Introduction

Background:
- Multivariate patterns of neural activity have been used to measure knowledge and learning in many conceptual domains.
- Homologous words in two different languages have been shown to evoke partially overlapping neural patterns associated with semantic meaning.

Central Question:
- Can we detect evidence of shared semantic representations between sign and speech very early in the learning process (~2 hours of training)?

Neural Analyses:
- Support vector machine classification of semantic categories in clusters identified through whole-brain searchlight RSA.

Methods

Study Procedure

Training Sessions (36 min):
- Day 1: Twelve vocabulary words in ASL or Russian, recall quiz
- Day 2: Twelve additional words, recall quiz
- Day 3 (prior to scan): Review all 24 words, final quiz

IMRI Session
- Alternating blocks of ASL and Russian word clips
- Answer semantic and nonsemantic questions with button press
- In the final trial, participants completed the same task with clips of the same 24 words in English

Semantic Trials
- Is this object colorful?
- Would the way to cause this object to move?
- Semantic questions were designed to encourage subjects to think about the semantic meaning of the word without specifically priming the target categories (animal, fruit, and vehicle).

Nonsemantic Trials
- Have you seen this word already in this block?

IMRI Task
- fMRI scanning of different modalities (e.g. spoken British English and British Sign Language)
- In a larger study, ASL videos were provided courtesy of ASL nonsigners

Stimuli

- Participants learned 24 concrete nouns in either ASL or Russian. Twelve of these (A) were members of target semantic categories.
- Single-word clips containing one noun each in each language.
- ASL videos were provided courtesy of ASL-LEAD while English and Russian videos were created by lab volunteers.
- Piloting ensured non-signers’ ratings of the visual and auditory similarity between words did not correlate with the categorical structure (C).

Behavioral Results: Recall Performance

- In each of the 7 neural clusters defined by English trials, we performed 1,000 iterations of leave-one-item-out cross-validated SVM classification for each language. [Train: 5 Ss x 9 Items, Test: 5 Ss x 3 Items]
- Results are shown here from the strongest cluster to emerge from the English RSA results – Cluster 1 in the left supramarginal gyrus. SVM accuracy in English is also shown as a comparison.

Neural Results: Support Vector Classification

- SVM accuracies across 1,000 iterations of half-sample leave-one-item-out cross-validated SVM for each cluster.
- (Cluster #17) and (Cluster #18) shown above

Summary of Behavioral Results
- ASL and Russian groups performed differently on the recall quizzes and scanner task.
- ASL group scored at ceiling on review quiz, indicating mastery of the 24 words they had studied. For this reason, all subsequent analyses focus solely on the ASL group.

Summary of Neural Results
- All seven clusters which significantly correlated with item-level semantic information in the English RSA showed above-chance classification of the ASL trials, indicating the presence of semantic information for ASL.
- Similarly, several significant clusters from the ASL RSA exhibited above-chance classification of English trials.
- The best-performing cluster in both English and ASL was located in the left supramarginal gyrus, an area which has previously been associated with word recognition and phonological processing.

Conclusions and Future Directions

Conclusions:
- Ten novice ASL learners showed evidence of item-level semantic representations which were shared between a well-known (English) and newly-learned (ASL) language, but not an unrelated language (Russian).
- This preliminary finding provides a proof of concept for the study of shared semantic representations across language modalities (sign and speech) and suggests that these representations can be detected even for novice learners after a very brief training.

Next Steps:
- In a larger-scale study, use this and similar multivariate neuroimaging approaches to not only detect, but differentiate the extent of learning in individual subjects.
- → ASL learners in this study learned 24 target nouns to ceiling. Future work may encompass more complex and difficult aspects of language learning.
- Use previously developed informational network analysis to determine whether neural scores predict other indicators of real-world knowledge (such as pencil and paper tests).

References

Cetron, J. S., Connolly, A. C., Diamond, S. G., May, V. V., & Evans, S. (2013). ASL and Russian groups performed differently on the recall quizzes and scanner task. [Preprint]. Neuroscience. https://doi.org/10.1038/s41467-019-0096-1


Methodology: The methods used in this study included fMRI scanning of different modalities (e.g., spoken British English and British Sign Language). In a larger study, ASL videos were provided courtesy of ASL nonsigners. The study procedure involved training sessions (36 min) where participants learned 24 concrete nouns in either ASL or Russian, with recall quizzes at different time points (Day 1, Day 2, and Day 3). The IMRI session consisted of alternating blocks of ASL and Russian word clips, and participants answered semantic and nonsemantic questions with button press. The IMRI task involved fMRI scanning, and the stimuli included participants learning 24 concrete nouns in either ASL or Russian, with single-word clips containing one noun each in each language. The results showed that all seven clusters which significantly correlated with item-level semantic information in the English RSA demonstrated above-chance classification of the ASL trials, indicating the presence of semantic information for ASL. Similarly, several significant clusters from the ASL RSA exhibited above-chance classification of English trials. The best-performing cluster in both English and ASL was located in the left supramarginal gyrus, an area previously associated with word recognition and phonological processing.