Comparing neural activation at the lexical, syntactic, and narrative levels of American Sign Language comprehension

Brennan Terhune-Cotter[1], Stephen McCullough[2], and Karen Emmorey[2]

1 Joint Doctoral Program for Language and Communicative Disorders, SDSU/UCSD, San Diego, CA | email: bterhunecotter@sdsu.edu

2 San Diego State University, San Diego, CA

SDSU San Diego State University

UC San Diego

SDSU-UCSD *Joint Doctoral Program in* LANGUAGE & COMMUNICATIVE DISORDERS

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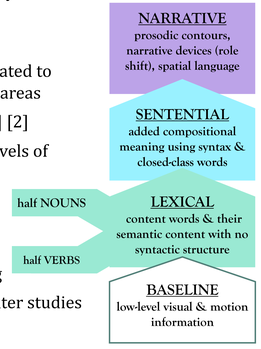
Background

- Traditional fMRI group-based designs suffer from reduced sensitivity and specificity of analyses with high inter-subject variation
  - Functional areas do not perfectly overlap across subjects
  - *Solution:* develop **functional localizers** to localize activation related to process of interest in each subject & constrain analyses to those areas
- Functional localizers have been developed for spoken languages [1] [2]
- We developed three conditions reflecting successively increasing levels of linguistic processing: word lists, sentence sets, and narratives
  - The word lists condition was further subdivided into *noun lists* and *verb lists* matched for lexical factors (frequency, etc.)
  - Contrasting conditions will give us neural activation *unique* to the linguistic processes within each level of linguistic processing
- These stimuli can be used as localizers for ASL comprehension in later studies



fMRI Study Design

7 minutes per run (20 17-second blocks; 5 blocks per condition; jittered fixations between each block)

4 runs per session (28 minutes of functional scans)

BASELINE

- Sentential videos degraded with a Gaussian blur
- Preserves low-level visual information but destroys linguistic information

LEXICAL

- Lists of 16 open-class words
- Half noun lists; half verb lists
- Words matched for **lexical frequency** and **iconicity** using ASL-LEX 2.0 [3]
- Signer's hands return to clasped position between signs

Noun List	Verb List
interpreter	chop
gas	mail
kangaroo	kiss_fist
doctor	register
water	meditate
forest	see_see
wall	visit
cookie	study
bread	discuss
mirror	escape
children	fix
rain	eat
woman	dont_care
problem	think_over
birthday	charge
wine	toothbrush-ca

SENTENTIAL

- Uses the same open-class words as the lexical condition, arranged into 4-5 sentences
- All declarative sentences

[The] children don't want [to] join [the] race

NARRATIVE

- ASL excerpts from *Alice in Wonderland*
- Directly analogous to spoken language localizers [1]
- Contains narrative devices (role shift, facial expressions) and use of rich spatial language (classifier constructions)

Analysis

- 9 native American Sign Language users
  - 6 F / 3 M ; mean age 29 (range 24 – 41) ; all began signing before age 5
- Analyses conducted using a **group-constrained subject-specific (GSS)** approach [1]
  - Individual activation patterns are constrained by group-level fROIs to create individual fROIs
  - Those individual fROIs are used to constrain statistical analyses
- The contrast between **narrative** and **baseline** conditions in this study is a signed-language analogue to previous spoken-language localizers [2,4]
- As an initial analysis, *Condition>Baseline* contrasts and *Noun/Verb* direct contrasts were analyzed with *a priori* ROI parcellations based on an English sentences-nonwords localizer contrast (N = 220; see evlab.mit.edu/funcloc/ for the language parcels used here)

Preliminary Results: Using the English Localizer

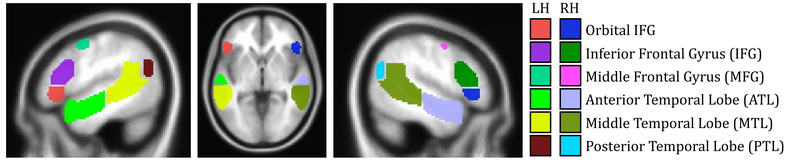


Figure 1. *A priori* fROIs from written English localizer (N = 220) *(data from Dr. Ev Fedorenko's lab)*

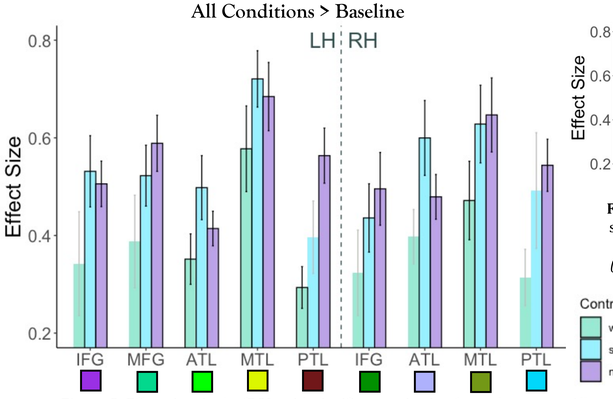


Figure 2. Effect sizes in the fROIs with significant activation for each contrast. All significant effects' $p < 0.001$ uncorr. & $p < 0.05$ FWE. Nonsignificant effect sizes are not outlined and error bars are grayed out. Error bars represent ±1 SE.

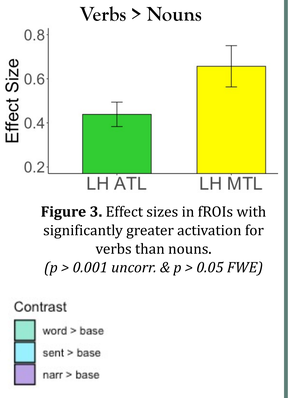


Figure 3. Effect sizes in fROIs with significantly greater activation for verbs than nouns. *($p > 0.001$ uncorr. & $p > 0.05$ FWE)*

Preliminary Results: Using the ASL Localizer

- Bilateral frontotemporal language areas are activated in each condition vs. baseline (Figure 4).
- GSS fROIs for ASL follow general pattern as GSS spoken language fROIs, but they *also* activate occipital and parietal areas (Figure 5).

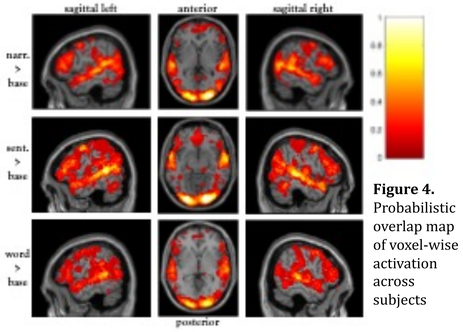


Figure 4. Probabilistic overlap map of voxel-wise activation across subjects

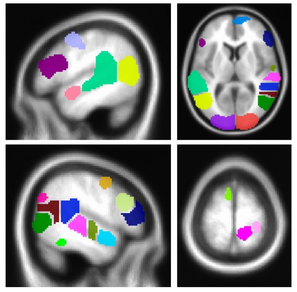


Figure 5. Thirty group-level fROIs identified from the *narrative > baseline* contrast using the GSS method of fROI parcellation ($p > 0.001$, uncorr.).

Discussion & Future Directions

- Using the English-derived fROIs to look at each level of ASL processing vs. baseline, we see higher bilateral activation in *sentences* and *narratives* as compared to the *word* condition (Figure 2).
- Verbs activate LH ATL and MTL more than nouns; as those regions are associated with semantic processing, this may reflect verbs' richer semantic content than nouns (Figure 3).
- Direct contrasts between Narrative/Syntactic/Lexical conditions and the Nouns>Verbs contrast did not produce significant activation. We expect significant differences to emerge with a larger sample.
- The added parietal and occipital activation in the ASL localizer reflects previous literature on signed vs. spoken language activation; parietal cortex supports visuospatial processing & signed languages engage visuospatial processes more.
- After establishing a set of fROIs for the ASL network in native signers, we will then examine **individual variation** in the signed language network
  - Is signed language activation more variable than spoken language activation? Which fROIs in the signed language network are more variable across subjects?
  - What are the sources of this variation? (e.g., age of acquisition? language skill?) [5]

References

[1] Fedorenko et al. (2010). New method for fMRI investigations of language: Defining ROIs functionally in individual subjects. *Journal of Neurophysychology.* **[2]** Malik-Moraleda, S., et al. (2021). The universal language network: A cross-linguistic investigation spanning 45 languages and 11 language families. **[3]** Sehyr, Z. S., et al. (2020). The ASL-LEX 2.0 Project: A Database of Lexical and Phonological Properties for 2,723 Signs in American Sign Language. *Journal of Deaf Studies & Deaf Education.* **[4]** Scott, T. L., et al. (2017). A new fun and robust version of an fMRI localizer for the frontotemporal language system. Cognitive Neuroscience. **[5]** Mayberry et al. (2011). Age of acquisition effects on the functional organization of language in the adult brain. Brain and Lang, 119(1), 16–29. *Brain activations visualized with* xjview *in* SPM *and with* AFNI **|** *Bar plots visualized with* ggplot2 *in* R.