# The neural basis of sign language processing in deaf signers: An Activation Likelihood Estimation meta-analysis

Trettenbrein, P. C.[1,2,*], Papitto, G.[1,2], Zaccarella, E.[1], & Friederici, A. D.[1]

[1] *Department of Neuropsychology, Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, Germany*

[2] *International Max Planck Research School on Neuroscience of Communication: Structure, Function, & Plasticity (IMPRS NeuroCom), Leipzig, Germany*

** trettenbrein@cbs.mpg.de*

MAX-PLANCK-GESELLSCHAFT @FriedericiLab

MAX PLANCK INSTITUTE FOR HUMAN COGNITIVE AND BRAIN SCIENCES LEIPZIG

NeuroCom

## Introduction

Sign language processing (SLP) has been studied using functional magnetic resonance imaging (fMRI) and positron emission tomography (PET) for about 25 years. Deaf signers have been shown to recruit similar peri-sylvian regions for SLP as those identified in studies on verbal language. To date, the literature on sign language has only been reviewed qualitatively and the involvement of the right hemisphere in SLP remains subject to debate.

**Aims of the present study:**

1. Investigate spatial convergence for fMRI and PET studies of SLP using Activation Likelihood Estimation.
2. Evaluate neuroanatomical localization and lateralization of converging clusters for SLP.
3. Dissociate linguistic and visuo-spatial processing when language is used in the visuo-gestural modality.
4. Assign robust functional associations to SLP regions using meta-analytic connectivity modeling.

## Methods

- **Systematic literature search** in PubMed and Web of Science (Müller et al., 2018). See Figure 1.
- **Activation Likelihood Estimation** using the GingerALE toolbox (Eickhoff et al., 2012, 2009) version 2.3.6 (Eickhoff et al., 2017) with the Turkeltaub ALE method which corrects for within-experiment effects derived from foci proximity (Turkeltaub et al., 2012).
- **Mass overlap analysis** in inferior frontal gyrus using cytoarchitetonically defined BA 44 and BA 45 (Amunts et al., 1999) from the SPM Anatomy Toolbox (Eickhoff et al., 2007, 2005).
- **Lateralization analysis** by computing weighted (AveLI) as well as "basic" lateralization indices using AveLI version 2017.4.3 (Matsuo, Chen, & Tseng, 2012).
- **Meta-analytic connectivity modeling** using BrainMap database (Laird et al., 2011).

### Systematic literature search

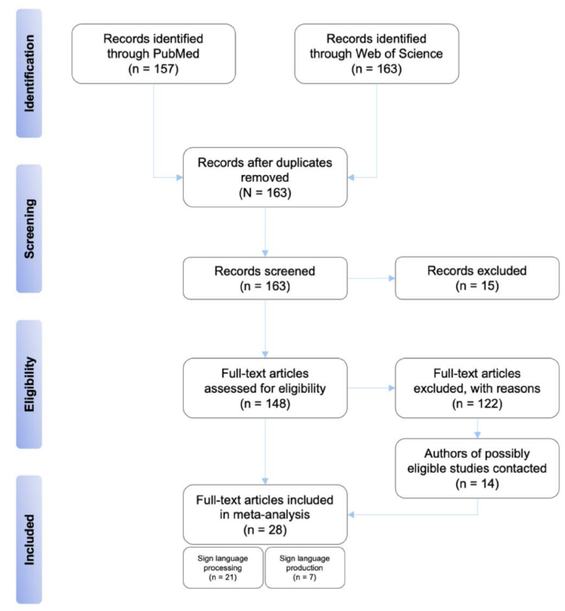


Figure 1: Search term: "sign language" AND ((mri OR fmri) OR ("magnetic resonance" imaging OR functional magnetic resonance imaging) OR pet OR "positron emission tomography")

## Results

### Sign language comprehension

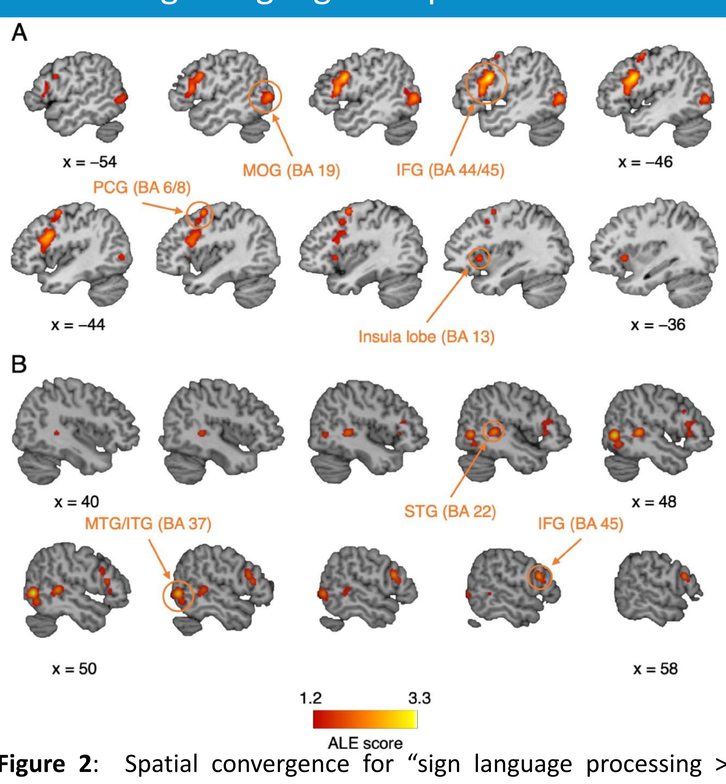


**Figure 2**: Spatial convergence for "sign language processing > control/baseline" contrasts. (A) Left hemisphere. (B) Right hemisphere. Mask dimensions = 77 x 96 x 79; number of within-brain voxels = 229,781; number of foci = 395; number of experiments = 24; number of subjects = 329; thresholding method = cluster-level inference; thresholding value = .05; number of thresholding permutations = 10,000; cluster-forming value = .001.

### Lateralization analysis

| Mask | AveLI | baseLI | # voxels LH | # voxels RH |
|---|---|---|---|---|
| Area 44 | 0.78 | 0.65 | 549 | 131 |
| Area 45 | 0.54 | 0.25 | 389 | 282 |
| Broca's region (area 44 and 45) | 0.68 | 0.46 | 645 | 282 |
| Entire hemisphere | 0.24 | 0.20 | 1196 | 808 |

**Figure 3**: Lateralization indices (AveLI and baseLI) and total number of voxels that survived cluster analysis (i.e. have an ALE score in output image) within cytoarchitectonic or hemispheric masks.

### Manual and facial action observation

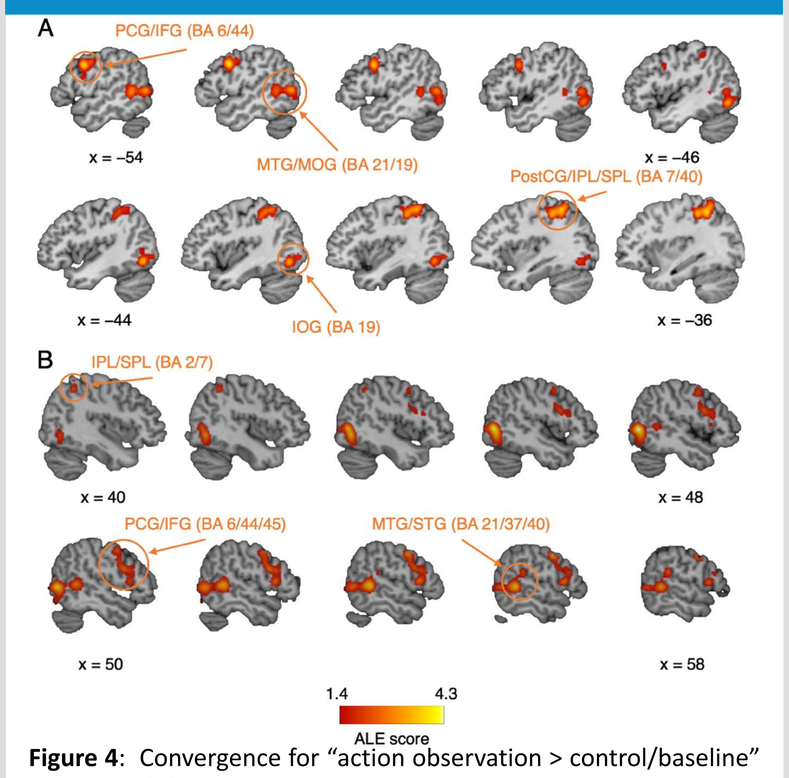


**Figure 4**: Convergence for "action observation > control/baseline" contrasts. (A) Left hemisphere. (B) Right hemisphere. Number of foci = 549; number of experiments = 26; number of subjects = 431; thresholding as in Figure 1.

### Sign language production

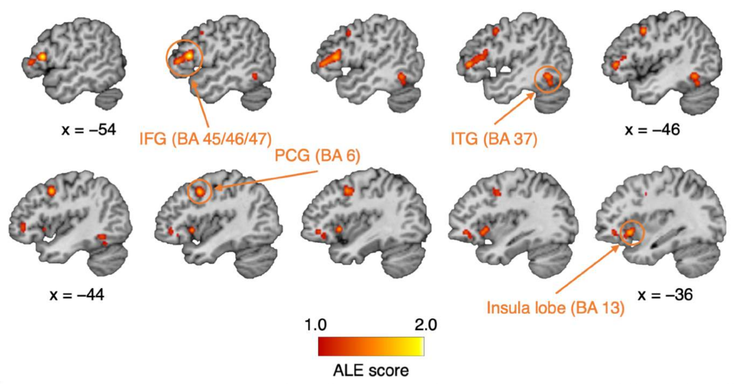


**Figure 5**: Convergence for "sign production > control/baseline" contrasts. Number of foci = 363; number of experiments = 8; number of subjects = 90; thresholding as in Figures 1 and 2.

### Mass overlap analysis in IFG

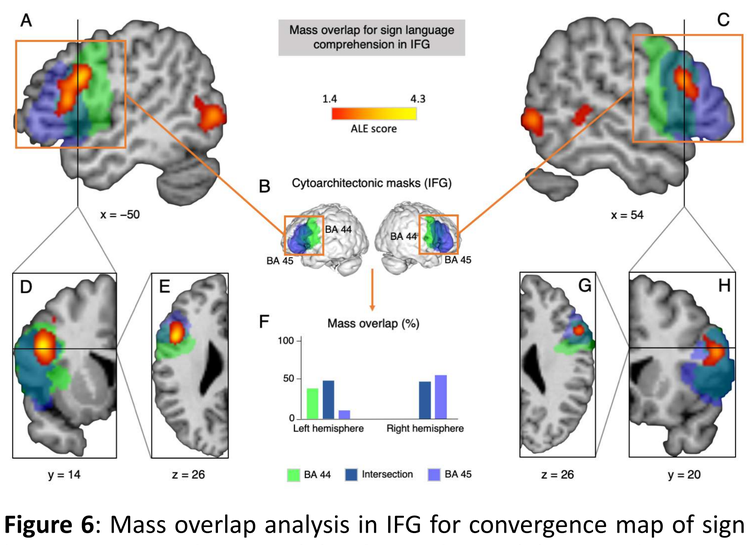


**Figure 6**: Mass overlap analysis in IFG for convergence map of sign language comprehension. (A) Left IFG cluster. (B) Cytoarchitectonic maps. (C) Right IFG cluster. (D) Coronal plane. (E) Transverse plane. (F) % of total mass overlap. (G) Coronal plane. (H) Transverse plane.

### Functional specialization for language

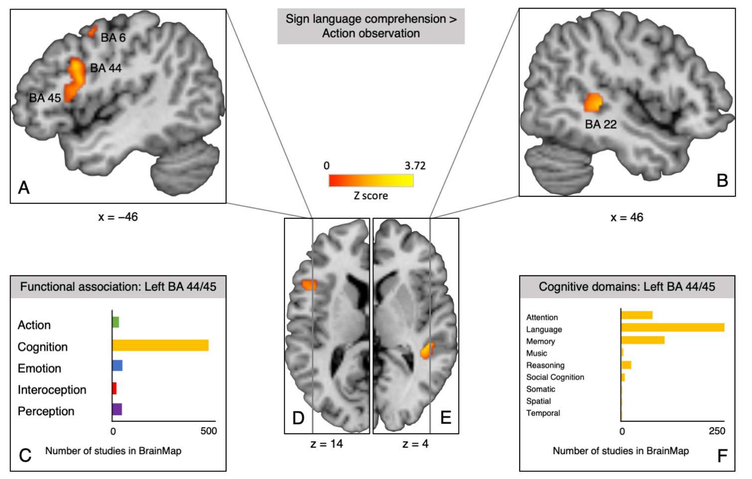


**Figure 7**: Significant clusters of sign language comprehension > action observation contrast and functional attributions in BrainMap database. (A) Left hemisphere. (B) Right hemisphere. (C) Functional association for voxels in cluster. (D) and (E) Transverse planes. (F) Number of studies organized by subdomain.

## Discussion

- Sign language comprehension in deaf signers recruits widely distributed bilateral fronto-temporo-occipital networks yet is strongly or completely left-lateralized in Broca's region (especially BA 44), insula, and precentral gyrus. Sign production is left-lateralized.
- Activation in right inferior frontal gyrus during sign language comprehension is not specific to language processing but may be specific to the processing of language in the visuo-gestural modality.
- Broca's region (left BA 44 and 45) is a hub in the language network, independent of the modality of language use (spoken, written, or signed).

### Neuroanatomy of sign language

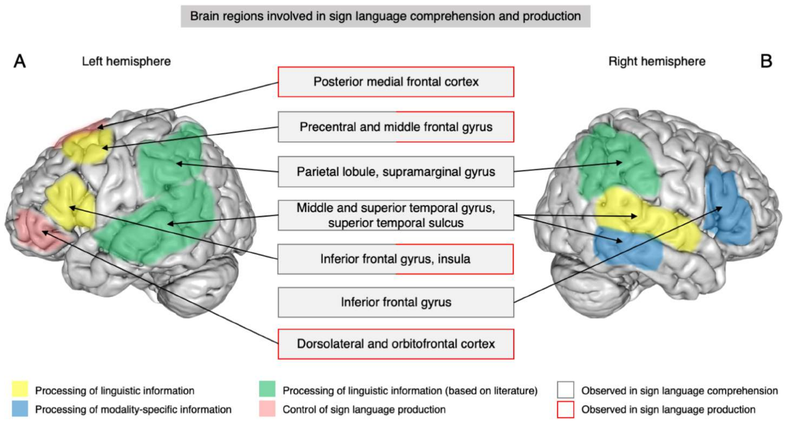


**Figure 8**: Schematic of brain regions involved in sign language comprehension and production identified in this study.

## Data availability

The collected foci data as well as all files resulting from the different analyses and diagnostics are available for download on the Open Science Framework.

OSF

Project page: https://osf.io/w7vau

## References

A complete list of references cited on this poster is available online.

Theoretical Issues in Sign Language Research (TISLR) 13, 26th–28th September 2019, Hamburg, Germany