HANDSHAPE ASSIMILATION IN ASL FINGERSPELLING
ULNAR DIGIT FLEXION AND SELECTED FINGERS

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Broad Questions

How do handshapes in fingerspelling, and ASL broadly, vary, and what causes this variation?

- environment?
- signer?
- phonological properties?

Objectives of this research

- Analyze a large corpus of fingerspelling data using a variety of manual, automated, and statistical techniques.
- Quantify and investigate the sources of variation within fingerspelling.
- Develop an articulatory model of handshape.
A basic description of fingerspelling

- Fingerspelling is a type of loanword system that makes up anywhere from 12–35% of ASL discourse (Padden, 1991; Padden and Gunsauls, 2003).

- Simplistically, fingerspelling is a set of static (except for -j- and -z-) handshape-orientation combinations strung together sequentially, where each maps to one letter in an English word.

- Many note that this description is not quite accurate (Wilcox (1992); Akamatsu (1982) &c.).
What fingerspelling looks like; full speed

data.mp4
Fingerspelling in ASL borrowings

There has been some work on the process of borrowing from neutral fingerspelling to core lexical items. Battison (1978) looked at 40 loan signs, noting changes to handshape, among other phonological parameters.

Phonological parameters for signed languages

- Handshape
- Location
- Movement
- Orientation
- Non-manuals
Structure of the ASL lexicon

adapted from Brentari and Padden (2001); Battison (1978)
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Structure of the ASL lexicon

neutral fingerspelling ———— fully assimilated loan signs

foreign fingerspelling

native core
spatial

foreign other SLS

adapted from Brentari and Padden (2001); Battison (1978)
Structure of the ASL lexicon

Neutral fingerspelling ——— fully assimilated loan signs

Foreign fingerspelling

Foreign core spatial

Fully assimilated loan signs

\textit{eg} NO

Adapted from Brentari and Padden (2001); Battison (1978)
Structure of the ASL lexicon

- neutral fingerspelling
- initialized signs (e.g., TEAM)
- foreign fingerspelling
- fully assimilated loan signs
- native core
- spatial
- foreign other SLS

adapted from Brentari and Padden (2001); Battison (1978)
Structure of the ASL lexicon

neutral fingerspelling ——— fully assimilated loan signs

foreign fingerspelling

native core

spatial

two fs-letter loans

eg WORKSHOP

adapted from Brentari and Padden (2001); Battison (1978)
Structure of the ASL lexicon

neutral fingerspelling ——— fully assimilated loan signs

foreign fingerspelling

partially assimilated loansigns
  eg #E A R L Y

adapted from Brentari and Padden (2001); Battison (1978)
Structure of the ASL lexicon

neutral fingerspelling ——— fully assimilated loan signs

foreign fingerspelling

native core |
spatial

neutral fingerspelling
eg F-R-E-E

adapted from Brentari and Padden (2001); Battison (1978)
Why neutral fingerspelling?

Fingerspelling involves quick and sequential handshape changes, unlike signing. Which results in an ideal data set to look at variation in handshape because there are

- a large number of individual tokens
- in a huge variety of contexts
- using (most of) the handshapes in ASL
Ulnar flexion

We defined ulnar flexion variants as apogees where either the proximal interphalangeal or the metacarpophalangeal joint was more flexed in ulnar digits than radial digits.


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Recording specifications

- 4 native signers, 1 early leaner (2 (native) coded so far) produced
- 300 words
  - 100 names
  - 100 nouns
  - 100 non-English words
- repeating each word twice
- being recorded by 2 or 3 video cameras
- recording at 60 FPS
- for a total of 8,115 apogees
Apogee detection

We used a combination of human coders, algorithmic averaging, forced alignment, and verification to code timing data.

Apogees

- are the point where the hand reached a target handshape and orientation, or
- the point of minimum instantaneous velocity of all of the articulators, but
- crucially are not defined as the canonical form.

(Keane et al., 2011)
Feature annotation

- We extracted still images from each apogee that has been coded.
- We human coded features of hand configuration:
  - all -C-, -D-, -E-, and -O- apogees for ulnar flexion.
- There are 4,741 word medial apogees annotated.

Two goals

- A simple task with only a minimal amount of training necessary
- A metric that would apply regardless of how canonical a given handshape was
Handshape variation

<table>
<thead>
<tr>
<th></th>
<th>c</th>
<th>d</th>
<th>e</th>
<th>o</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>canonical</td>
<td>+flexion</td>
<td>canonical</td>
<td>+flexion</td>
</tr>
<tr>
<td>count</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td>400</td>
</tr>
</tbody>
</table>

The bar chart shows the variation in handshape counts for different handshape variants. The chart indicates a significant difference in counts for the 'e' variant compared to others.
Handshape variation

- **c**: canonical, +flexion
- **d**: canonical, +flexion
- **e**: canonical, +flexion
- **o**: canonical, +flexion

Count for each handshape variant:
- c: 0
- d: 0
- e: 400
- o: 275
What features encourage ulnar digit flexion?

**Selected Fingers**

- are described as the most salient fingers for a given handshape,
- are often (but not always!) extended, with other fingers (more) flexed,
- are used by many models of sign language phonology.

<table>
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<tr>
<th>one finger</th>
<th>two fingers</th>
<th>three fingers</th>
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<th>others (ulnar)</th>
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<td>-F-, -I-, -J-, and -Y-</td>
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<th>radial: [−flex] (&gt;extension)</th>
</tr>
</thead>
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<th>others (ulnar)</th>
<th>all: [±flex]</th>
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conditioning

non-conditioning
Flexion based on surrounding handshapes

<table>
<thead>
<tr>
<th>Condition</th>
<th>Handshape - Immediately Previous</th>
<th>Handshape - Immediately Following</th>
<th>Percent ++flex</th>
</tr>
</thead>
<tbody>
<tr>
<td>nonconditioning</td>
<td>nonconditioning</td>
<td>nonconditioning</td>
<td>0.00</td>
</tr>
<tr>
<td>conditioning</td>
<td>conditioning</td>
<td>conditioning</td>
<td>0.25</td>
</tr>
<tr>
<td>nonconditioning</td>
<td>conditioning</td>
<td>nonconditioning</td>
<td>0.15</td>
</tr>
<tr>
<td>conditioning</td>
<td>nonconditioning</td>
<td>conditioning</td>
<td>0.10</td>
</tr>
</tbody>
</table>

Legend:
- ● 0.00
- ● 0.05
- ● 0.10
- ● 0.15
- ▼ 0.20
- ▲ 0.25
What effects the -E- handshape?

- I -   - N -   - T -   - E -   - R -   - E -   - S -   - T -
What effects the -E- handshape?

-I-  -N-  -T-  -E-  -R-  -E-  -S-  -T-

apogee handshape
What affects the -E- handshape?

word type
name, noun, foreign

signer
s₁, s₂

apogee handshape
### What effects the -E- handshape?

<table>
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<th>Signer</th>
<th>Previous Handshape</th>
<th>Apogee Handshape</th>
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<td>Name, noun, foreign</td>
<td>s₁, s₂</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **Conditioning Variables**
  - What effects the -E- handshape?
  - Conditioning Variables:
    - Word type: name, noun, foreign
    - Signer: s₁, s₂
    - Previous handshape
    - Apogee handshape
What effects the -E- handshape?

word type
name, noun, foreign

signer
s1, s2

previous handshape

previous transition time

apogee handshape
What effects the -E- handshape?

- I-  - N-  - T-  - E-  - R-  - E-  - S-  - T-

word type
name, noun, foreign

signer
s1, s2

previous handshape → apogee handshape ← following handshape

previous transition time
What effects the -E- handshape?

- Word type:
  - name, noun, foreign

- Signer:
  - s1, s2

- Previous handshape

- Previous transition time

- Following handshape

- Following transition time

- Apogee handshape
Significant effects for ulnar flexion

- **word type**: name, noun, non-English
- **signer**: s1, s2
- **previous handshape**
- **following handshape**
- **previous transition time**
- **following transition time**
- **interaction**
- **apogee handshape**

(Keane et al., 2012)
**Significant effects for ulnar flexion**

- **word type**: name, noun, non-English
- **signer**: s₁, s₂
- **previous handshape**
- **following handshape**
- **apogee handshape**
- **interaction**
- **previous transition time**
- **following transition time**

(Keane et al., 2012)
Model predictions for ulnar flexion (mean transition times)

- **Conditioning Variables**

  - **Handshape Position**
  - **Number of Conditioning Handshapes**

- **Graph Key**
  - Red: none
  - Green: one
  - Blue: two
Conditioning features

- Increased ulnar digit flexion occurs in the context of surrounding apogees with handshapes that have extended radial fingers and flexed ulnar fingers.
- It seems that flexed, nonselected ulnar fingers are spreading from surrounding apogees to -E- and -O-.

Apogees from I-N-T-E-R-E-S-T and T-R-O-U-B-L-E
Conditioning features

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Apogees from I-N-T-E-R-E-S-T and T-R-O-U-B-L-E
Conditioning nonselected fingers? Really?

Alternatively, the selected fingers specification assimilates from surrounding apogees, to apogees that are underspecified for selected fingers (*ie* [all]).

- Many phonological theories of handshape use underspecification, especially for [all] selected fingers.
- Underspecified features are traditionally assumed to be the most susceptible to assimilation (*cf* alveolar nasals).
- A similar phenomenon has been observed in sign errors (*eg* MUST SEE (Klima and Bellugi, 1979)).
Because of underspecification, handshapes that have [all] fingers selected should be more susceptible to assimilation.

Of the [all] fingers selected handshapes:

- -E- and -O- show variation.
- -A- and -S- show no variation, but all fingers completely flexed.
- -C- shows little variation, but this could be physiological, (cf lexical handshape contours).
- -B- (seemingly) shows no variation, has all fingers extended, this might be physiological or phonological blocking (eg -u-).
If this phenomenon is the result of the assimilation of a phonological feature, and not the result of overlapping gestural constraints more like coarticulation, we expect:

- no temporal variation
- no effect of word category
Case study: I-N-T-E-R-E-S-T

I-N-T-E-R-E-S-T; half speed

Clipsinterest.mp4
Articulator trajectories

Case study: I-N-T-E-R-E-S-T
Conclusions

For ulnar digit flexion, handshapes vary based on phonological properties of surrounding apogees.

This variation is similar to processes that are used to nativize fingerspelling loan signs.

This process reduces the number of changes to which fingers are selected, bringing the neutral fingerspelling more phonologically toward ASL, without other large scale reductions or deletions.

Fingerspelling is important to study to develop theories about coarticulation and assimilation of handshape, because it pushes the boundaries of what is allowed by ASL phonology.
Future Directions

- We need feature annotation between the apogees for a more concrete sense of temporal variation.
- We need more precise timing measurements to look at the systematicity of holds and transitions.
- We need more precise articulator movement measurements.
I must also acknowledge the contributions of many who contributed in ways big and small:

**Fingerspelling data**  
Andy Gabel, Rita Mowl, Drucilla Ronchen, and Robin Shay

**Main advisors**  
Jason Riggle and Diane Brentari

**Other researchers**  
References


Padden, Carol, and Darline Clark Gunsauls. 2003. How the alphabet came to be used in a sign language. Sign Language Studies 4.10–33.

Model predictions based on transition time

- zscore(log(time))
- probability of ulnar flexion
- number of conditioning handshapes
  - none
  - one
  - two

- e
- o

- both
- following
- neither
- previous

$z_{score} \cdot log(time)$
Canonical -έ- (no increased ulnar digit flexion)
Canonical -ئ- (no increased ulnar digit flexion)

hand

- nonselected fingers [flexed]
- selected fingers
  - joints [flexed]
  - thumb
    - nonbase
  - fingers₁
    - quantity [all]
  - fingers₀
    - point of ref. [radial]
Canonical -ε- (no increased ulnar digit flexion)

- Hand
  - Nonselected fingers [flexed]
  - Selected fingers
    - Joints [flexed]
      - Nonbase
    - Thumb
    - Fingers$_1$
      - Quantity [all]
    - Fingers$_0$
      - Point of ref. [radial]
-E- with increased ulnar digit flexion

hand
  /\nonselected fingers    selected fingers
   \   /\ joints          fingers₁
    \  /  \ flexed       thumb
     \  /   \ nonbase      fingers₀
          \  /  \ quantity [one]>[all]
            \  /  \ point of ref.
-E- with increased ulnar digit flexion

hand
  └── nonselected fingers [flexed]
  └── selected fingers
    └── joints [flexed]
      └── nonbase
    └── thumb
    └── fingers₁
    └── fingers₀
      └── quantity [one]>[all]
      └── point of ref. [radial]
-E- with increased ulnar digit flexion