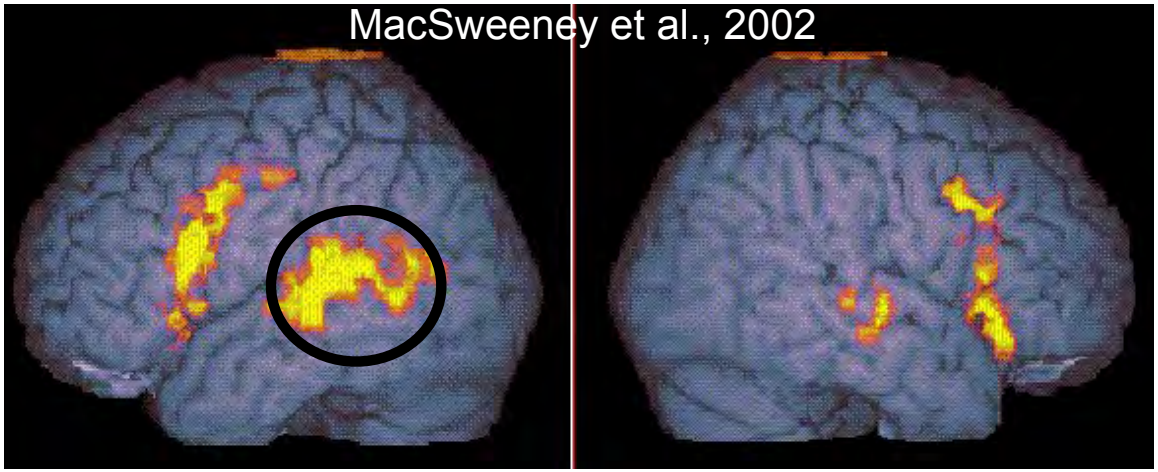
Signed sentences



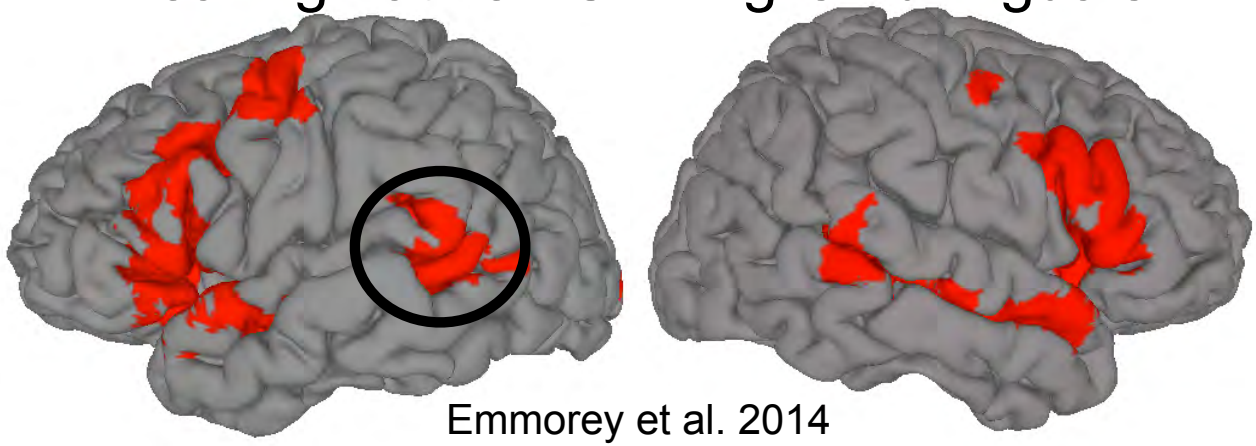
Audio-visual speech



Deaf BSL signers and hearing English speakers



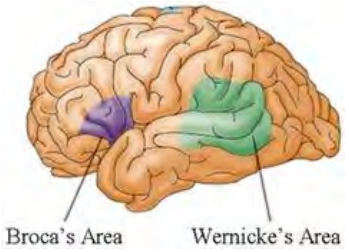
Hearing native ASL-English bilinguals



Emmorey et al. 2014

Implications for the neurobiology of language

- Are the same key brain regions engaged? *YES*

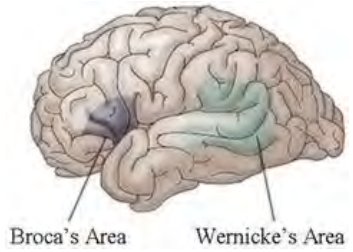


The same key brain areas are recruited for both spoken and signed languages

Broca's area (inferior frontal gyrus)
Wernicke's area (posterior temporal cortex)
Perisylvian cortices

Implications for the neurobiology of language

- Are the same key brain regions engaged? *YES*



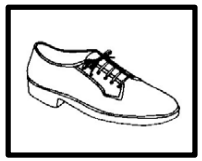
- Do neural differences extend beyond sensory & motor cortices?

Direct contrasts between signed and spoken language

- What differences are observed when motor and perceptual baselines are not "subtracted out"?

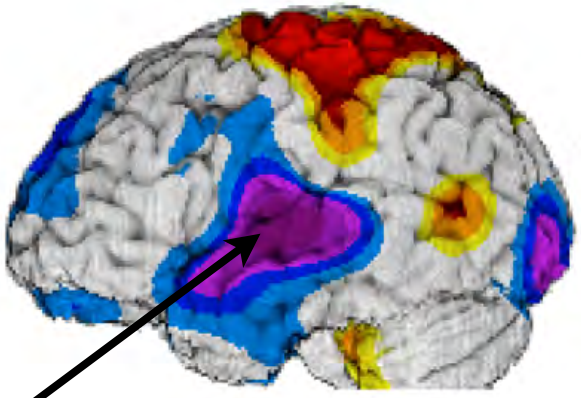
ASL vs. English Production

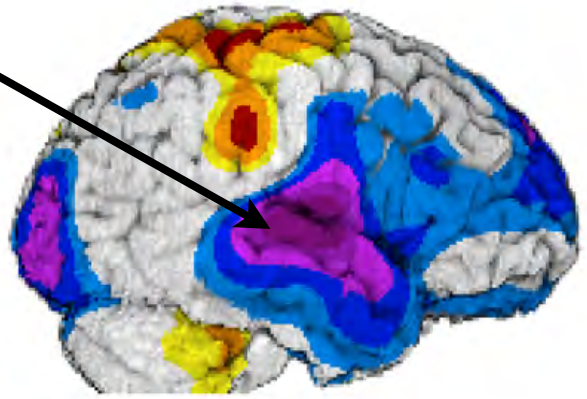
Bilingual picture naming

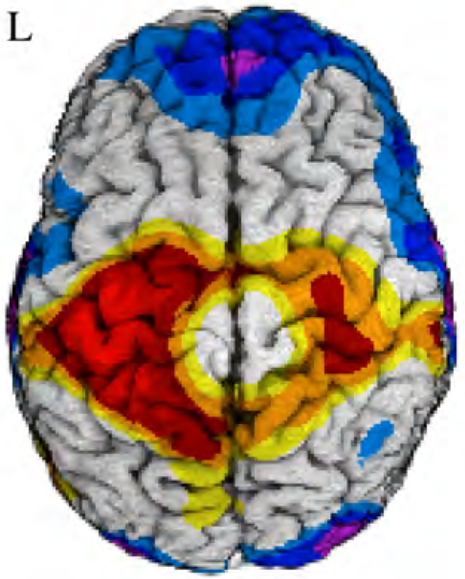


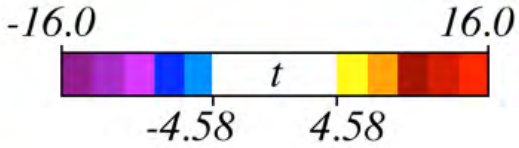
"shoe"

PET study (N = 14)









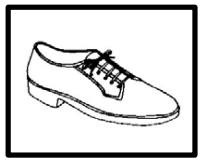
English
Superior temporal cortex

Auditory feedback from speech production

Emmorey, McCullough, Mehta, Grabowski (2014)

ASL vs. English Production

Bilingual picture naming



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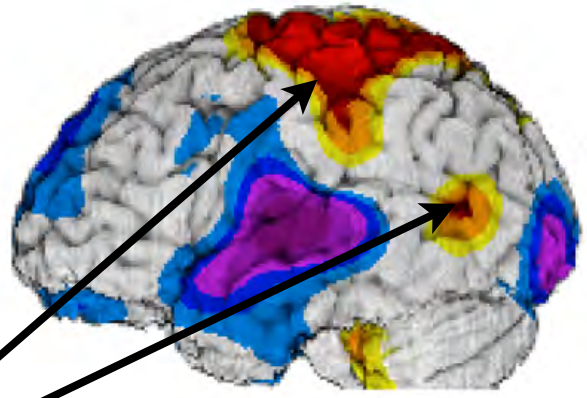
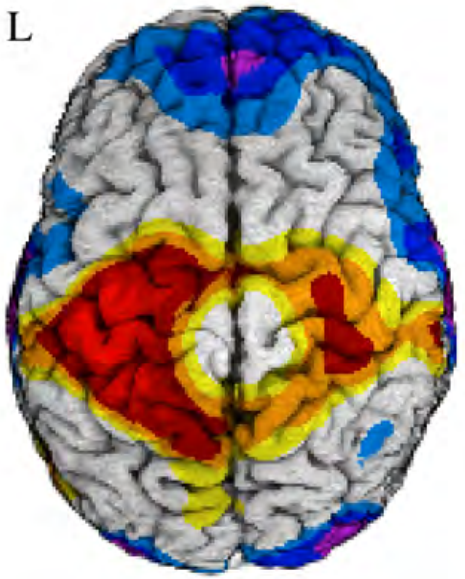
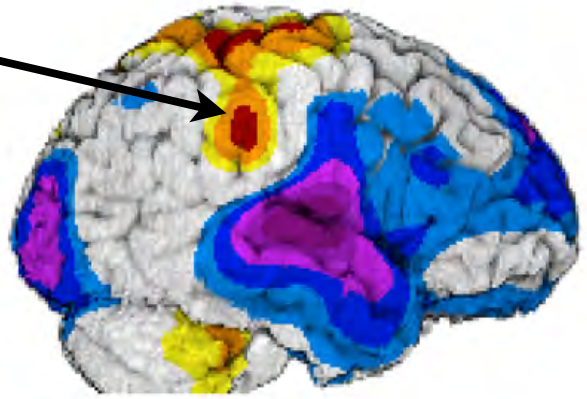
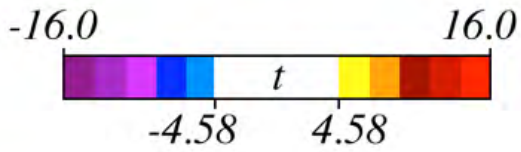








ASL

Superior and inferior parietal cortex

SPL: Control of hand and arm movements in space

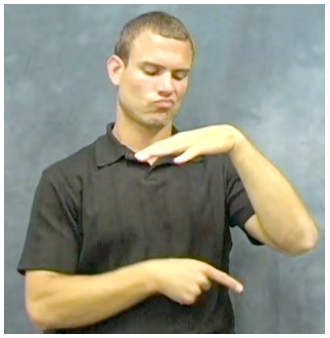
IPL: Sign-based phonological encoding

Emmorey, McCullough, Mehta, Grabowski (2014)

Emmorey, Mehta, McCullough, Grabowski (2016) *Brain and Language*

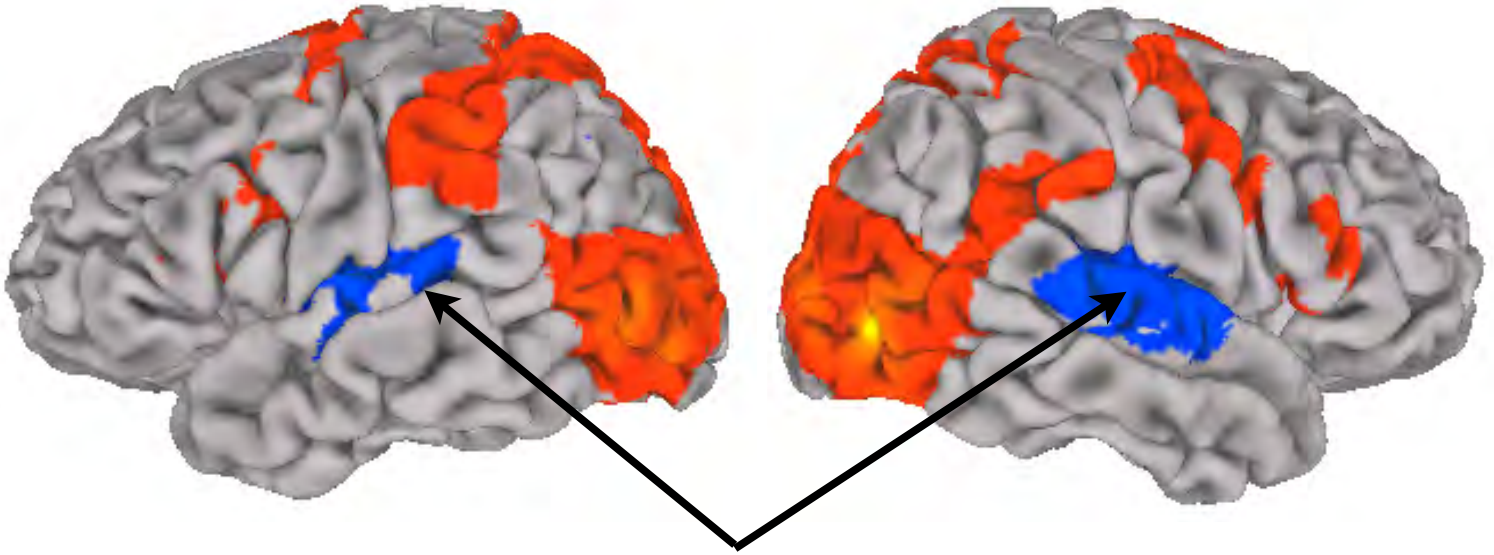
ASL vs. English Comprehension

Signed sentences



Spoken sentences

sensibility judgments
fMRI study
Bilinguals (N = 13)



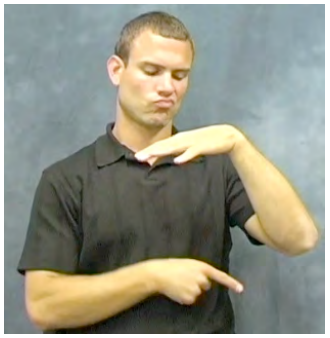
English: Greater activation
in superior temporal cortex

Comprehension of spoken language requires more sustained activation in auditory cortices

Emmorey, McCullough, Mehta, Grabowski (2014)

ASL vs. English Comprehension

Signed sentences



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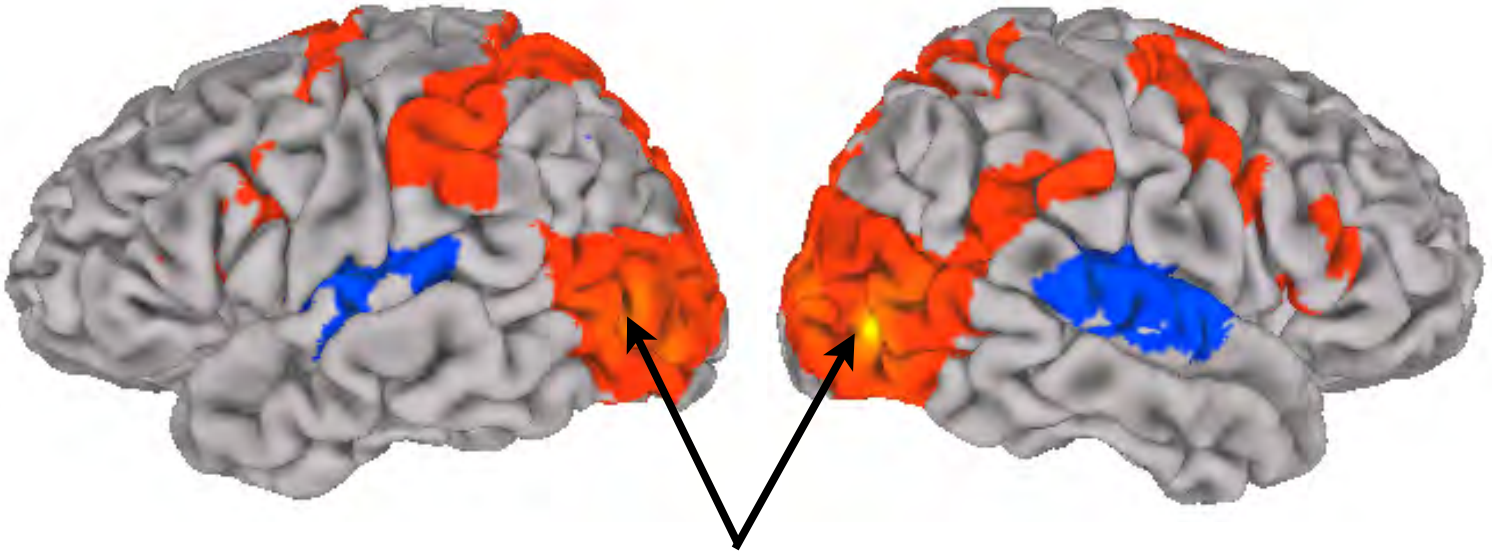


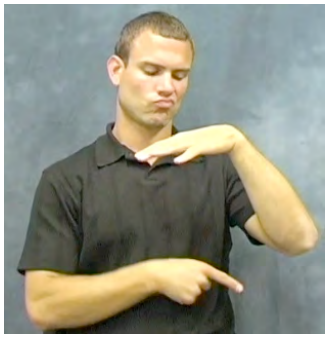
ASL: Greater activation in temporal-occipital cortices

Signing involves large movements of the hands and arms, engaging MT+ (motion-sensitive cortex) and extrastriate visual cortex

Emmorey, McCullough, Mehta, Grabowski (2014)

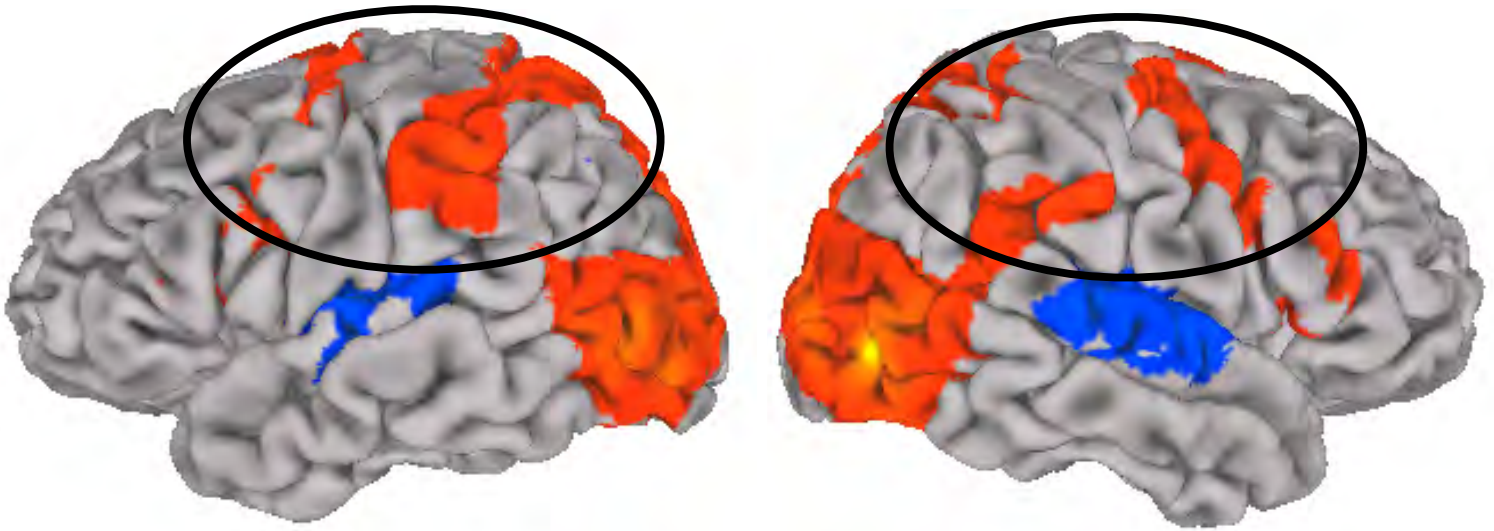
ASL vs. English Comprehension

Signed sentences



Spoken sentences

sensibility judgments
fMRI study
Bilinguals (N = 13)



ASL: Greater activation
in frontal-parietal cortices

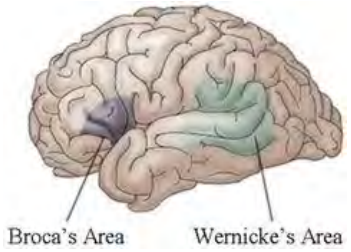
Frontal-parietal network is part of the **Action Observation Network** which may function as a predictive model for sign language comprehension

Emmorey, McCullough, Mehta, Grabowski (2014)

YES

Implications for the neurobiology of language

- Are the same key brain regions engaged? *YES*



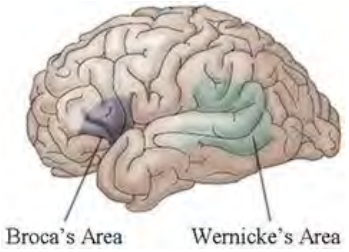
- Do neural differences extend beyond sensory & motor cortices?

YES: Sensory-motor differences impact language processing in non-obvious ways

- parietal regions engaged during sign, but not speech comprehension
- a different production-comprehension interface

Implications for the neurobiology of language

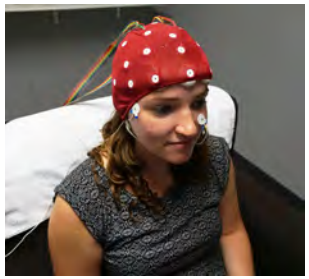
- Are the same key brain regions engaged? *YES*

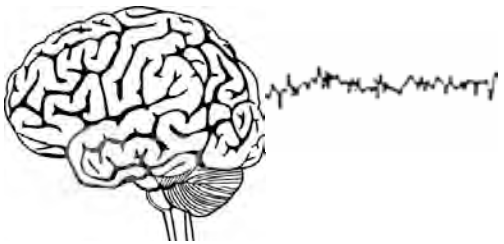


- Do neural differences extend beyond sensory & motor cortices?

YES

- Impact on electrophysiological responses?



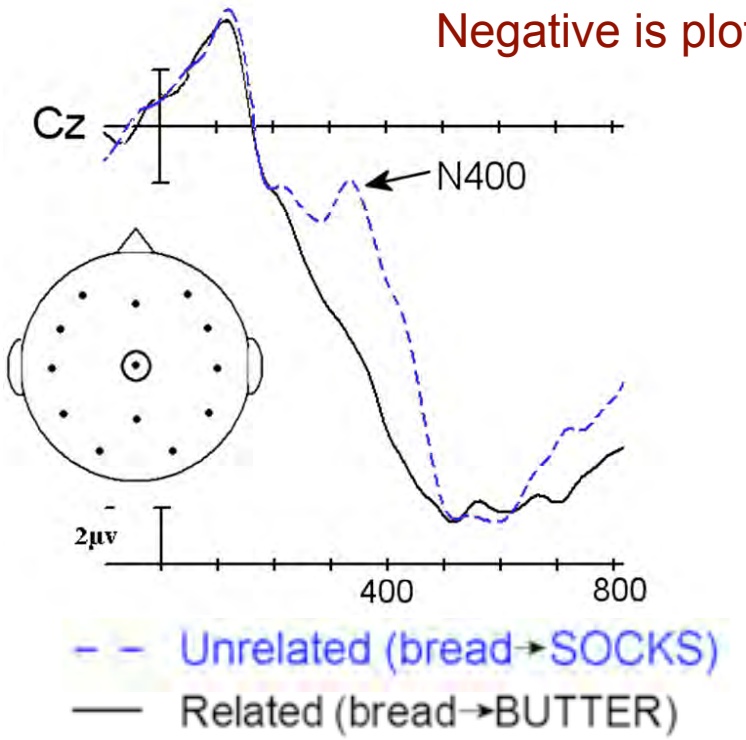


Event-Related Potentials (ERPs)
The N400 component

A negative-going (↑) brain wave elicited by meaningful stimuli (words) that peaks ~400 ms after word onset

Size of N400 increases with more elaborate processing

- Unrelated vs. related word pairs
- Low vs. High frequency words
- Concrete vs. Abstract words
- *Iconic vs. arbitrary signs?*



written words

ASL-LEX Database

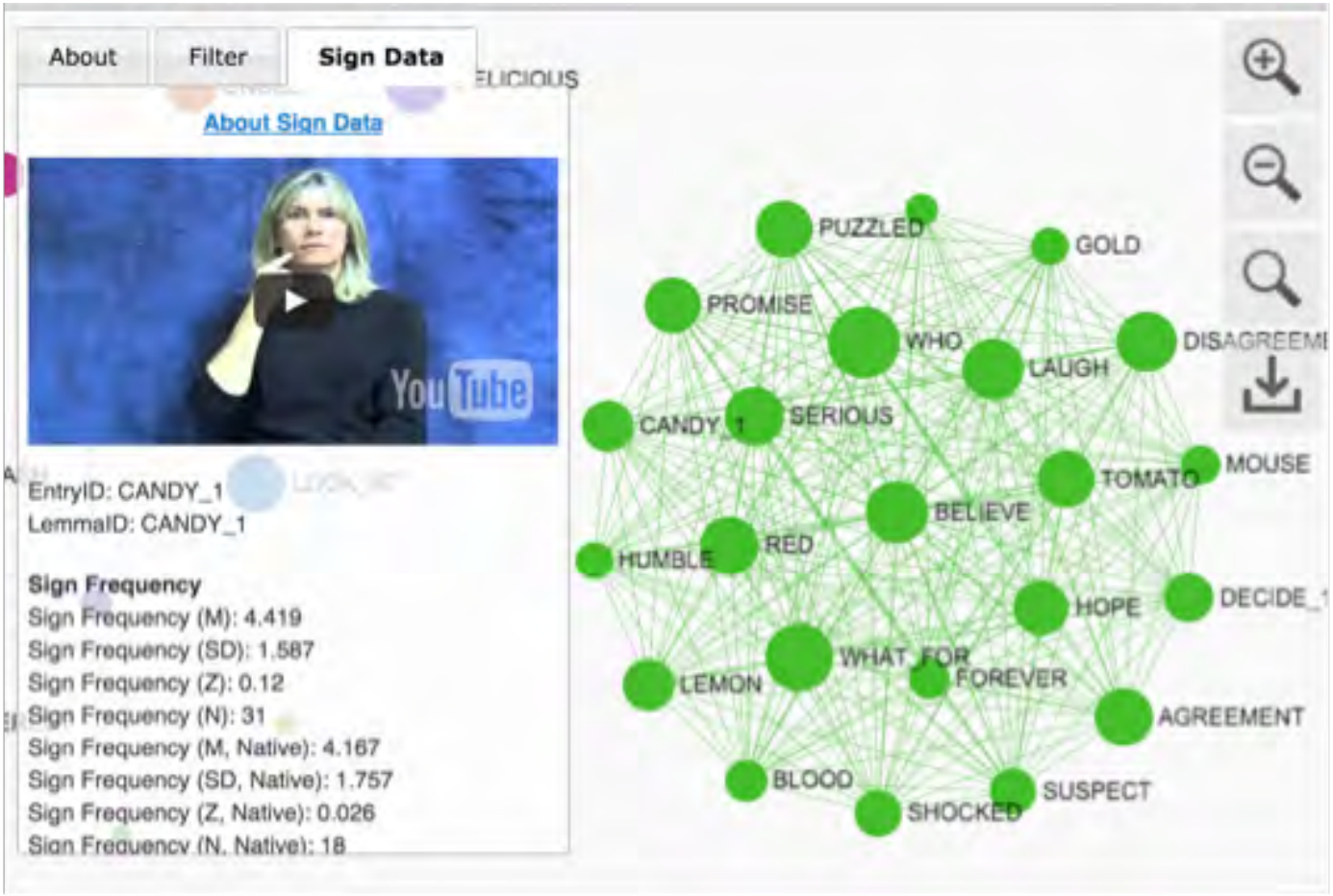
~1000 signs

Frequency
rated by ~25 deaf signers

Iconicity
rated by ~25 hearing non-signers

Phonology
Selected fingers, location, movement

- Clip duration
- Sign onset, offset
- Lexical info (e.g. class, loan sign)



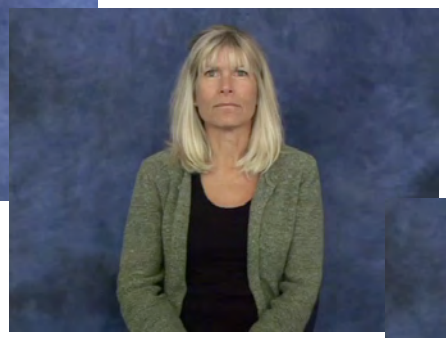
http://asl-lex.org

Caselli, Sevcikova Sehyr, Cohen-Goldlberg, & Emmorey, (2017)

ERPs to ASL signs

- Go/No Go TASK
  - Deaf signers (N = 40): Press a button when you see a "person" sign (rare: 10%). 400 signs

FINE



CABINET

BOY

High frequency signs

Low frequency signs

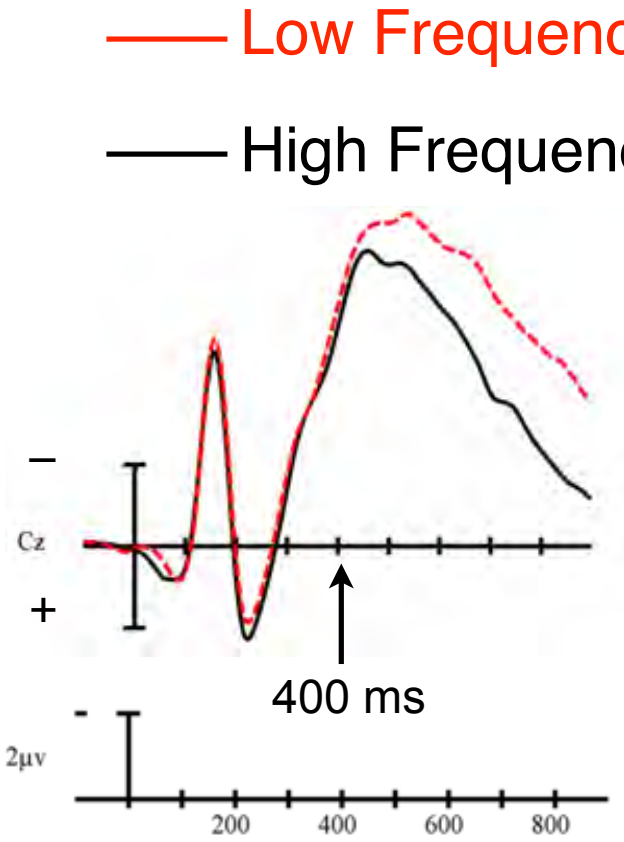
(Targets – not analyzed)

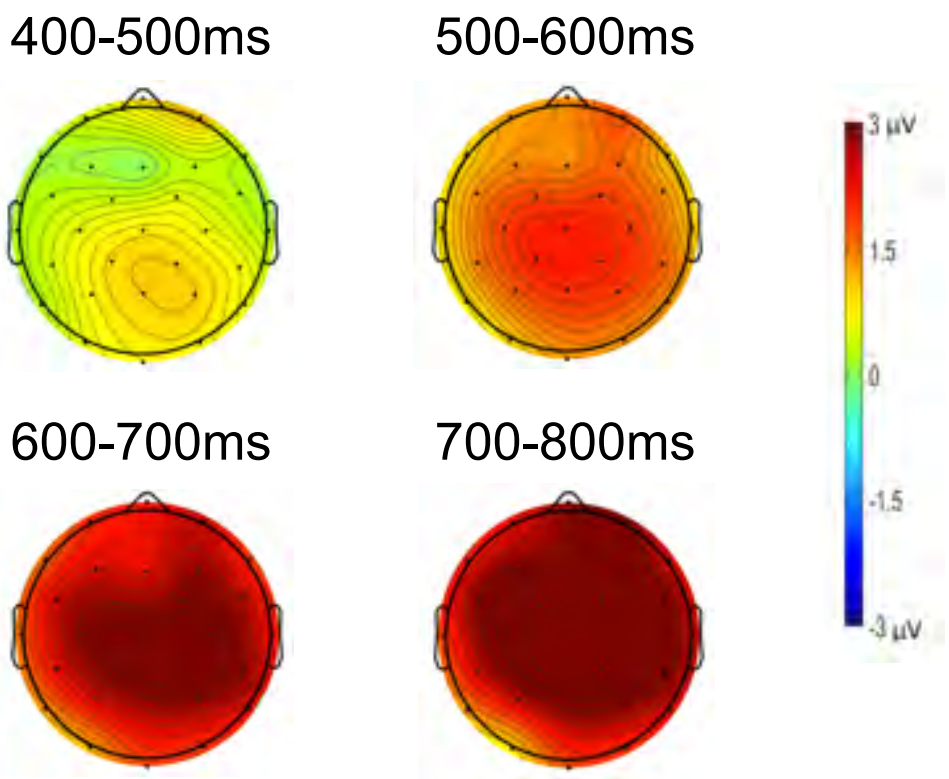
Video clips were separated by 1 second of blank screen.

Linear Mixed Effects Regression (LMER) Analyses

- Rather than averaging across participants or items, single trial EEG data were entered into the statistical model
- LMER simultaneously takes into account both subject and item variation
- LMER controls simultaneously for continuous variables (e.g., frequency, concreteness, length)
- Estimate results per electrode (*t* values) are plotted as scalp maps (similar to voltage maps)
- For illustration, averaged ERPs are plotted with upper and lower quartiles

Frequency effect for spoken words

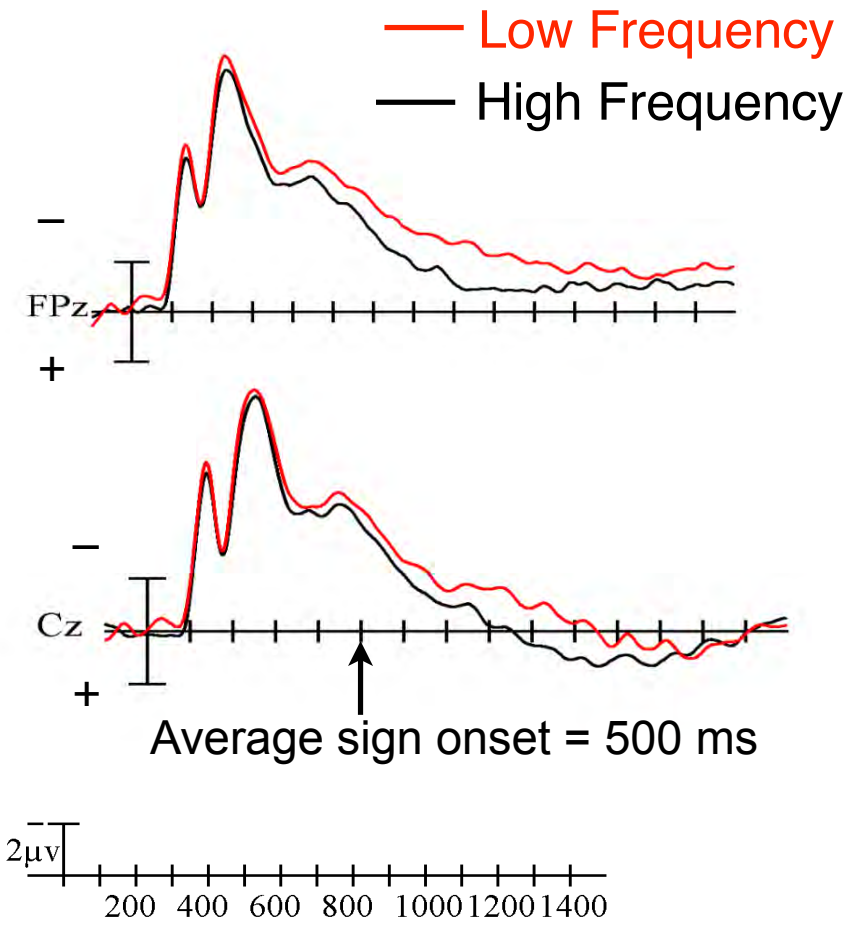


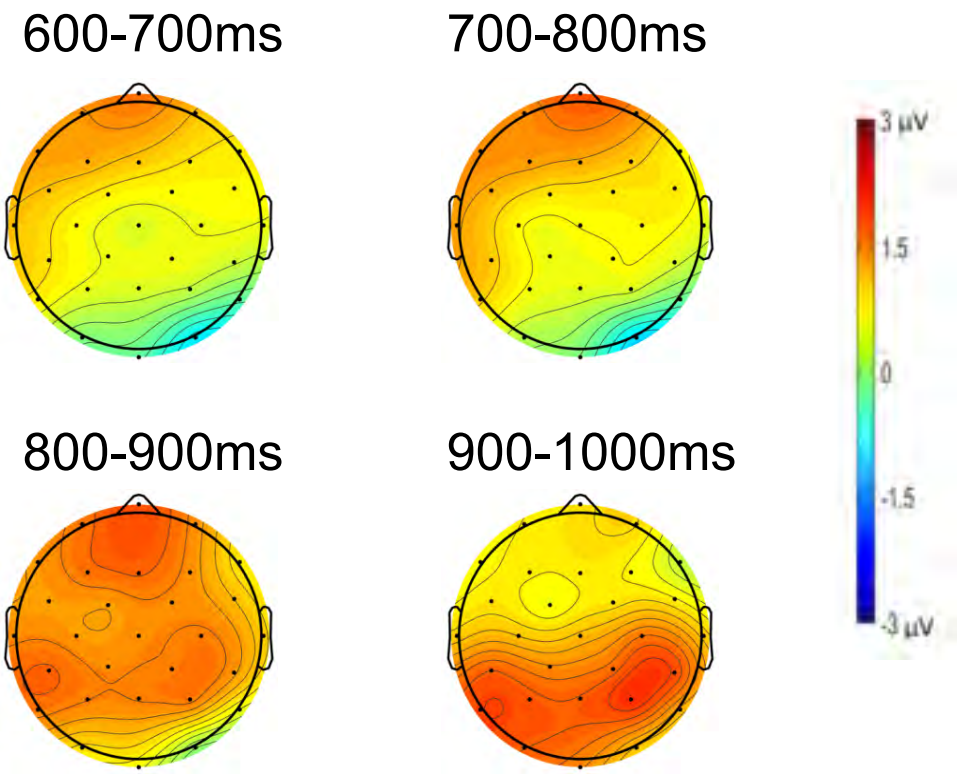


More negative response for low frequency words that is centrally distributed across the scalp.

Winsler, Midgley, Grainger, & Holcomb (2018)

ERPs to signs: Frequency effects





Time-locked to video onset

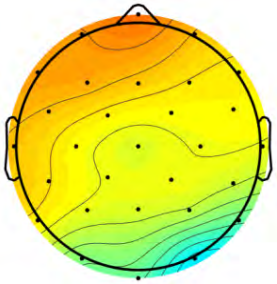
More negative response for low frequency words, but the distribution differs from that observed for spoken words

ERPs to signs: Frequency effects

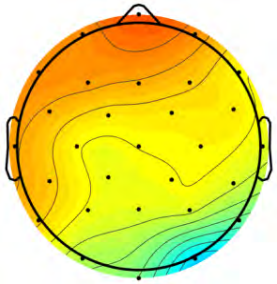
Early form-based frequency effect

Phonological priming in ASL elicits an anterior negativity

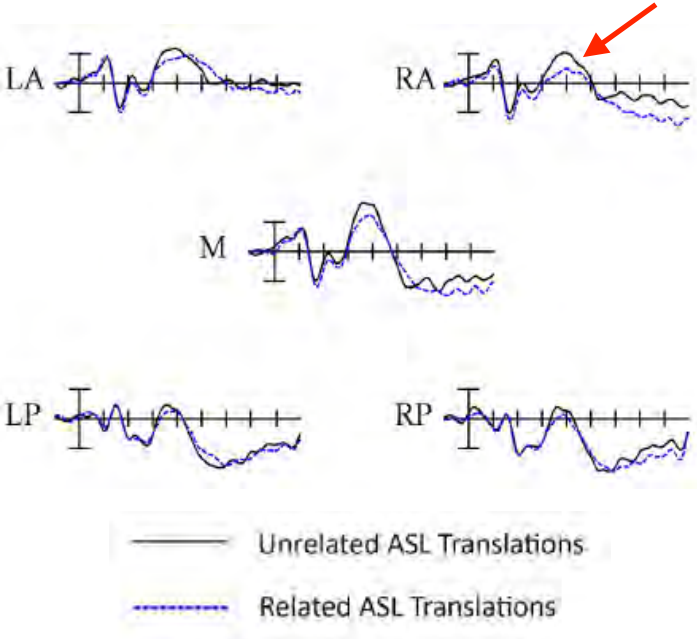
600-700ms



700-800ms



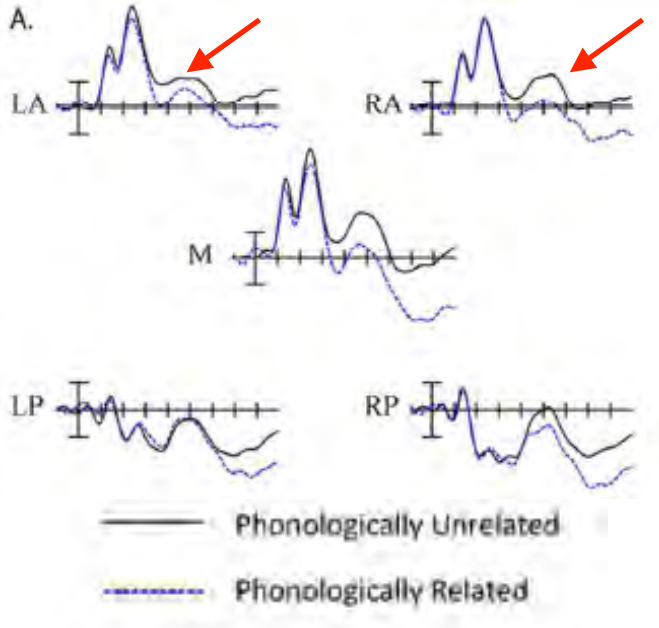
Implicit priming (English words)



Phonologically Related

SUSHI NURSE

Explicit priming (ASL signs)



Meade, Midgley, Sehyr, Holcomb, & Emmorey (2017)

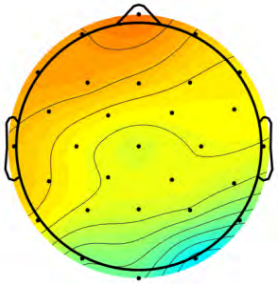
Meade, Lee, Midgley, Holcomb, & Emmorey (2018)

ERPs to signs: Frequency effects

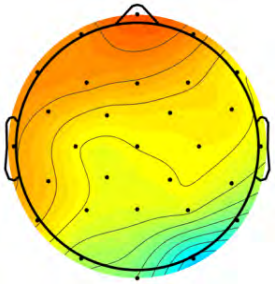
Early form-based frequency effect: Phonological priming in ASL elicits an anterior negativity

Later lexical-semantic frequency effect: Centro-posterior distribution is typical for semantic N400

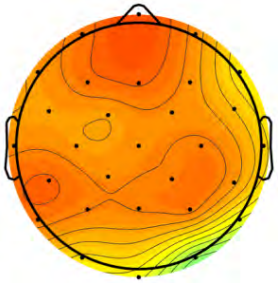
600-700ms



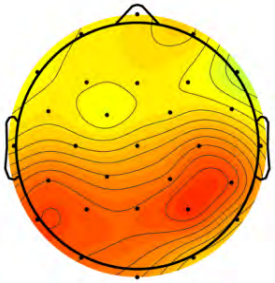
700-800ms

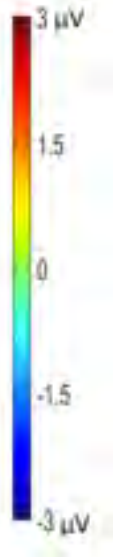


800-900ms



900-1000ms





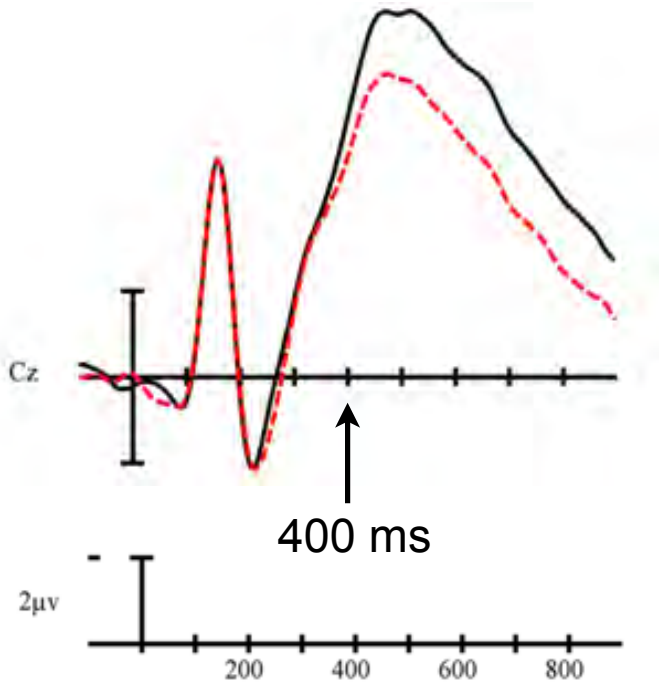
Time-locked to video onset

Form-based and lexical-semantic frequency effects may have distinct neural generators for sign language

Concreteness effect: spoken words

High concrete words (“tree”)

Low concrete words (“hope”)

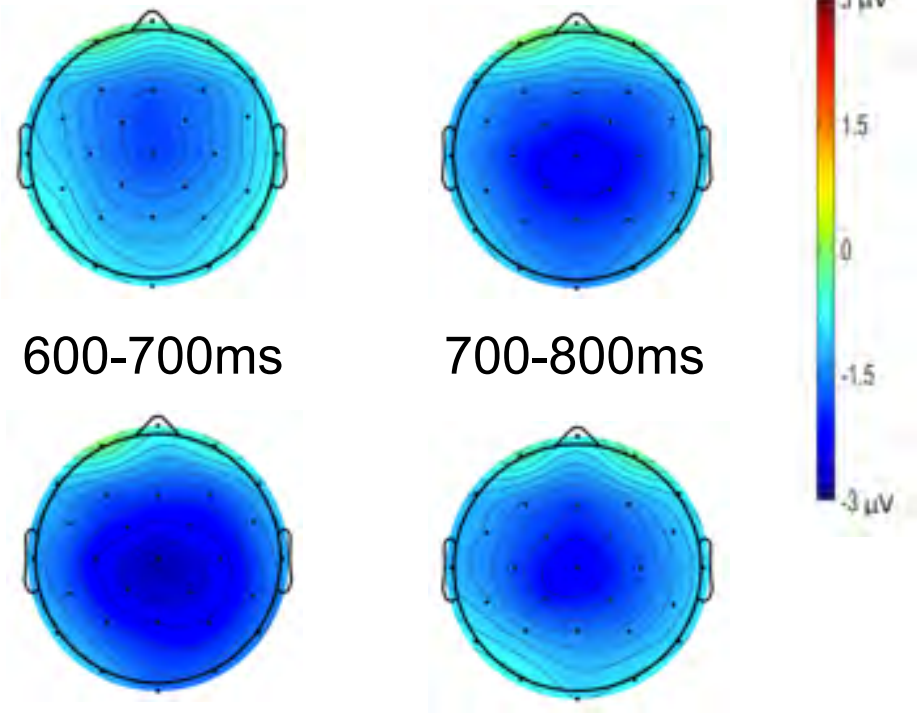


400-500ms

500-600ms

600-700ms

700-800ms



More negative response for highly concrete words that is centrally distributed across the scalp.

Winsler, Midgley, Grainger, & Holcomb (2018)

Concreteness - ASL

Concrete Signs

BEER

GLASSES

Abstract Signs

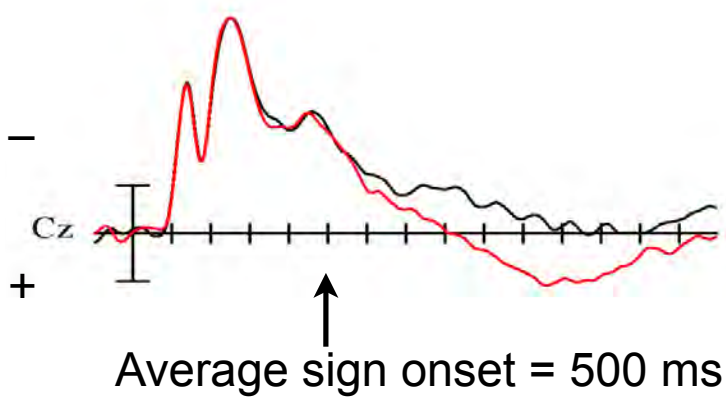
HONOR

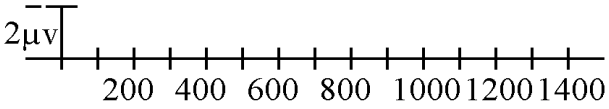
MAYBE

Concreteness effects: ASL signs

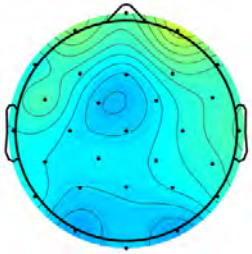
High concrete words (BEER)

Low concrete words (HONOR)





600-700ms



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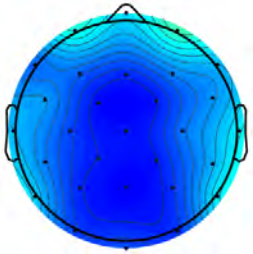
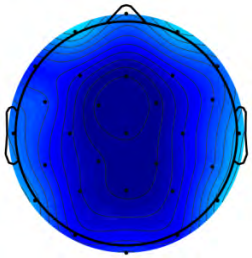
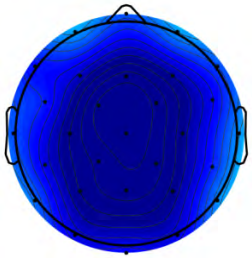
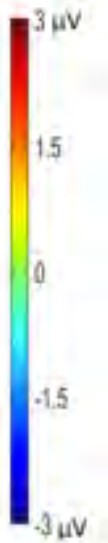


800-900ms



900-1000ms





Neural response to concrete signs parallels that for spoken words in terms polarity (more negative for concrete signs) and distribution (centro-posterior).

Iconicity - ASL

Iconic Signs

DRINK

MAYBE

Non-iconic Signs

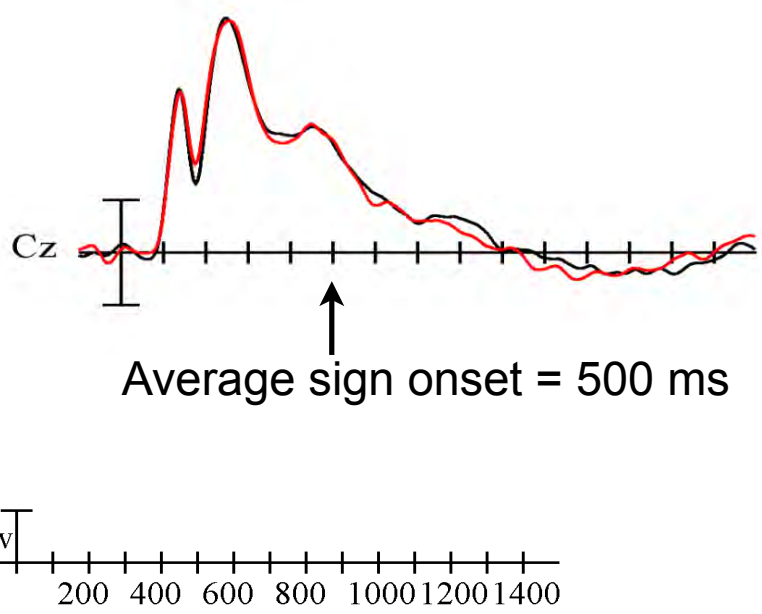
BEER

AND

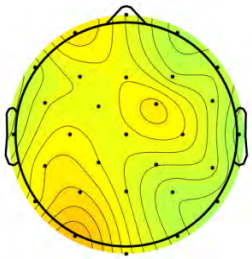
Iconicity (non)effects

Low Iconicity

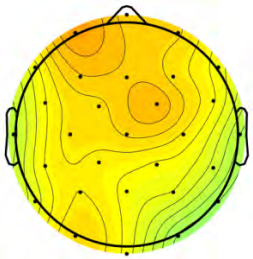
High Iconicity



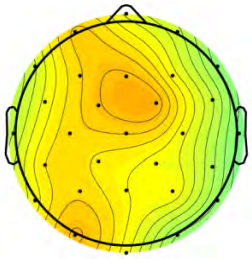
600-700ms



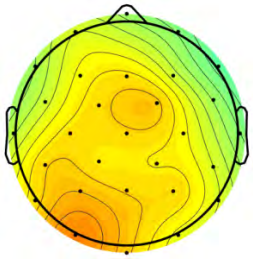
700-800ms

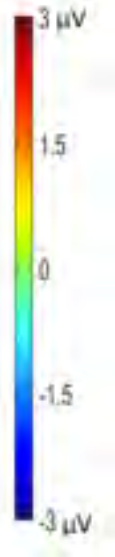


800-900ms



900-1000ms

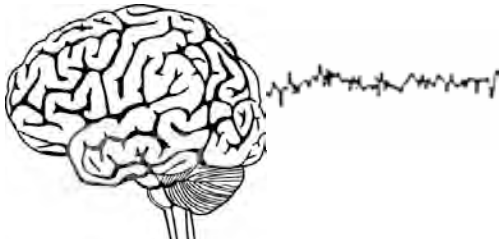




Neural response to iconic signs is very weak compared to frequency and concreteness effects.

Implications for the neurobiology of language

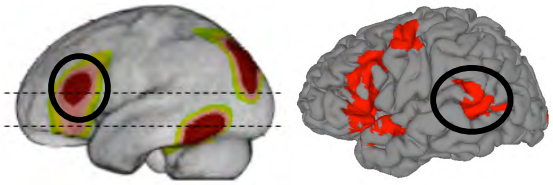
- Impact on electrophysiological responses? *YES and NO*



  - Frequency: Distinct distribution - anterior (form-based) and centro-posterior (lexical-semantic)
  - Concreteness: Same polarity (more negative for concrete signs) and same scalp distribution
  - Iconicity: No clear neural response associated with lexical variation in iconicity

The neurobiology of language: Take home messages

- The same key neural regions engaged for signed and spoken languages



The neurobiology of language: Take home messages

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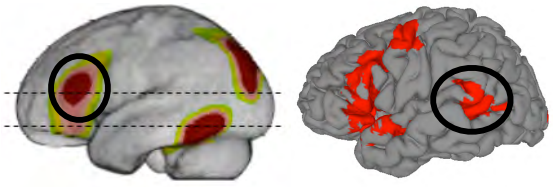
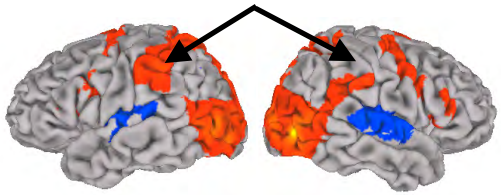


- Sensory-motor differences may impact language processing (predictive models)



The neurobiology of language: Take home messages

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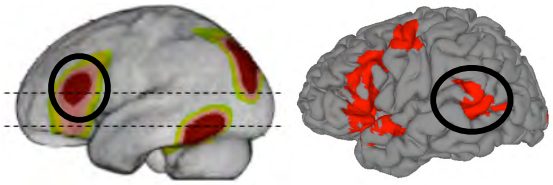

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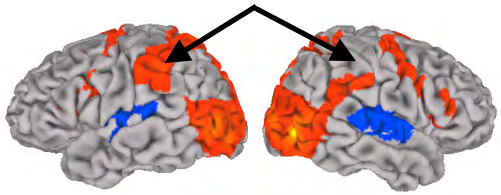
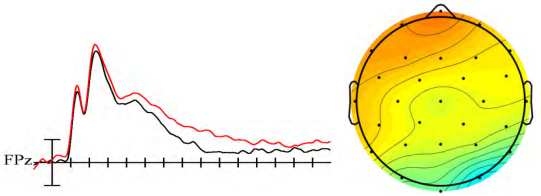


- Neural dynamics of sign and word recognition are similar (but not identical)



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Questions?

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