SIGN language in the BRAIN

by Gregory Hickok, Ursula Bellugi
and Edward S. Klima
Why does language “set up shop” where it does?

- Does modality affect the functional neuroanatomy of language?
- For example, the M350 and the N400 localize in the vicinity of auditory cortex. Is that just an accident or is it because this activity indexes access to representations that are auditory?
- Does the location of lexical access in the brain depend on modality?
Sign language phonology

- Signs are made up of
  - hand shapes
  - the locations around the body where signs are made
  - the movements of the hands and arms
  - orientation of the hands.
A phonological similarity neighborhood in ASL
- same hand shape, movement and orientation but different location

SUMMER

UGLY

DRY
Figure 2.4. Minimal contrasts of signs illustrating major parameters. (Based on The Signs of Language, by E. S. Klima and U. Bellugi, Harvard University Press, 1979.)
ASL morphology

Example of derivational morphology:

- Adding a rolling movement to the sign “give” (and to most ASL verb signs) changes the sign’s meaning to “give continuously.” Signers can use different patterns to modify the verb to mean “give to all,” “give to each,” “give to each other” and many other variations.
ASL syntax

- No fixed word order.
- Grammatical function (subject, object) encoded by positions in space and direction of movement.
Sign language and iconicity

- Sign language has more iconicity than spoken language. For example, many verbs denoting mental states are signed close to the head.
- However, the relationship between signs and their meanings are as conventional as the sound meaning pairs of spoken languages.
- Different sign languages such as ASL and BSL mutually incomprehensible.
- Sign language not “just a loose collection of pantomime-like gestures thrown together willy-nilly”
- In fact ability to pantomime does not at all correlate with one’s ability to sign…

**WL**

- 76-year-old congenitally deaf right-handed male.
- As a result of stroke, WL has a large frontotemporoparietal lesion in the left hemisphere.
  - Brodman’s areas 44 and 45 (Broca’s area) and subsequent white matter tracts, including arcuate fasciculus, were damaged.
  - Most of middle and posterior area 22 (Wemicke’s area) was not involved in the lesion.
WL’s damage
Elderly Deaf Controls

RATING SCALE PROFILE OF SIGN CHARACTERISTICS

- **MELODIC LINE**
  - intonational contour

- **PHRASE LENGTH**
  - longest occasional (I/O) uninterrupted sign runs

- **ARTICULATORY AGILITY**
  - facility at phonemic and syllable level

- **GRAMMATICAL FORM**
  - variety of grammatical constructions (even if incomplete)

- **PARAPHASIA IN RUNNING SIGN**

- **SIGN FINDING**
  - informational content in relation to fluency

- **SIGN COMPREHENSION**
  - converted from objective z-score mean

Legend:
- RA
- LL
- GW
Left-Hemisphere Lesioned Signer, W.L.

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PARAPHASIA IN RUNNING SIGN

SIGN FINDING
informational content in relation to fluency

SIGN COMPREHENSION
converted from objective z-score mean

1 2 3 4 5 6 7

Absent    limited to short phrases and stereotyped expressions

1 sign    4 signs    7 signs

always impaired or impossible

never impaired

limited to simple declaratives and stereotypes

normal range

present once per minute of conversion

exclusively content signs

fluent without information

information proportional to fluency

absent

(z = -1.5) (z = -1) (z = -0.5) (z = 0) (z = +0.5) normal

(z = +1)
PRESERVED NONLANGUAGE SPATIAL COGNITION

Benton Test of Judgment of Line Orientation

Stimulus:

Choice Array:

W.L.'s score:
30/30 (perfect)
PRESERVED NONLANGUAGE SPATIAL COGNITION

WAIS-R Block Design Test

Model:

W.L.'s response: (LHD)

S.M.'s response: (RHD)

not available
Fig. 6. Comparisons of drawings from model of left-lesioned W.L. and right-lesioned S.M., showing preservation of nonlanguage abilities in the left- as opposed to the right-lesioned signer.
WL does well on spatial cognition tasks.

But WL’s signing is severely impaired.

Two main types of errors:

- **Paraphasias** ("mispronounciations")
- **Substituting pantomime gestures for signs**
Fig. 7. Phonological paraphasias from left-hemisphere-damaged signer W.L. implicate impairment of a specific phonological tier: handshape.
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Fig. 9. Spontaneously substituted pantomime forms for ASL signs.
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Fig. 9. Spontaneously substituted pantomime forms for ASL signs.
Fig. 9. Spontaneously substituted pantomime forms for ASL signs.
“Point to the door and then point to the ceiling”

“Will a brick float on water?”

![Comprehension Tasks Graph](image)

**Fig. 10.** Comprehension scores illustrating sign language deficits of left-lesioned signer W.L. in contrast with the excellent performance of right-lesioned S.M.
Sign language and aphasia more generally

- LHD causes similar problems for sign and spoken languages.
Lateralization


13 LHD Deaf signers
10 RHD Deaf signers

Administered a range of clinical aphasia assessment tests (ASL adapted)
<table>
<thead>
<tr>
<th>Age of Sign Exposure</th>
<th>Onset Deafness</th>
<th>Sex Handedness</th>
<th>Age at Testing</th>
<th>Lesion Size/Location</th>
<th>Lesion Etiology</th>
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<tr>
<td>Left Lesioned:</td>
<td></td>
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<tr>
<td>LHD01 6 5 m r</td>
<td>81</td>
<td>lg/frontal-parietal</td>
<td>Ischemic Infarct</td>
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<tr>
<td>LHD02 5 5 f r</td>
<td>66</td>
<td>mod/inf parietal</td>
<td>Ischemic Infarct</td>
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<td>lg/frontal</td>
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<td></td>
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<td>Hematoma*</td>
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<tr>
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<td>mod/temp-par-occ</td>
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</tr>
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</table>

* = surgical intervention
Superimposed Lesions

Left Hemisphere Damage (n=13)

Right Hemisphere Damage (n=8)

Cortical
Subcortical
Normal

RATING SCALE PROFILE OF SIGN CHARACTERISTICS

MELODIC LINE
- Absent
- Limited to short phrases and stereotyped expressions
- Runs through entire sentence

PHRASE LENGTH
- 1 sign
- 4 signs
- 7 signs

ARTICULATORY AGILITY
- Always impaired or impossible
- Normal only in familiar signs and phrases
- Never impaired

GRAMMATICAL FORM
- None available
- Limited to simple declaratives and stereotypes
- Normal range

PARAPHASIA IN RUNNING SIGN
- Present in every utterance
- Once per minute of conversation
- Absent

SIGN FINDING
- Fluent without information
- Information proportional to fluency
- Exclusively content signs

SIGN COMPREHENSION
- Absent
- Normal
  (z = 0) (z = -1.5) (z = -1) (z = -0.5) (z = 0) (z = 0.5) (z = +1)
Right Hemisphere Damaged
(n=7)

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  - Absent

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  - Fluent without information
  - Information proportional to fluency
  - Exclusively content signs

- **SIGN COMPREHENSION**
  - Absent
  - Information proportional to fluency
  - Normal (z = +0.5) (z = +1)
Left Hemisphere Damaged  
(n=10)

RATING SCALE PROFILE OF SIGN CHARACTERISTICS

MELODIC LINE

PHRASE LENGTH

ARTICULATORY AGILITY

GRAMMATICAL FORM

PARAPHASIA IN RUNNING SIGN

SIGN FINDING

SIGN COMPREHENSION

Absent
Always impaired or impossible
Normal only in familiar signs and phrases
None available
Present in every utterance
Fluent without information
Normal
1
2
3
4
5
6
7

(z = -2) (z = -1.5) (z = -1) (z = - .5) (z = 0) (z = +.5) (z = +1)
Role of the left hemisphere in sign language comprehension

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Accepted 20 November 2001

11 LHD Deaf signers
8 RHD Deaf signers

Three ASL comprehension measures
1. Single sign-to-picture matching (BDAE)
2. Simple commands (one clause, one step)
3. Complex commands (multi-clause/-step)

Analysis looked at
1. Left vs. right hemisphere damage
2. Temporal lobe lesioned vs. spared
Single signs

![Bar chart showing proportion correct for LHD and RHD with temporal lobe spared and involved conditions.](chart.png)
Simple sentences

![Bar chart showing proportion correct for LHD and RHD with temporal lobe involvement.

- LHD: Proportion Correct
- RHD: Proportion Correct

Legend:
- Open bars: temporal lobe spared
- Shaded bars: temporal lobe involved

Data points:
- LHD: Proportion Correct ± 0.2
- RHD: Proportion Correct ± 0.4
Complex sentences
RHD has been associated with discourse-level deficits in hearing patients

The same appears to hold in the Deaf signing population
Local vs. global hemispheric asymmetries in Deaf signers
(Hickok et al. 1998. Brain Lang. 65:276-86)

12 LHD Signers
8 RHD Signers

Two drawing tasks:
1. Copy line drawings (BDAE)
2. Hierarchical figure task
Trunk Lines
Toe Nails
Eye
Lip
Right Ear
Left Ear
Tail
Leg Contour

Chimney Line
Chimney
Attic Window
Double Line on Roof
Window Panes
Door Knob
Window Sills
Pathway
Bunches
A. LHD  
   ![Sketch of a house]
   ![Sketch of an elephant]

B. LHD
   A of M's
   ![Drawing of an A]
   D of Y's
   ![Drawing of a D]

RHD
   G of K's
   ![Drawing of a K]
   S of J's
   ![Drawing of a S]
Brain Imaging of Sign language (Neville et al, 1998. fMRI)

Written English -- Native Speakers

American Sign Language -- Native Signers
Brain Imaging of Sign language (Neville et al, 1998. fMRI)

- Both hearing and deaf subjects use classical anterior and posterior language areas within the left hemisphere when recognizing their native language, English or American Sign Language respectively.

- However, activity is also observed in right hemisphere prefrontal regions and posterior and anterior parts of the superior temporal sulcus when native signers, both deaf and hearing, recognize and process sentences in sign.

- These findings imply that the specific nature and structure of ASL results in employing the right hemisphere in processing language. This "[activity] within the right hemisphere may be specifically linked to the linguistic use of space" (Corina, 2002).
How stable is the left lateralization of signs? E.g., does it matter which hand you’re signing with?

Language Lateralization in a Bimanual Language

David P. Corina¹, Lucila San Jose-Robertson², Andre Guillemin², Julia High¹, and Allen R. Braun²

Abstract

Unlike spoken languages, sign languages of the deaf make use of two primary articulators, the right and left hands, to produce signs. This situation has no obvious parallel in spoken languages, in which speech articulation is carried out by symmetrical unitary midline vocal structures. This arrangement affords a unique opportunity to examine the robustness of linguistic systems that underlie language production in the face of contrasting articulatory demands and to chart the differential effects of handedness for highly skilled movements. Positron emission tomography (PET) technique was used to examine brain activation in 16 deaf users of American Sign Language (ASL) while subjects generated verb signs independently with their right dominant and left nondominant hands (compared to the repetition of noun signs). Nearly identical patterns of left inferior frontal and right cerebellum activity were observed. This pattern of activation during signing is consistent with patterns that have been reported for spoken languages including evidence for specializations of inferior frontal regions related to lexical–semantic processing, search and retrieval, and phonological encoding. These results indicate that lexical–semantic processing in production relies upon left-hemisphere regions regardless of the modality in which a language is realized, and that this left-hemisphere activation is stable, even in the face of conflicting articulatory demands. In addition, these data provide evidence for the role of the right posterolateral cerebellum in linguistic–cognitive processing and evidence of a left ventral fusiform contribution to sign language processing.
Does it matter which hand you’re signing with?
A CASE OF ‘SIGN BLINDNESS’ FOLLOWING LEFT OCCIPITAL DAMAGE IN A DEAF SIGNER

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(Received 28 December 1993; accepted 1 June 1994)

Abstract—We report on a right-handed, deaf, life long signer who suffered a left posterior cerebral artery (PCA) stroke. The patient presented with right homonymous hemianopia, alexia and a severe sign comprehension deficit. Her production of sign language was, however, virtually normal. We suggest that her syndrome can be characterized as a case of ‘sign blindness’, a disconnection of the intact right hemisphere visual areas from intact left hemisphere language areas. This case provides strong evidence that the neural systems supporting sign language processing are predominantly in the left hemisphere, but also suggests that there are some differences in the neural organization of signed vs spoken language within the left hemisphere.

Key Words: language; sign language; spatial cognition; hemispheric asymmetries.
- The neuroanatomy of sign largely consistent with the neuroanatomy of spoken languages.

- Even though the physical properties of signs and spoken words are very different, what seems to matter for the brain is that they both encode a form-meaning relationship that then gets “fed” into the computational system of language.