A THEORY-DRIVEN MODEL OF HANDSHAPE SIMILARITY

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Introduction

Which two of these are similar?

videos/book-look-side.mp4

Are these more or less similar?

videos/side-book-road.mp4

This talk

- Metrics for handshape similarity
- The Articulatory Model of Handshape
- Extension to fingerspelling similarity
- Psycholinguistic Experiments
- Results

Metrics for handshape similarity

How do we compare these words?

In the early days of sign language research there were a number of studies that used similarity or confusability to derive handshape classes. Locke (1970); Weyer (1973); Lane et al. (1976); Stungis (1981); Richards and Hanson (1985).

"The present study, then, undertakes to see what sort of featural analysis for ASL results when, using certain specific statistical techniques, we proceed from psychological data to a linguistic model, rather than the reverse" Lane et al. (1976)

The Articulatory Model of Handshape (AMOHS) (Keane, 2014)

Phonological specification for -c-

group	feature	value
psf	members	index, middle, ring, pinky, thumb
	base (MCP) joint	ext
	nonbase (PIP and DIP) joints	mid
	abduction	adducted
ssf	members	none
	base (MCP)	NA
	nonbase (PIP and DIP)	NA
thumb	opposition	opposed
nsf	members	none
	joints	NA
wrist	orientation	FS-default

Broadly compatible with phonological models Sandler (1989); Brentari (1998) among others; as well as phonetic models like Johnson and Liddell (2011a,b); Liddell and Johnson (2011a,b).

Phonetic target (joint angles) for -c-

	flexion			abduction
	DIP	PIP	MCP	MCP
index	135°	135°	180°	0°
middle	135°	135°	180°	0°
ring	135°	135°	180°	0°
pinky	135°	135°	180°	0°
		IP	MCP	CM
thumb		135°	180°	(-22°,-27°,13°)
		flexion	rotation	pronation
wrist		-10°	0°	0°

Phonetic target (joint angles) for -A-

	flexion			abduction
	DIP	PIP	MCP	MCP
index	90°	90°	90°	0°
middle	90°	90°	90°	0°
ring	90°	90°	90°	0°
pinky	90°	90°	90°	0°
		IP	MCP	CM
thumb		180°	135°	(23°,0°,8°)
		flexion	rotation	pronation
wrist		-10°	0°	0°

Difference in joint angles for -C- and -A- AKA δ(-C- ; -A-)

	flexion			abduction
	DIP	PIP	MCP	MCP
index	45°	45°	90°	0°
middle	45°	45°	90°	0°
ring	45°	45°	90°	0°
pinky	45°	45°	90°	0°
		IP	MCP	CM
thumb		45°	45°	(45°,27°,5°)
		flexion	rotation	pronation
wrist		0°	0°	0°

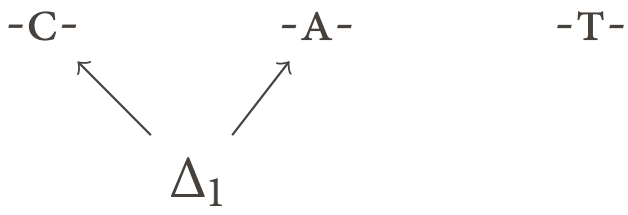
Fingerspelling

Comparing C-A-T and L-O-T — *Contour Difference Method*

-C- -A- -T-

-L- -O- -T-

Comparing C-A-T and L-O-T — *Contour Difference Method*



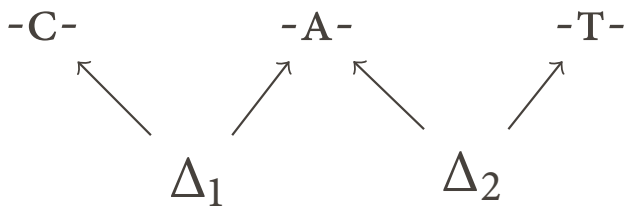
-L- -O- -T-

(-C-; -A-)

Δ_1

2031

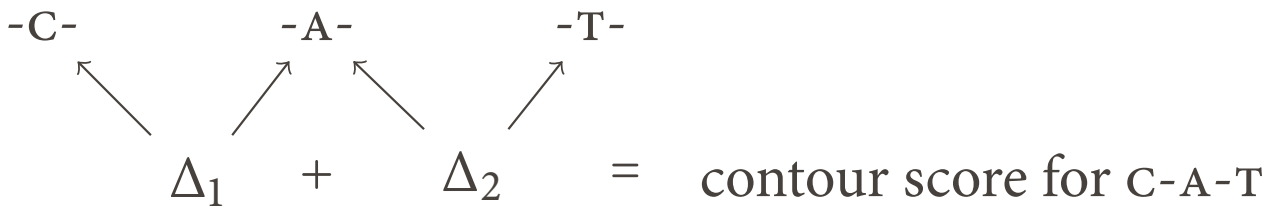
Comparing C-A-T and L-O-T — *Contour Difference Method*



-L- -O- -T-

(-C-; -A-)	(-A-; -T-)
Δ_1	Δ_2
2031	360

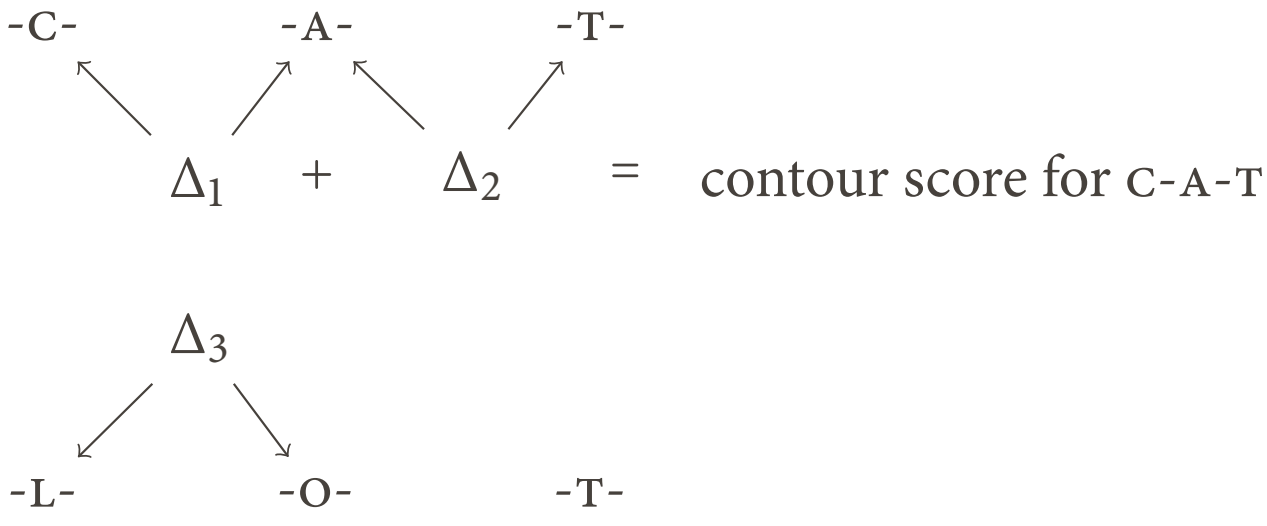
Comparing C-A-T and L-O-T — *Contour Difference Method*



-L- -O- -T-

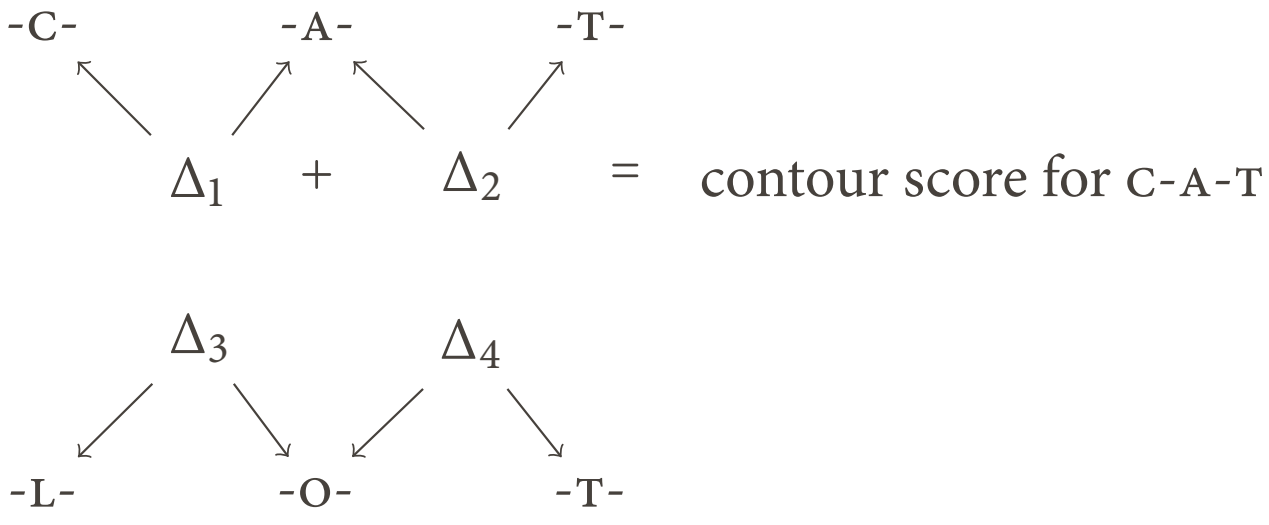
(-C-; -A-)	(-A-; -T-)
Δ_1	Δ_2
2031	360

Comparing C-A-T and L-O-T — *Contour Difference Method*



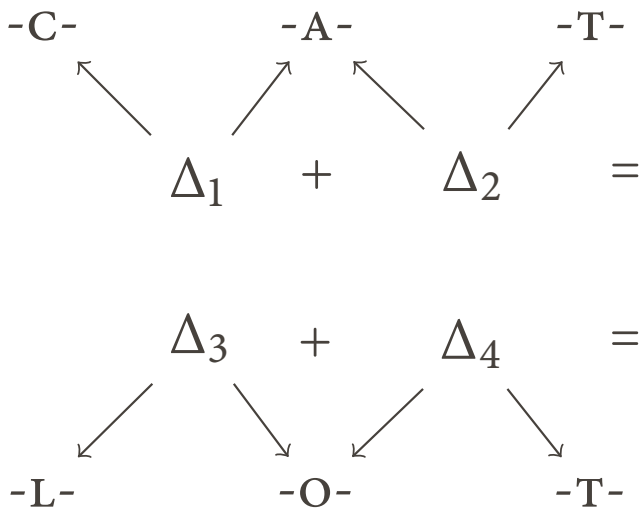
(-C-; -A-)	(-A-; -T-)	(-L-; -O-)
Δ_1	Δ_2	Δ_3
2031	360	1521

Comparing C-A-T and L-O-T — *Contour Difference Method*



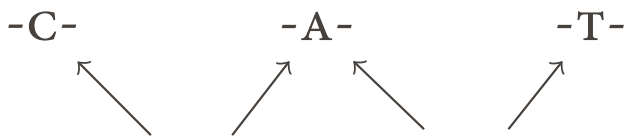
(-C-; -A-)	(-A-; -T-)	(-L-; -O-)	(-O-; -T-)
Δ_1	Δ_2	Δ_3	Δ_4
2031	360	1521	1356

Comparing C-A-T and L-O-T — *Contour Difference Method*



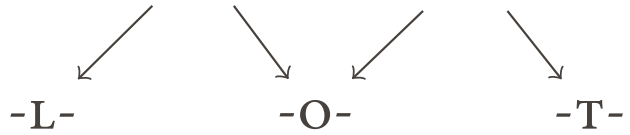
(-C-; -A-)	(-A-; -T-)	(-L-; -O-)	(-O-; -T-)
Δ_1	Δ_2	Δ_3	Δ_4
2031	360	1521	1356

Comparing C-A-T and L-O-T — *Contour Difference Method*



$\Delta_1 + \Delta_2 =$ contour score for C-A-T

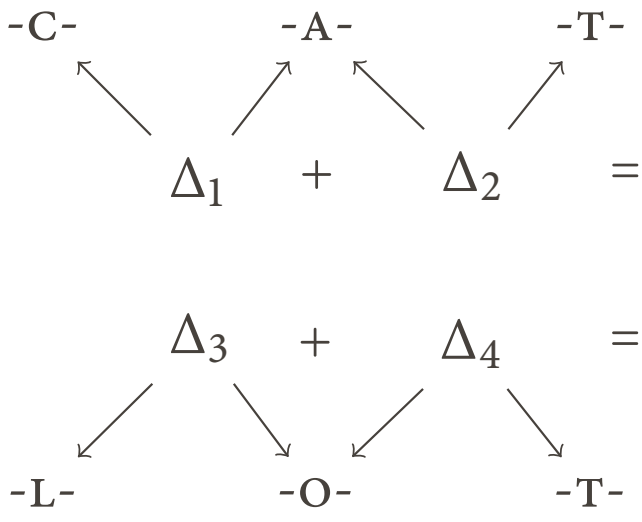
$\Delta_3 + \Delta_4 =$ contour score for L-O-T



$\left|\text{c.s. C-A-T} - \text{c.s. L-O-T}\right| =$ contour diff. score

(-C-; -A-)	(-A-; -T-)	(-L-; -O-)	(-O-; -T-)
Δ_1	Δ_2	Δ_3	Δ_4
2031	360	1521	1356

Comparing C-A-T and L-O-T — *Contour Difference Method*



$$\left|\text{c.s. C-A-T} - \text{c.s. L-O-T}\right| = \text{contour diff. score}$$

For this pair, the contour difference score is:

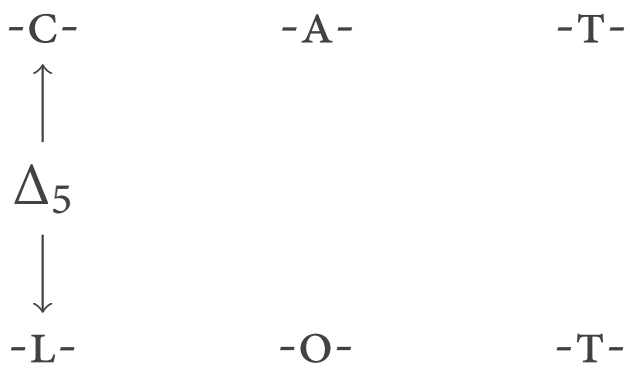
$$\begin{aligned}
&\left|\left(\text{(-C-; -A-)} + \text{(-A-; -T-)}\right) - \left(\text{(-L-; -O-)} + \text{(-O-; -T-)}\right)\right| = \\
&\left|\left(\Delta_1 + \Delta_2\right) - \left(\Delta_3 + \Delta_4\right)\right| = \\
&\left|\left(2031 + 360\right) - \left(1521 + 1356\right)\right| = 486
\end{aligned}$$

Comparing C-A-T and L-O-T — *Positional Similarity Method*

-C- -A- -T-

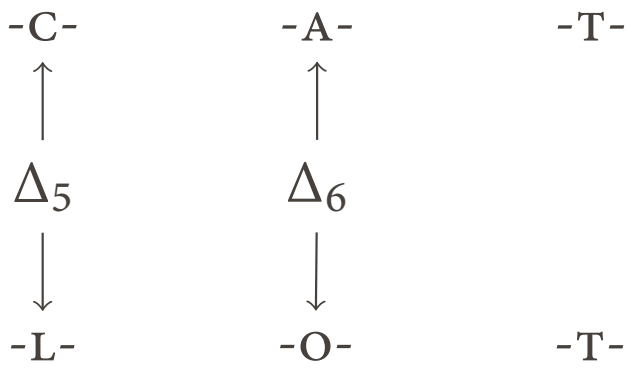
-L- -O- -T-

Comparing C-A-T and L-O-T — *Positional Similarity Method*



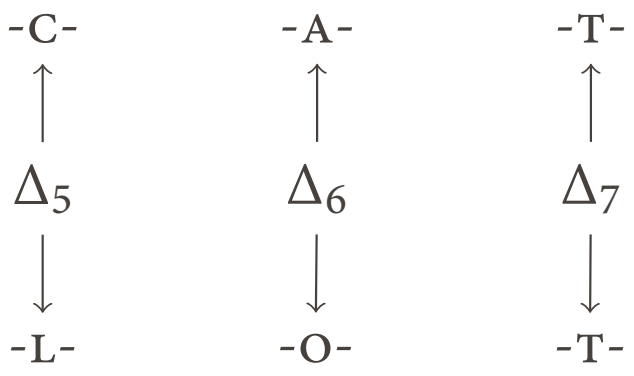
$$(\text{-C-}; \text{-L-})$$
$$\Delta_5$$
$$1656$$

Comparing C-A-T and L-O-T — *Positional Similarity Method*



(-C-; -L-)	(-A-; -O-)
Δ_5	Δ_6
1656	1356

Comparing C-A-T and L-O-T — *Positional Similarity Method*



(-C-; -L-)	(-A-; -O-)	(-T-; -T-)
Δ_5	Δ_6	Δ_7
1656	1356	0

Comparing C-A-T and L-O-T — *Positional Similarity Method*

$$\begin{array}{ccccccc} \text{-C-} & & \text{-A-} & & \text{-T-} & & \\ \uparrow & & \uparrow & & \uparrow & & \\ \Delta_5 & + & \Delta_6 & + & \Delta_7 & = & \text{positional similarity score} \\ \downarrow & & \downarrow & & \downarrow & & \\ \text{-L-} & & \text{-O-} & & \text{-T-} & & \end{array}$$

(-C-; -L-)	(-A-; -O-)	(-T-; -T-)
Δ_5	Δ_6	Δ_7
1656	1356	0

Comparing C-A-T and L-O-T — *Positional Similarity Method*

$$\begin{array}{ccccccc} \text{-C-} & & \text{-A-} & & \text{-T-} & & \\ \uparrow & & \uparrow & & \uparrow & & \\ \Delta_5 & + & \Delta_6 & + & \Delta_7 & = & \text{positional similarity score} \\ \downarrow & & \downarrow & & \downarrow & & \\ \text{-L-} & & \text{-O-} & & \text{-T-} & & \end{array}$$

For this pair, the positional similarity score is:

$$\begin{array}{ccccccc} (\text{-C-}; \text{-L-}) & + & (\text{-A-}; \text{-O-}) & + & (\text{-T-}; \text{-T-}) & = & \\ \Delta_5 & + & \Delta_6 & + & \Delta_7 & = & \\ 1656 & + & 1356 & + & 0 & = & 3012 \end{array}$$

Psycholinguistic experiments

Methods

2 separate rating experiments:

- 24 Deaf ASL signers
  - (11 in study 1, 13 in study 2)
- rated pairs of words
  - (214 pairs in study 1, 132 in study 2)
- presented in two different ways
  - (video of a native signer fingerspelling, written text)
- We used the AMOHS to make *contour difference* and *positional similarity* scores for each pair.

The first study was designed as a norming experiment for a separate study before either of our metrics were developed.

Models

We fit a number of hierarchical (AKA mixed effects) linear regression models.

For all models the **outcome** was the signers' similarity rating.

Null model

predictors

- none

varying intercepts

- experiment
- subject
- first word of the pair
- second word of the pair

Models

We fit a number of hierarchical (AKA mixed effects) linear regression models.

For all models the **outcome** was the signers' similarity rating.

Contour difference score model

predictors

- the contour difference score for the word pair
- the length of the words (3 letters, 4 letters, or mismatched)
- the two way interaction of these

varying intercepts and slopes

- experiment
- subject
- first word of the pair
- second word of the pair

Models

We fit a number of hierarchical (AKA mixed effects) linear regression models.

For all models the **outcome** was the signers' similarity rating.

Positional similarity score model

predictors

- the positional similarity score for the word pair
- the length of the words (3 letters, 4 letters, or mismatched)
- the two way interaction of these

varying intercepts and slopes

- experiment
- subject
- first word of the pair
- second word of the pair

Model comparison

model	AIC	BIC	R^2
null	12194.00	12231.54	0.00
contour difference	11868.27	11987.15	0.02
positional similarity	11438.10	11556.97	0.16

Burnham and Anderson (2004); Anderson and Burnham (2006); Nakagawa and Schielzeth (2013); Johnson (2014)

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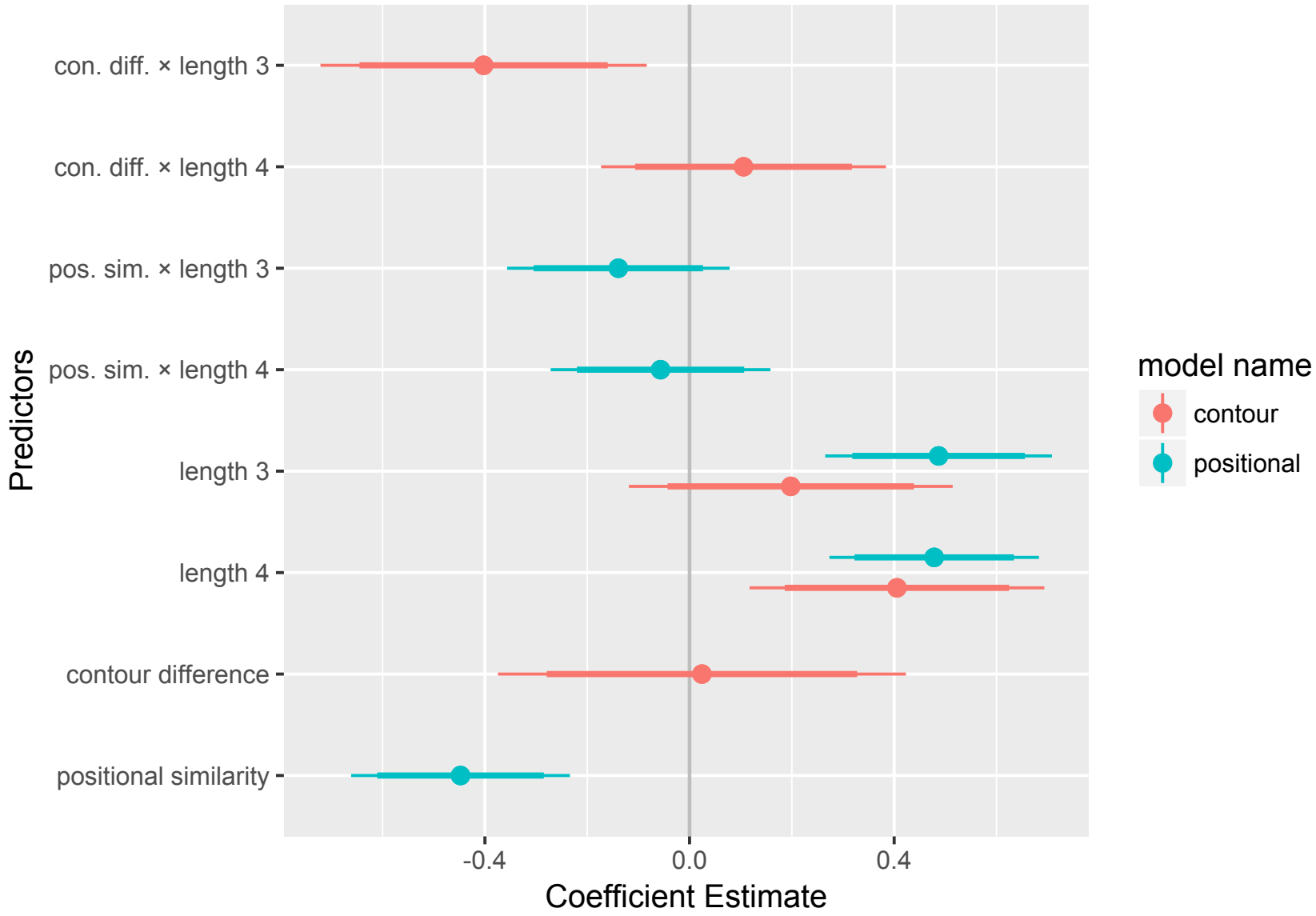
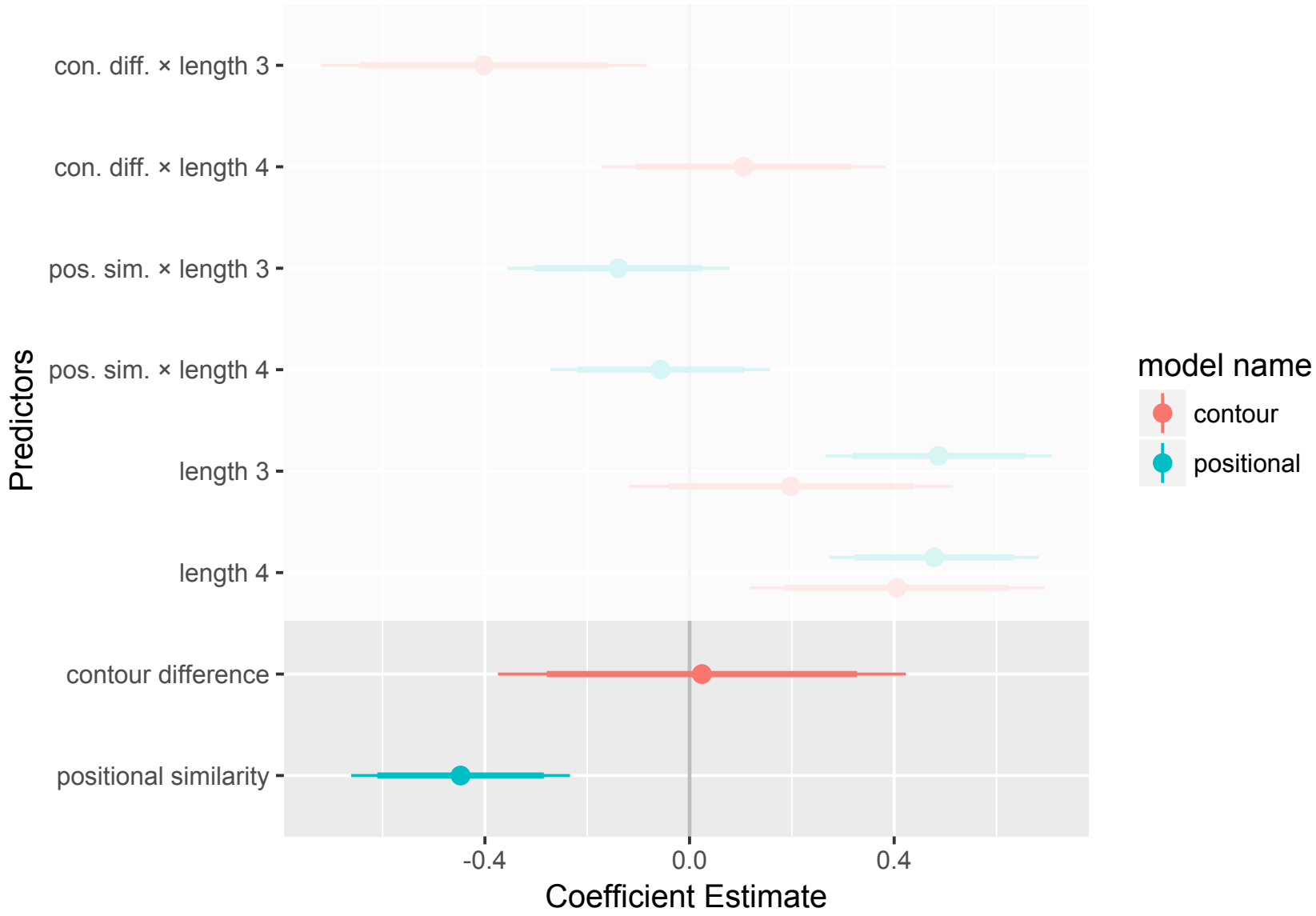
Results

Coefficient plot



Coefficient plot



Significant results

	model	
predictor	contour difference	positional similarity
contour diff.	✗	NA

Significant results

	model	
predictor	contour difference	positional similarity
contour diff.	✗	NA
positional sim.	NA	✓

Significant results

	model	
predictor	contour difference	positional similarity
contour diff.	✗	NA
positional sim.	NA	✓
length	✗(3)/✓(4)	✓

Significant results

	model	
predictor	contour difference	positional similarity
contour diff.	✗	NA
positional sim.	NA	✓
length	$\text{✗}^{(3)}/\text{✓}^{(4)}$	✓
score × length	$\text{✓}^{(3)}/\text{✗}^{(4)}$	✗

Conclusions

The Articulatory Model of Handshape provides a way to gradiently measure the similarity between handshapes.

The positional similarity score method is the only method for comparing two fingerspelled words that is supported by signers' similarity ratings of fingerspelled words.

Thank you

This work would not be possible without the contributions of the Deaf signers who participated in our experiments.

This project greatly benefited from my collaborators Zed Sevcikova, Karen Emmorey, and Diane Brentari as well as from the feedback of our colleagues Leah Geer, Jordan Fenlon, and Jason Riggle.

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Additional plots

Ratings, with predictions (positional similarity model)