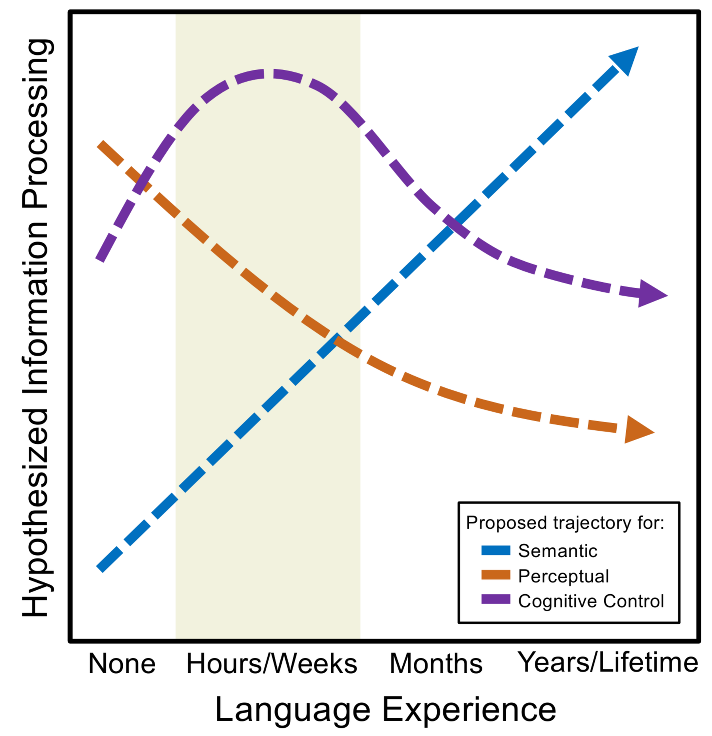
From seeing to understanding: Novice sign language learners shift focus from perceptual to semantic information for newly learned signs

Megan E. Hillis & David J. M. Kraemer
Dept. of Psychological & Brain Sciences, Dartmouth College

Introduction

- Comprehending a newly learned language requires interactions between **perceptual, semantic, and executive processing systems.**

- **Perceptual**: Some studies suggest that novices activate sensory regions (e.g. occipital for reading[1]) more than fluent users
- **Semantic:** Recruitment of semantic regions and alignment to semantic features increases with learning and comprehension[2,3]
- **Executive:** Frontal activation may be a hallmark of successful engagement at earliest stages[4], but associated with poorer performance later in learning[5].



- In addition to being an understudied case, **signed languages** provide opportunity to study perceptual features that are maximally dissimilar from spoken language users' prior experience.

Across three datasets, how does representation of <u>semantic</u> and <u>perceptual</u> features change during sign language learning?

Methods

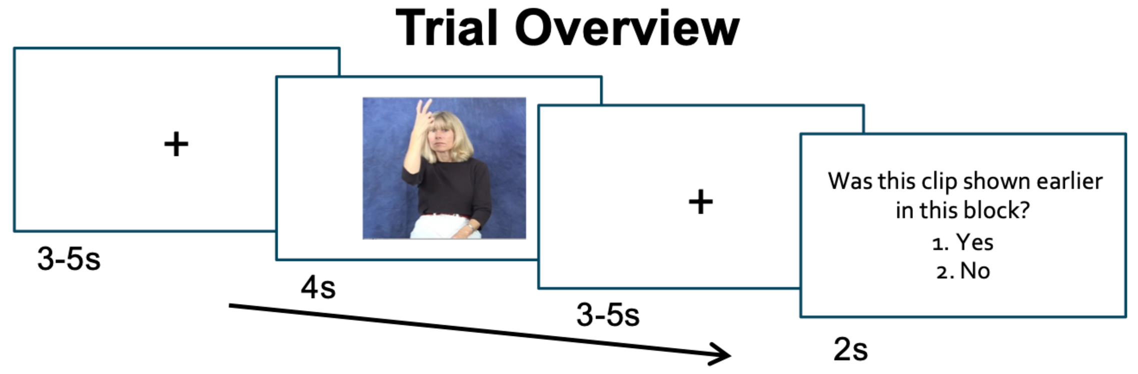
- Across three studies, hearing, non-signing English speakers were scanned while they viewed clips of concrete nouns in American Sign Language (ASL)

Study 1: 30-minute lesson → (1 day) → 30-minute lesson → (1 day) → 30-minute review, fMRI scan — Pilot Sample

Study 2: 30-minute lesson → (1 day) → 15-minute review, fMRI scan → (~1 week) → Follow Up — Cross-sectional (compare studied & unstudied signs)

Study 3: Pre-learning fMRI scan → (~3 weeks self-paced coursework) → Post-learning fMRI scan — Longitudinal (same signs viewed before & after learning)

Trial Overview

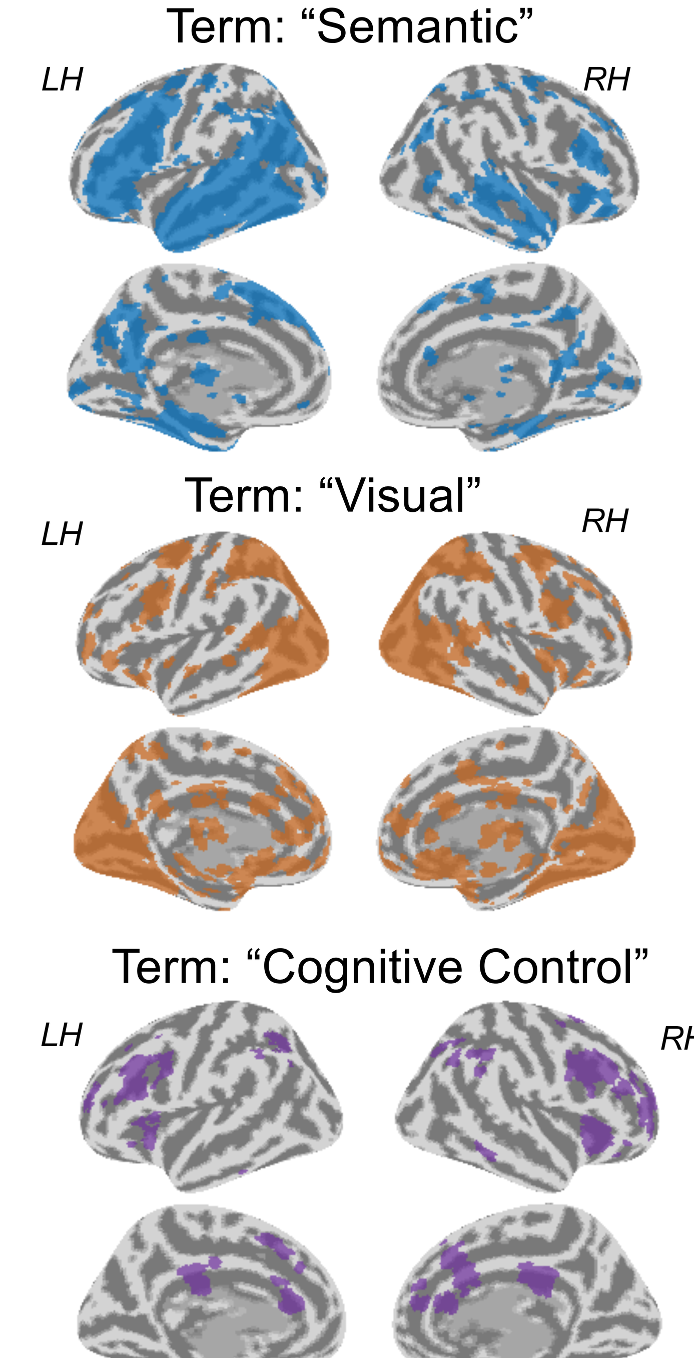


Supplementary Methods

ASL stimulus images courtesy of ASL-LEX (www.asl-lex.com), used with permission

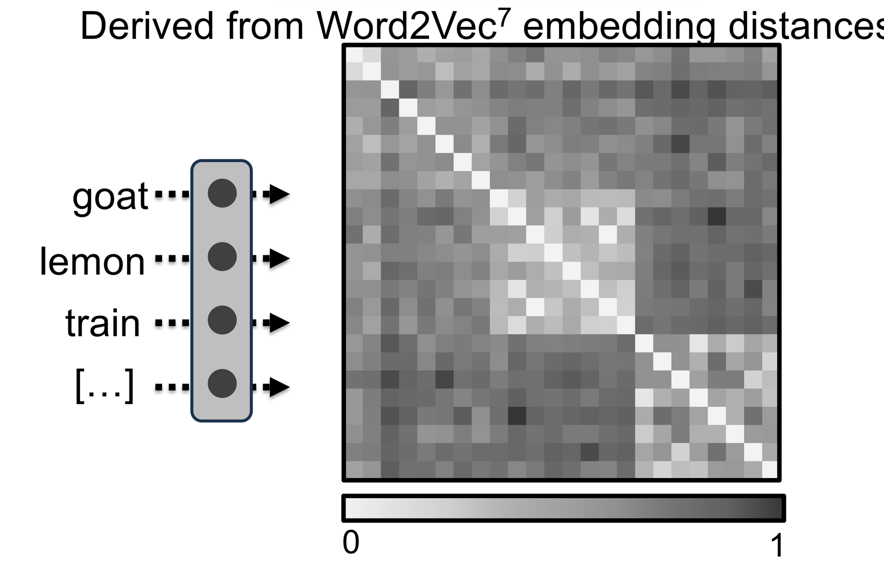
Results

Term-based Association Maps derived from Neurosynth[6]

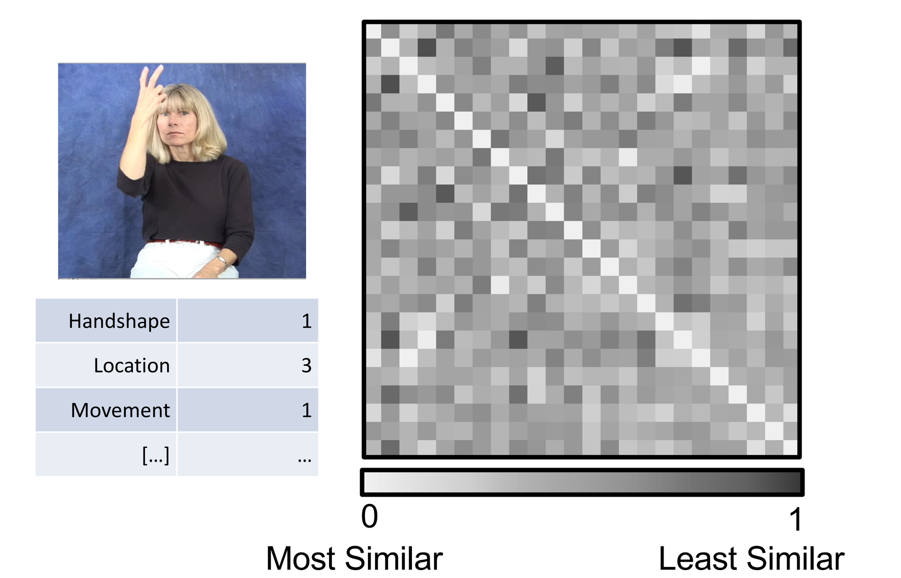


RSA target models

Semantic Feature Model
Derived from Word2Vec[7] embedding distances

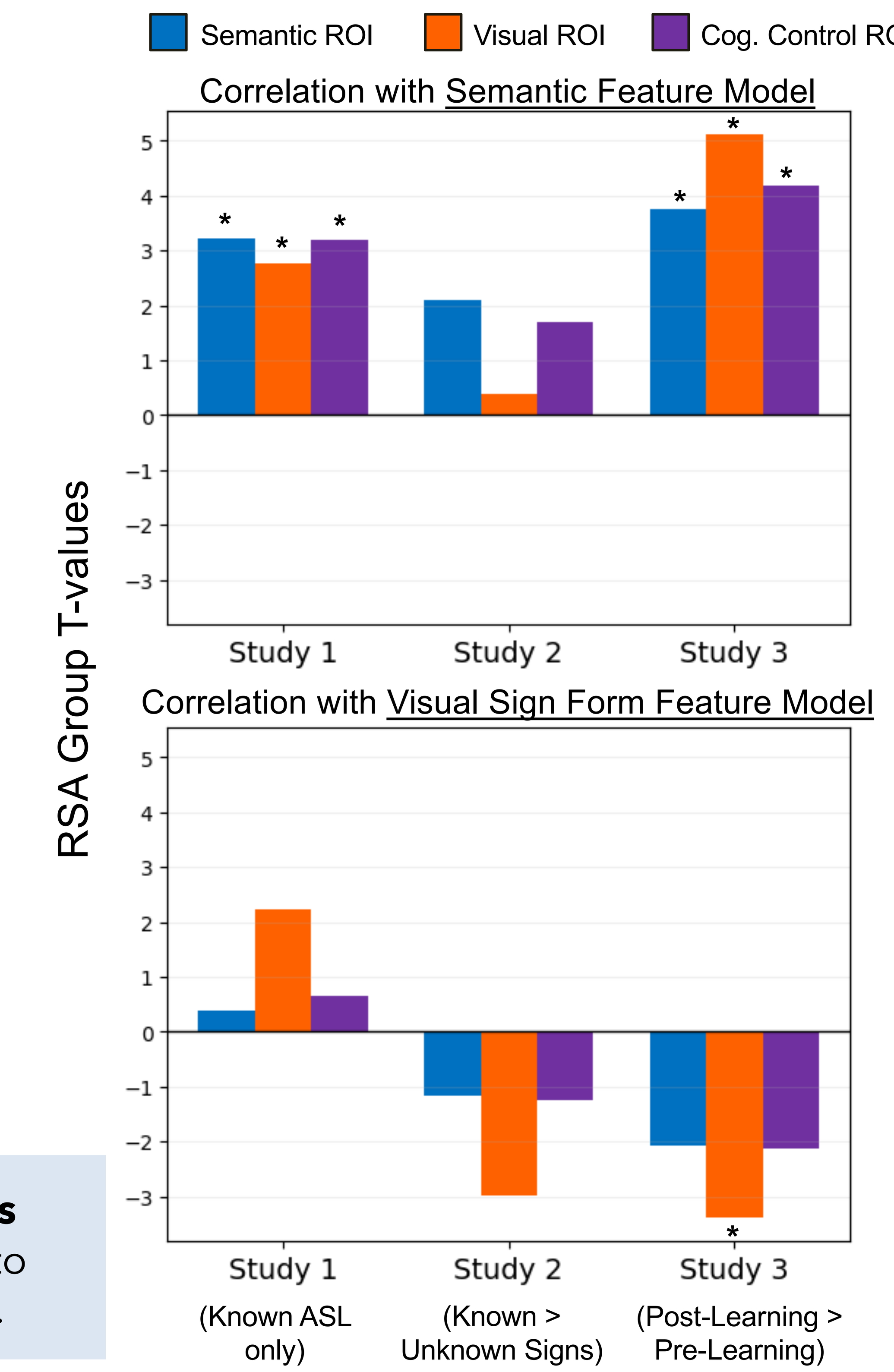


Visual Sign Form Feature Model
Derived from ASL-LEX[8] sign form metadata



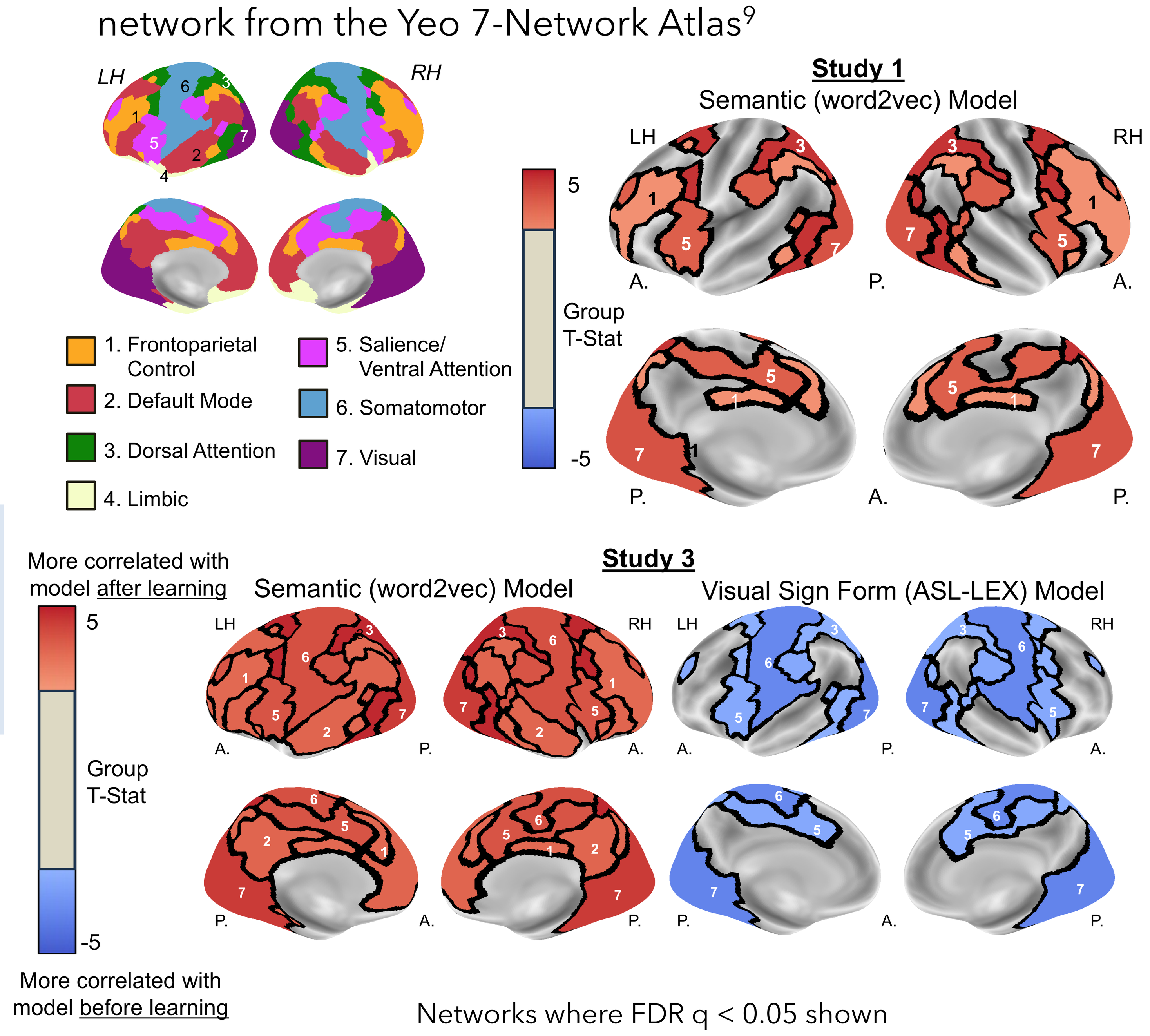
In studies 1 & 3, alignment to **semantic features increased with learning**. In study 3, alignment to sign form features also decreased in visual ROI.

RSA results for each model and ROI



Yeo Network ROIs

- To look beyond the term-based ROIs, we also ran RSA in each network from the Yeo 7-Network Atlas[9]



Networks where FDR q < 0.05 shown

Conclusions

- Functional changes resulting from learning occur rapidly and involve many distributed areas of the brain (rather than visual areas responding exclusively to visual features, etc.)
- At this early stage of learning, recruitment cognitive control regions are associated with successful comprehension.
- In Study 1 (who learned to ceiling) and Study 3 (who learned over 3 weeks), alignment to **semantic features increased with learning.** In Study 3, alignment to **sign form features decreased** with learning.
  - In Study 2, (where the lesson was shortest and behavioral performance was poorest), there was no significant shift.
- Together, these studies provide novel insight into the often-understudied initial stages of learning.

References

1. Lai, C.-H., Hsieh, S.-K., Lee, C.-L., Su, L. I.-W., Liu, T.-H., Lu, C.-R., Tsai, I.-N., & Chou, T.-L. (2021). Neuro-Cognitive Differences in Semantic Processing Between Native Speakers and Proficient Learners of Mandarin Chinese. *Frontiers in Psychology*, *12*. https://doi.org/10.3389/fpsyg.2021.781304
2. Alotaibi, S., Alamri, S., Alsaleh, A., & Meyer, G. (2025). Neural adaptations in short-term learning of sign language revealed by fMRI and DTI. *Scientific Reports*, *15*(1), 5345. https://doi.org/10.1038/s41598-024-84468-z
3. Hillis, M. E., & Kraemer, D. J. M. (2025). *Initial signs of learning: Decoding newly-learned vocabulary from neural patterns in novice sign language learners* (p. 2025.04.11.648265). bioRxiv. https://doi.org/10.1101/2025.04.11.648265
4. Johnson, L., Fitzhugh, M. C., Yi, Y., Mickelsen, S., Baxter, L. C., Howard, P., & Rogalsky, C. (2018). Functional Neuroanatomy of Second Language Sentence Comprehension: An fMRI Study of Late Learners of American Sign Language. *Frontiers in Psychology*, *9*. https://doi.org/10.3389/fpsyg.2018.01626
5. Williams, J. T., Darcy, I., & Newman, S. D. (2018). Neural substrates of sign language vocabulary processing in less-skilled hearing M2L2 signers: Evidence for difficult phonological movement perception. *Bilingualism*, *21*(3), 550–562. https://doi.org/10.1017/S1366728917000347
6. Yarkoni, T., Poldrack, R. A., Nichols, T. E., Van Essen, D. C., & Wager, T. D. (2011). Large-scale automated synthesis of human functional neuroimaging data. *Nature Methods*, *8*(8), 665–670. https://doi.org/10.1038/nmeth.1635
7. Mikolov, T., Chen, K., Corrado, G., & Dean, J. (2013, January 16). *Efficient Estimation of Word Representations in Vector Space*. International Conference on Learning Representations. https://www.semanticscholar.org/paper/Efficient-Estimation-of-Word-Representations-in-Mikolov-Chen/f6b51c8753a871dc94ff32152c00c01e94f90f09
8. Caselli, N. K., Sehyr, Z. S., Cohen-Goldberg, A. M., & Emmorey, K. (2017). ASL-LEX: A lexical database of American Sign Language. *Behavior Research Methods*, *49*(2), 784–801. https://doi.org/10.3758/s13428-016-0742-0
9. Yeo, B. T., Krienen, F. M., Sepulcre, J., Sabuncu, M. R., Lashkari, D., Hollinshead, M., Roffman, J. L., Smoller, J. W., Zöllei, L., Polimeni, J. R., Fischl, B., Liu, H., & Buckner, R. L. (2011). The organization of the human cerebral cortex estimated by intrinsic functional connectivity. *Journal of Neurophysiology*, *106*(3), 1125–1165. https://doi.org/10.1152/jn.00338.2011