Defining an articulatory joint space for sign language handshapes

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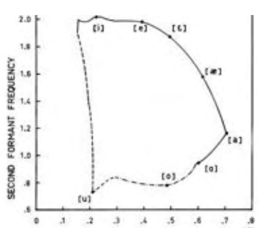
Introduction

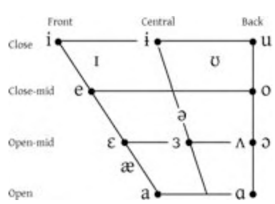
- Phonologists strive to discover the articulatory and perceptual principles governing how linguistic segments (spoken or signed) are organized with respect to each other.
- The goal of this work is to contribute methodologically to this pursuit for sign languages.

Spoken language phonology

- A useful tool in this pursuit for spoken languages has been the modeling of vowel spaces based on analysis of biomechanical and/or acoustic characteristics of the oral articulators (e.g. Lindblom & Sundberg 1969)



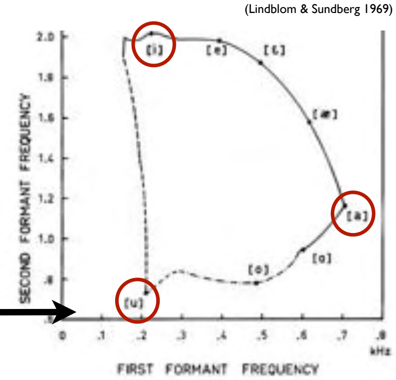
(Lindblom & Sundberg 1969)



Spoken language phonology

(Lindblom & Sundberg 1969)

- Different languages vary in their segment distributions depending on how constraints are prioritized



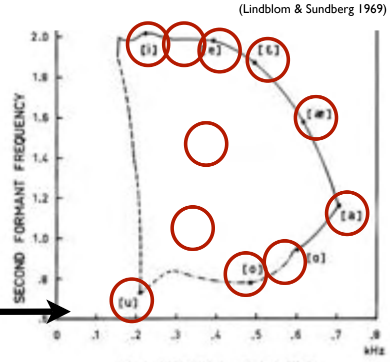
harder to confuse

fewer potential lexical contrasts

Spoken language phonology

(Lindblom & Sundberg 1969)

- Different languages vary in their segment distributions depending on how constraints are prioritized



easier to confuse

more potential lexical contrasts

Sign language phonology

- In sign language research, phonemic inventories have been proposed based on observed lexical contrasts, but little is known about the phonetic boundaries of those phonemes or how they are distributed in relation to one another in any quantitative way.
- Until recently, this pursuit has been limited by the available technology...

Goal of this work

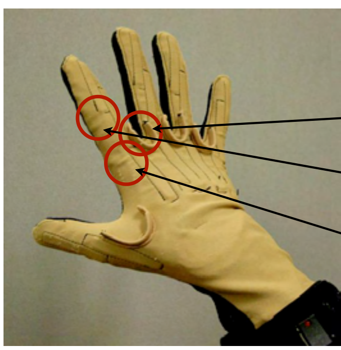
- To develop a way of measuring and visualizing the quantitative ‘distance’ between phonemic handshapes in sign languages so that we can better understand:
  - where category boundaries are located
  - the factors underlying their distribution

The technology

- CyberGlove (by Immersion Inc.)

- Used in sign language work, but mostly for motion capture recreating general configurations.
- Rarely (if ever) used for collecting quantitative measurements for joint angles (cf. Kessler, Hodges & Walker 1995)

The technology



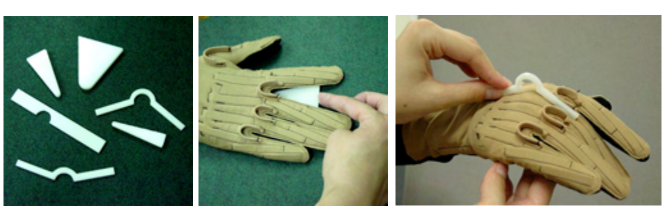
- 21 sensors, but currently calibrating 11 (with more techniques being developed):
  - Metacarpophalangeal abduction/adduction (ABD)
  - Proximal interphalangeal (PIP) flexion/extension
  - Metacarpophalangeal (MCP) flexion/extension
- This talk focuses on data from the index finger sensors

Our project

- STEP 1: Translate raw glove signals into angle measurements.
- STEP 2: Establish biomechanical boundaries for handshapes (i.e. what are the physiological limits?)
- STEP 3: Plot articulatory data from signer handshapes within the space and look for useful patterns.

STEP 1: Sensor to angle translation

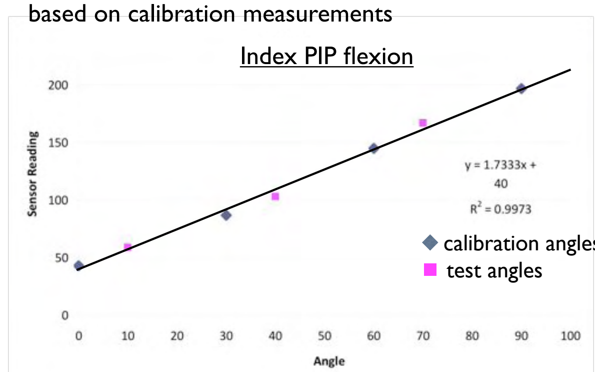
Calibration tools and techniques



Abduction Flexion

STEP 1: Sensor to angle translation

- Interpolation/extrapolation of angles from sensor readings based on calibration measurements

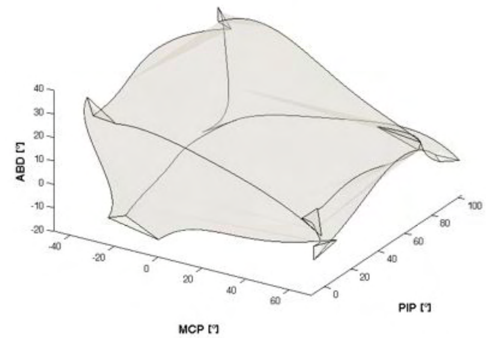


STEP 2: Establishing a boundary space

- Need to establish the biomechanical boundaries within which sign language handshapes could occur. (Not all angle combinations are created equal!)

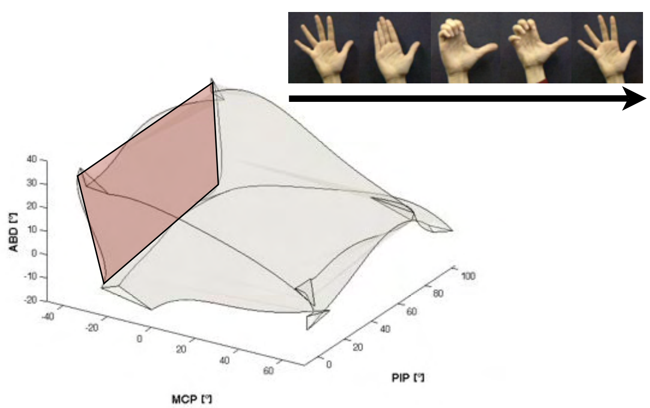
STEP 2: Establishing a boundary space

- Current space is based on the average dynamic flexion and abduction ranges of 6 non-signers



- Boundaries for this work are limited to handshapes with all five fingers in the same joint configuration (one group of selected fingers)

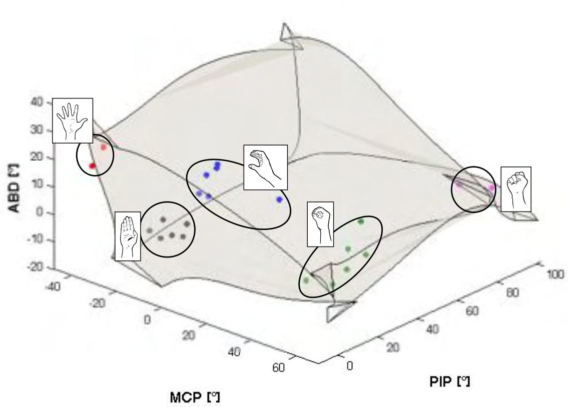
STEP 2: Establishing a boundary space



STEP 3: Plot articulation data

- Pilot subject (*for example purposes only; more data needed for conclusions!*):
  - Native hearing signer (CODA)
  - Deaf family for 4 generations
  - Employed as an ASL interpreter and active in the Milwaukee Deaf Community
- Brief methodology:
  - shown slides containing various pictures, English words, letters, and numbers designed to elicit a variety of handshapes across many lexical contexts
  - asked to sign the ASL word or description while wearing the CyberGlove

STEP 3: Plot articulation data



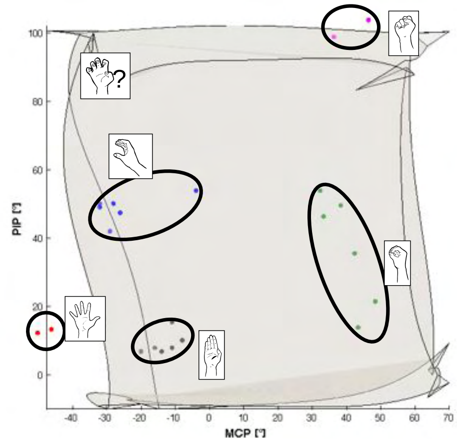
Applications

- Eventually, by collecting & plotting large amounts of handshape data across many signers, we can:
  - Gain phonetic information about typical phonemic category boundaries and acceptable variation
  - Establish 'norms' for language therapy or L2 learning
  - Answer more theoretical questions about handshape distribution and the linguistic factors driving them

Cross-lexical differences

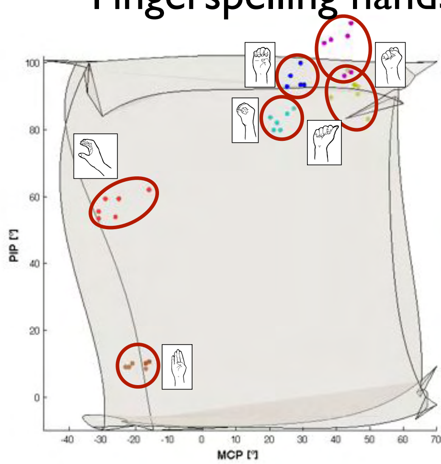
- Due in large part to the utilization of fingerspelling and iconic forms such as classifiers, phonemic inventories are not consistent across the lexicon of a given language (Brentari & Padden 2001; Eccarius 2008)
    - e.g. E only occurs in fingerspelling and initialized forms

Core handshapes



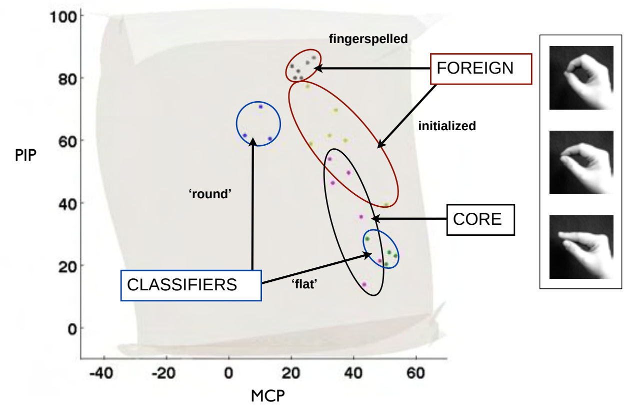
- Small number of contrasts
- Spread out within the space
- Often found at/near biomechanical boundaries

Fingerspelling handshapes



- Crowded distribution
- Suggests that other factors are more prominent (e.g. number of potential contrasts, historical influences, written-letter-to-handshape iconicity)

Cross-lexical differences

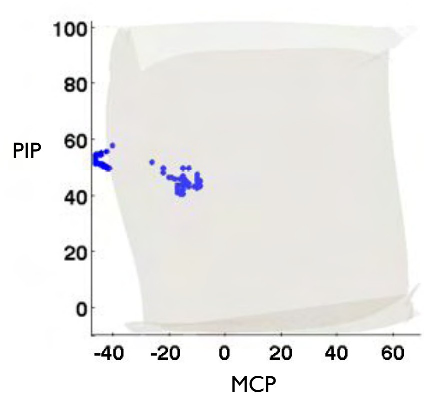


Iconic representations

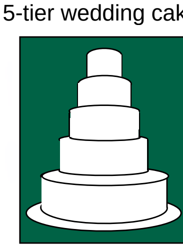
5-tier wedding cake

Is the representation gradient or categorial?
(cf. Emmorey & Herzig 2003)

Iconic representations



5-tier wedding cake



Summary

- The purpose of this study was to develop a methodology for collecting quantitative handshape data and visualizing that data within a joint space based on the biomechanical limits for joint movement.
- Several linguistic questions can be explored using such a methodology

Future work

- Create even more representative biomechanical boundaries:
  - based on the greater flexibility of signers' hands
  - using data points from the individual themselves?

Future work

- Develop more calibration techniques/better understand how the CyberGlove sensors react to:
  - combinations of flexion and abduction (e.g. for multi-fingergroup handshapes, stacked handshapes)
  - Thumb rotation calibrations (in progress)
  - configurations like [crossed]

Future work

- More handshape data from signers!!!
- Experiments are needed that will utilize this methodology, allowing some of the research questions asked here to be answered more definitively.

Thanks!

Acknowledgments

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- Handshape photos used here are from a project funded by NSF grant 0112391-BCS; P.I. Diane Brentari, and the handshape font used was developed by Gladys Tang (available: http://www.cuhk.edu.hk/lin/Faculty_gladystang/handshape2002-dec.TTF).

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