The Influence of Modality and Early Language Experience on the Neural Network for Language

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Introduction

- There is a large network of regions underpinning the global process of sign language comprehension. [1]
- Many, but not all, of these regions respond to all modalities of language input, meaning they are *supramodal* language regions presumed to engage in abstract linguistic processes. [2]
- However, no studies have *directly* compared written and sign language neural processing within signers.
- Early delays in accessible language input may shift attention from higher-level (supramodal) language processes to lower-level (modality-specific) processes. [3]
- Late signers exhibit a shift in neural activation from anterior fronto-temporal to posterior parieto-occipital regions. [4]

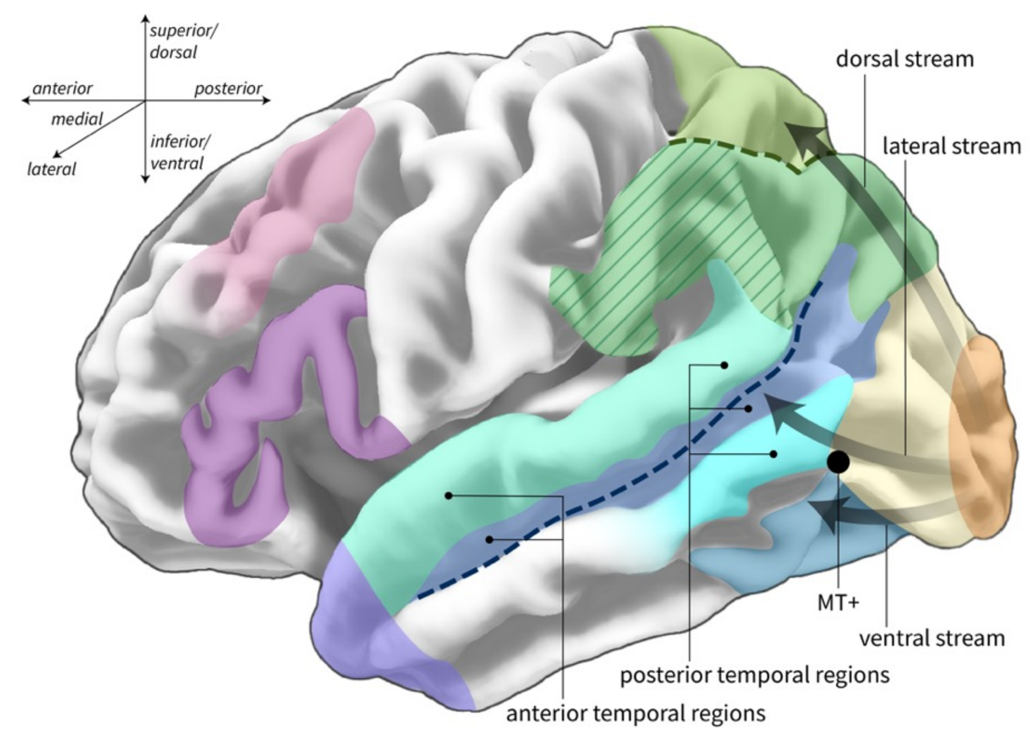

Figure 1: An overview of the regions involved in sign language comprehension. Also displayed are visual processing 'streams' which roughly identify discrete properties of the visual signal: form (ventral), motion (lateral), and space (dorsal). [1]

Stimuli & Scanning

- We collected fMRI data from 19 deaf signers with ages of acquisition (AoA) of ASL ranging from birth to 20 years (mean AoA = 8.3; SD = 7.1 years).
  - Our sample has relatively high proficiency in both ASL and written English.
- Participants viewed sentences and pseudosentences in written English[5] and in ASL, plus a visual "body/motion" baseline condition for ASL (Figure 2).
  - Pseudosentences in each language were sentences made up of phonologically legal but non-existing words or signs.

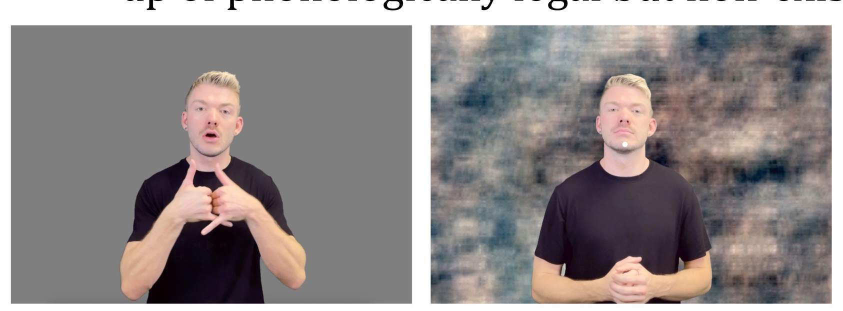

Figure 2: Still frames from the pseudosentences (left) and baseline (right) conditions.

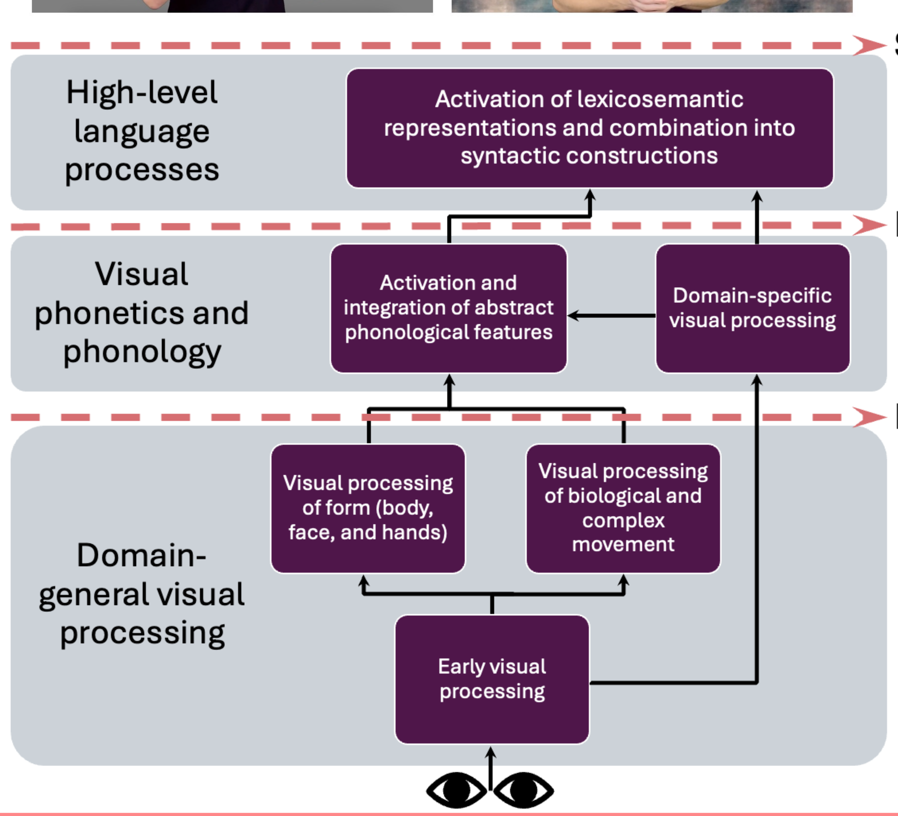

Figure 3: Hypothesized processes underlying sign language comprehension, and the conditions in this study.

Analysis

- We evaluated the effects of language (ASL vs. English) and stimulus type (sentences vs. pseudosentences) on neural effect sizes using linear mixed-effects models, with age as a covariate.
- Effect sizes = estimated responses within subject-specific functional regions of interest (fROIs)[5], defined using the *ASL sentences > baseline* contrast. fROIs were constrained by group-level parcels (Figure 4).

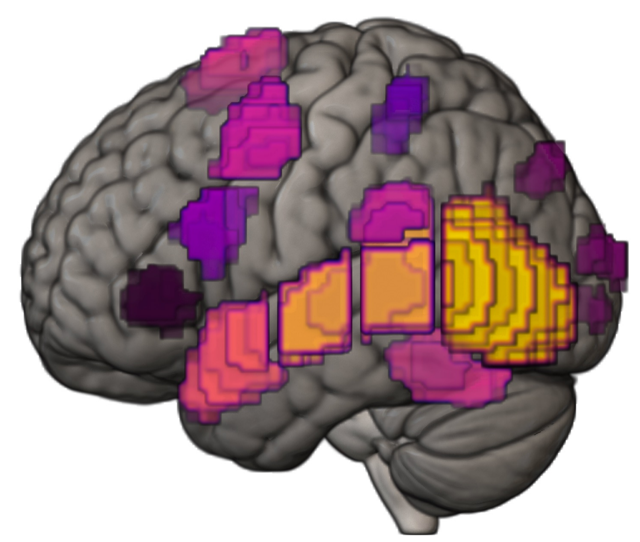

Figure 4: Group-level parcels from the *sentences > baseline* contrast, derived by conducting a group-constrained subject-specific analysis in *spm_ss*[5]. Individual activation maps thresholded at $p < 0.001$ (uncorrected) were intersected with these parcels to create individual fROIs.

- To investigate the effect of early language experience on neural activation, we included *ASL AoE* and *early sign access* as predictors in the model.

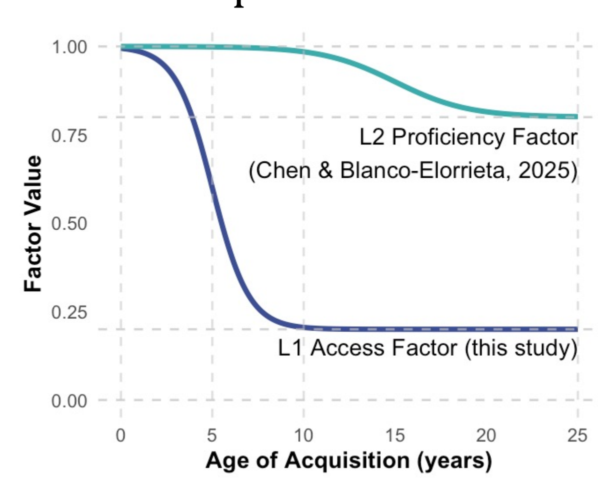

Figure 5: *Early sign access* scores (range 0 – 1) were calculated by collecting self-report ratings of percent sign exposure during childhood. These ratings were scaled with an *L1 access factor*, so that earlier sign access was given more weight relative to later sign access. Adapted from an L2 proficiency factor in multilinguals. [6]

Results

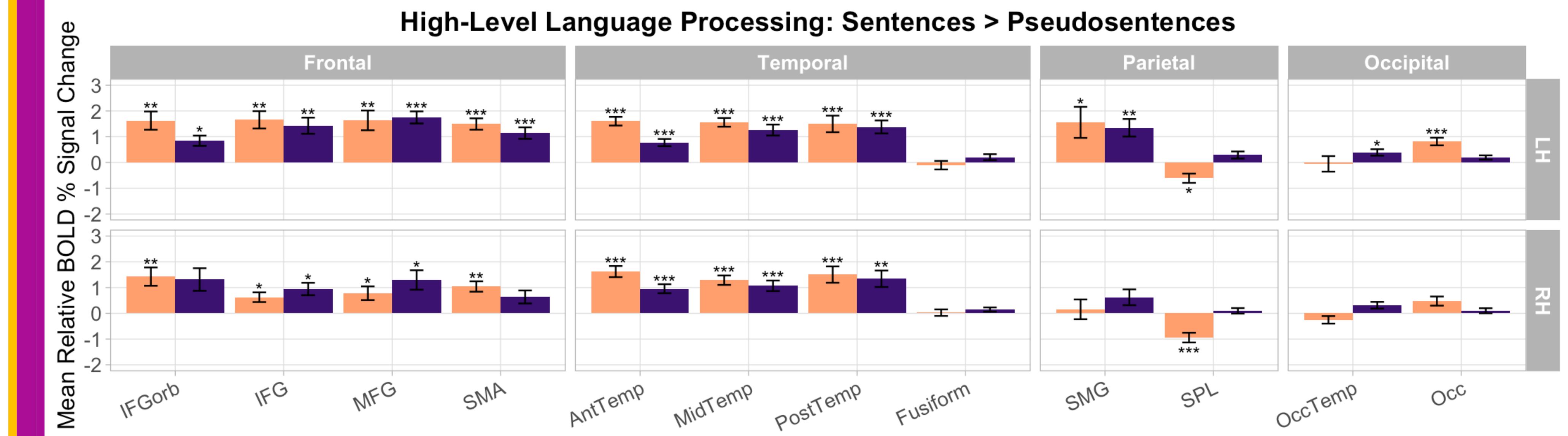

Figure 6: Regional responses to sentences versus pseudosentences in ASL and English. Each region is shown with its effect size for each language (ASL and written English). FDR-corrected significance values are displayed; error bars = ±1 SEM (*** $p < .001$; ** $p < .01$; * $p < .05$).

- High-level contrasts in both languages elicited **broadly similar** activation, despite very different input modalities.
- There was a clear distinction between **supramodal** regions, which were activated by the high-level language contrast, and **modality-specific** regions, which were only activated for the low-level ASL contrast (pseudosentences > baseline).
- High-level language activation was slightly **left-lateralized** for both languages; left-lateralization was strongest in the SMG.

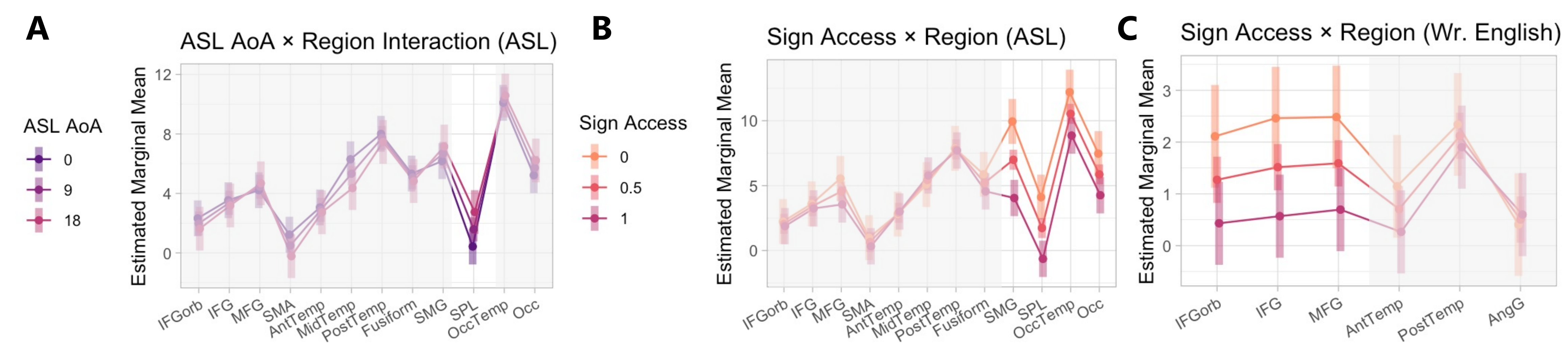

Figure 7: Estimated marginal means (with 95% CIs) for the effect of ASL AoA (A) or sign access (B,C) on ASL (A,B) or written English (C) activation within each neural region.

- Later ASL AoA predicts **higher** activation in the SPL ($p = .035$) (Figure 7A).
- Lower early sign access predicts **higher** activation in parietal and occipital regions ($ps < .05$) (Figure 7B).
- Early sign access effects on English were marginal ($p = .067$), but post-hoc regional means were significantly different in frontal regions, in which higher early sign access predicted lower activation while reading written English (Figure 7C).

Conclusions

- Both hemispheres are recruited for both ASL and written English comprehension in deaf signers, which has been found in previous research [7], but high-level language comprehension is slightly left-lateralized for both languages.
- Supramodal frontotemporal regions respond similarly to high-level comprehension in both ASL and written English.
  - *Exceptions:* The left SMG (both languages) and bilateral occipital regions (only ASL) seem to be involved in high-level language comprehension. Past studies have implicated these regions in abstract sign language processing; the specific computational roles of these regions is unknown and of particular interest in future research. [8]
- Our findings replicate prior research showing that degraded/delayed early language exposure predicts increased occipito-parietal activation[4], but we do not find attenuated frontotemporal activation. Our sample was characterized by high proficiency in both languages.

[1] Terhune-Cotter and Emmorey, 2025 **[2]** Emmorey et al., 2015; Liu et al., 2020; Trettenbrein et al., 2020; Matchin et al., 2022 **[3]** e.g., Boudreault and Mayberry, 2006; see Corina et al., 2014 **[4]** Mayberry et al., 2011; Twomey et al., 2020
[5] Fedorenko et al., 2010; Nieto-Castanon et al., 2012 **[6]** Chen & Blanco-Elorrieta, 2025 **[7]** Neville et al., 1998 **[8]** Corina et al., 1999; Stroh et al., 2019; Almeida et al., 2016; Evans et al., 2019

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