Neural selectivity for sign-based phonological units: Evidence from fMRI adaptation

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Introduction

- Sign languages exhibit phonological structure that is parallel, but not identical to spoken languages.

- However, very little is known about how the brain recognizes and processes phonological structure in a sign language, or whether body-selective brain regions play important role in sign perception.

- We conducted an fMRI adaptation study to investigate neural selectivity for sign-based phonological units – handshape (HS) and place of articulation (POA or location) on the body.

- We hypothesized that neural areas tuned to sublexical phonological features would show decreased BOLD response for identical signs and for pairs with overlapping phonological features when compared to pairs with no phonological overlaps (NPO).

Methods

Participants. Deaf native and early signers (n = 14, 9 females, mean age: 34 ± 5.3)

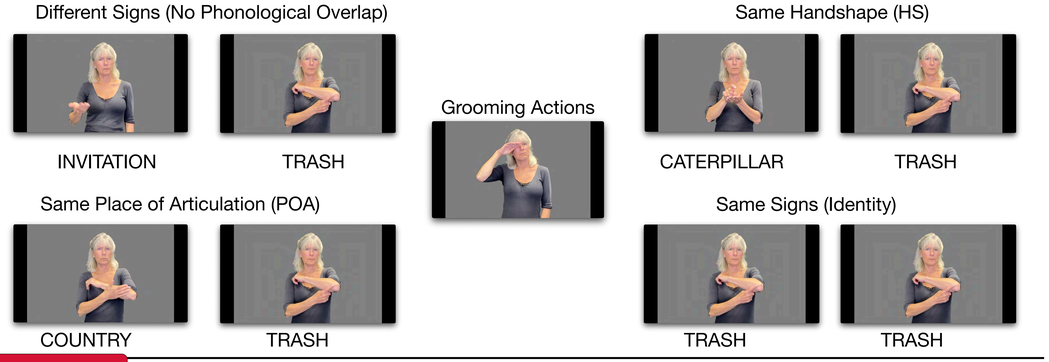
Experimental design. An event-related fMRI adaptation paradigm with four different probe conditions (68 trials each): same sign (Identity), same handshape (HS), same place of articulation (POA), and no phonological overlap (NPO). Each trial, randomly presented, lasts 5s and consists of two video clips (adaptor and probe) presented sequentially, with 1s ISI. Signs in all four conditions were matched for ASL frequency, and a number of specific phonological variables usingthe ASL-LEX data base (Caselli, et al., 2017; Sehyr et al., 2022).

Task. Nonlinguistic grooming actions (e.g., rubbing the eyes) appeared occasionally in the trials, and subjects pressed a button when they appeared.

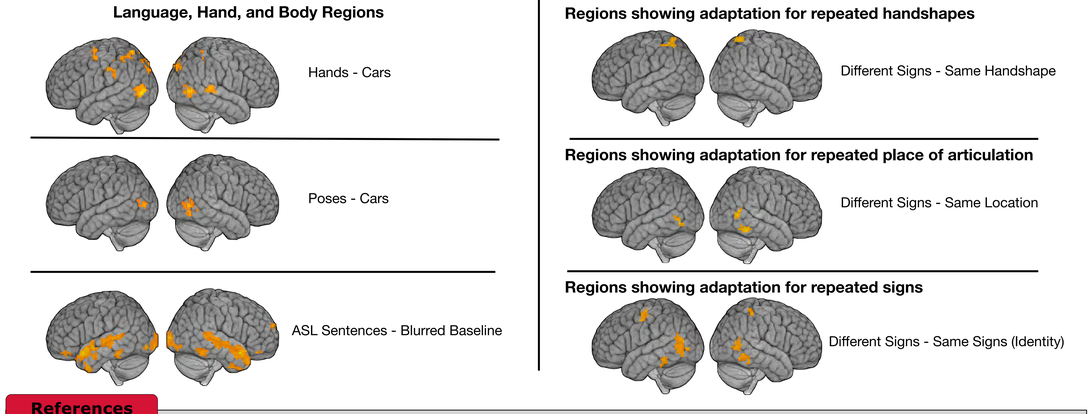
Localizer scans. To identify body-part selective brain regions, we contrasted pictures of hands and of body poses with pictures of cars (Sephyr, et al. 2020). To identify language-selective regions, we contrasted ASL sentences with degraded (blurred) signs (Terhune-Cotter et al., paper in progress).

Statistical analysis. Using AFNI (Cox, 1996), hemodynamic response functions (HRFs) corresponding to the probe videos—representing the adaptation effect—were calculated for each condition. Four whole-brain adaptation-probe maps were generated for each subject. Planned whole-brain contrasts using repeated measures were performed to reveal the differences between no phonological overlap adaptation and adaptations for Identity, Handshape, and Place of articulation.

Stimuli



Results



Results and Conclusions

Neural Selectivity for Handshape
Repetition suppression effects were found in the bilateral superior parietal lobule / intraparietal suclus (SPL / IPS), regions known to be involved in the control of hand configurations (e.g., Vingerhoets et al., 2010).

Neural Selectivity for Place of Articulation (Location)
Repetition suppression effects were found in occipito-temporal regions bilaterally and in the right fusiform gyrus, regions known to be involved in the recognition of body postures.

Neural Selectivity for lexical signs (Identity condition)
Full sign repetition suppression effects were found in bilateral parietal and temporal cortices. These regions overlap with regions activated by the hand and body localizers

Body and Hand localizers
These localizers revealed bilateral activity in the regions previously identified as extrastriate body area (Downing et al., 2001) and in the IPS area known to be involved viewing bimanual actions (Heitger et al., 2012). Neural selectivity for Place of Articulation was found within these regions

Language localizer
ASL sentences activated frontotemporal and occipital regions, compared to the blurred baseline. Repetition effects for lexical signs overlapped with inferior temporal regions.

Conclusions
Early phonological processing of signs occurs in parietal and occipitotemporal regions, which are selectively tuned to viewing hand and body actions. This result contrasts with spoken languages, where early phonological processing occurs in superior temporal cortex.

The lack of an adaptation effect in the supramarginal gyrus (SMG) is surprising, given its hypothesized role in phonological processing (Emmorey, 2021; Corina et al., 1999, Cardin et al., 2016). SMG may play a role in the integration of phonological units, rather than in recognizing sign-based phonological units.

These findings suggest that language neural circuitry can easily expand and repurpose "non-language" brain regions to encode linguistic representations (on-going data collection from hearing non-signers will test this hypothesis).

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Acknowledgments

This research is supported by NIH Grant R01 DC010997 to San Diego State University and Karen Emmorey. Thank you to all who participated in our research.

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