Quantifying Handshape Similarity

A Theory-Driven Approach

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There have been several attempts to quantify handshape similarity within signs (e.g., Locke (1970); Lane, Boyes-Braem, and Bellugi (1976); Stungis (1981); Richards and Hanson (1985)). These attempts used psycholinguistic data (e.g. signers' similarity judgements or errors perceiving handshapes) to produce a linguistic model of similarity, rather than using psycholinguistic data to confirm the validity of a linguistic model. We take the opposite approach: we develop a theory-driven similarity metric, confirmed by psycholinguistic data.

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

group	feature	value
psf	members	index, middle, ring, pinky
	base (MCP) joint	flex
	nonbase (PIP and DIP) joints	flex
	abduction	adducted
ssf	members	thumb
	base (MCP)	mid
	nonbase (PIP and DIP)	ext
thumb	opposition	unopposed
nsf	members	none
	joints	NA

Tables 1 and 2: **Phonological features** for -C- (left) and -A- (right) handshapes. A modified version of Brentari's (1998) feature system for handshapes, adapted by Keane (2014)

feature	joint angle target
ext	180°
mid	135°
flex	90°

Table 3: **Translation table** between phonological features and joint angle targets for flexion-extension from Keane's (2014) Articulatory Model of Handshape.

	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			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°)

Tables 4 and 5: **Phonetic joint angle targets** for -C- (left) and -A- (right) handshapes. Calculated based on Keane's (2014) Articulatory Model of Handshape.

	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°)

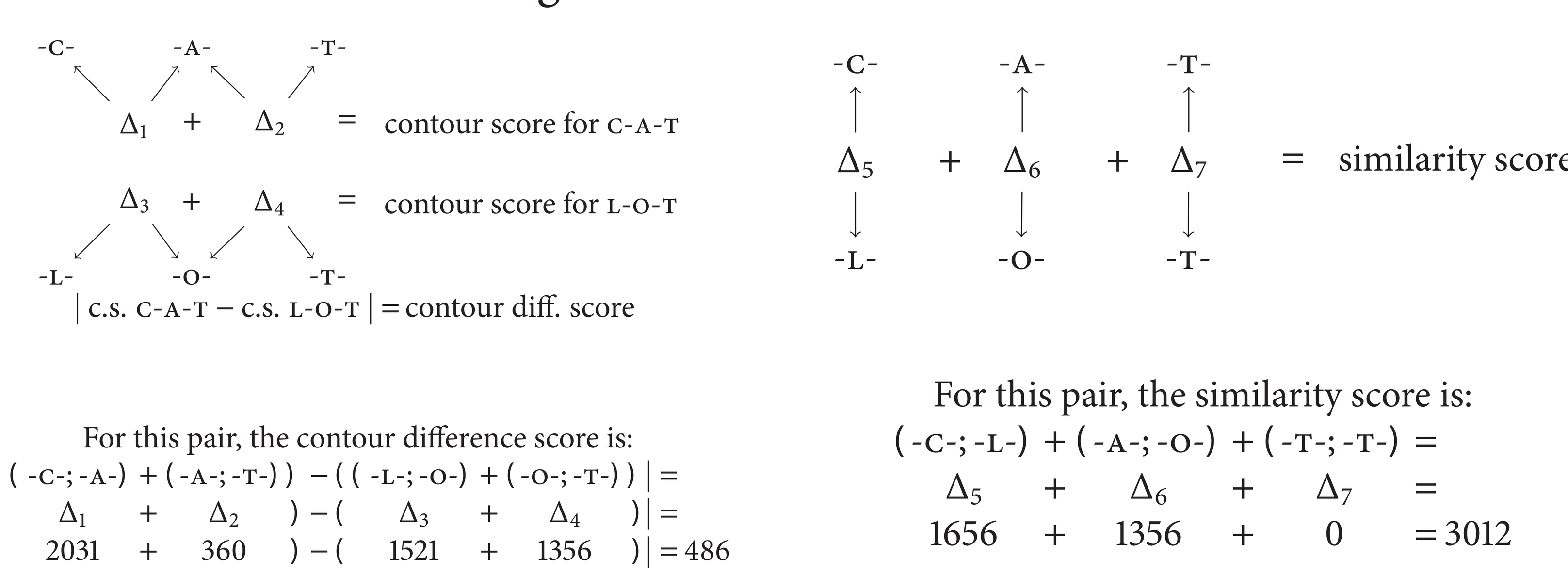
Table 6: **Difference between** -C- and -A- handshapes. Calculated based on Keane's (2014) Articulatory Model of Handshape.

Metrics of similarity

The Movement Envelope for fingerspelling (Akamatsu, 1985) has been interpreted in two different ways: first as being a property of the transitions between letters; second as being a property of the overall shape of the word. Based on these, there are two possibilities for comparison, respectively:

1. The first method, the *contour difference score*, calculates the difference between each sequential pair of letters within a single word. The difference between each pair of words is then summed together (see Figure 1).
2. The second method, the *similarity score*, compares pairs of letters in the same position across two words to calculate the difference between the two. The differences for each pair across the two words are then summed together (see Figure 2).

With both scores, words that are similar will have a low score, and words that are dissimilar will have a high score.



Figures 1 and 2: **Contour difference** (left) and **Similarity** (right) score calculation between the words C-A-T and L-O-T.

Psycholinguistic experiment

Similarity ratings for pairs of 239 fingerspelled words were collected from 24 Deaf signers. In order to test which method is more accurate, similarity scores produced by the two methods above were compared with the signers' scores using multiple hierarchical linear regressions (see figure 3 for model visualization). We fit the following models:

1. Null model with no predictor variables, which had varying intercepts (AKA mixed effects) for subject group, subject, first word, and second word.
2. Contour difference score model with predictor variables of the contour difference score for the word pair, the length of the words (3 letters, 4 letters, or mismatched), and the two way interaction of these. There were varying intercepts and slopes for subject group, subject, first word, and second word.
3. Similarity score model with predictor variables of the similarity score for the word pair, the length of the words (3 letters, 4 letters, or mismatched), and the two way interaction of these with the same varying intercepts and slopes as the previous model.
4. Full model which included predictor variables of the similarity score, contour difference score, the length of the words (3 letters, 4 letters, or mismatched), and all possible two and three way interactions with the same varying intercepts and slopes as the previous model.

The results show that the similarity score significantly predicts signers' similarity ratings. In contrast, there was no model where the contour difference score significantly predicts signers' similarity ratings. We conclude that the similarity score is the theory-driven description of similarity that best matches signers' intuitions. This metric is exactly the kind of theory-driven similarity that was missing from previous research. Additionally, this method of handshape similarity is not just restricted to fingerspelling: but can apply to any pair of handshapes used in sign languages.

model	AIC	BIC	R^2
null	9166.8	9202.6	0.000
contour diff. score	8868.5	8981.8	0.040
similarity score	8600.7	8714.0	0.173
full	8540.9	8761.6	0.161

Table 7: **Model comparison**.

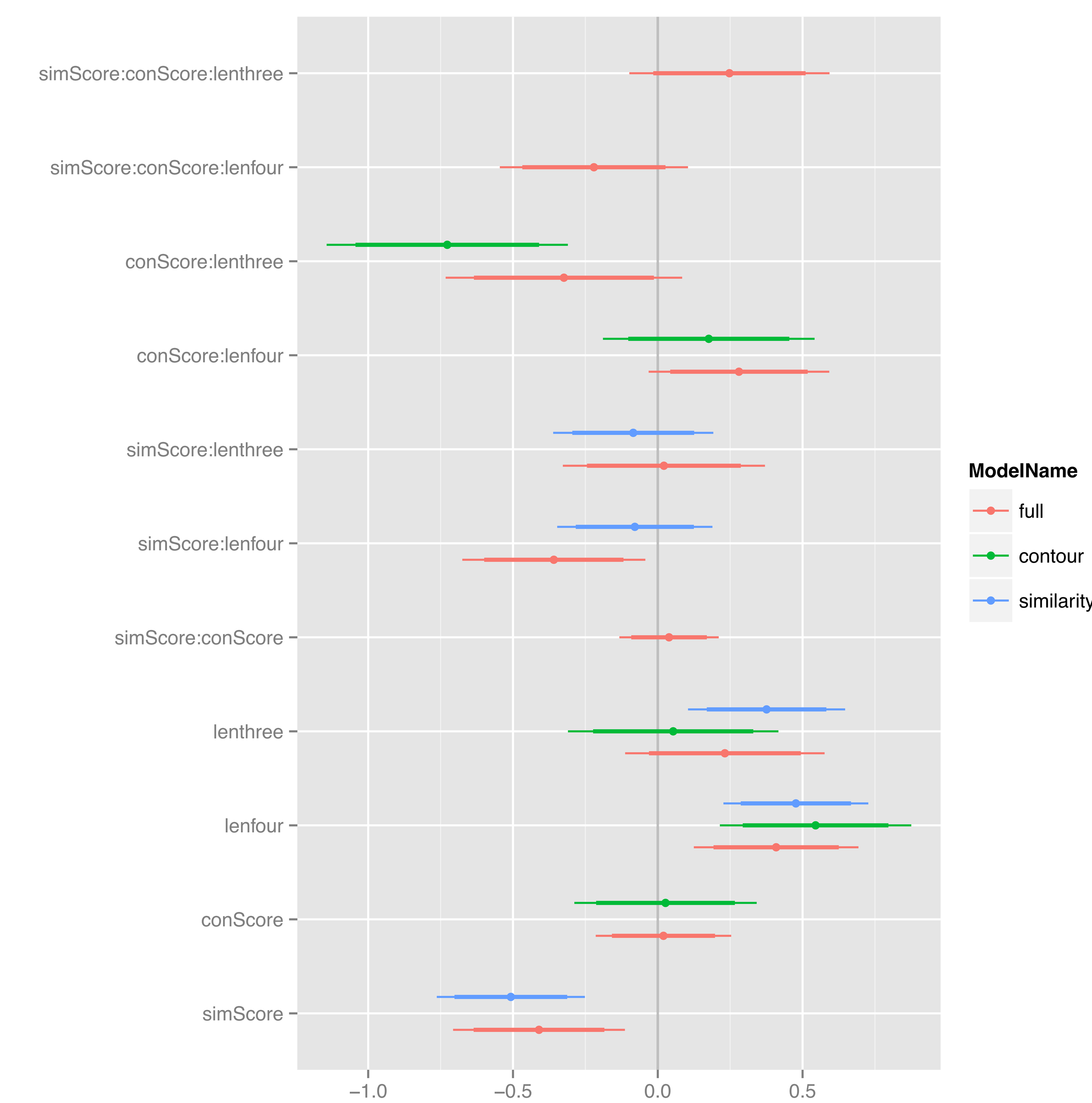


Figure 3: **Coefficient plot** for contour difference score, similarity score, and full models. Thick lines are 95% confidence interval, thin lines: 99% confidence interval, and dots: estimates of the predictor coefficients. conScore: contour diff. score; len: length of word with levels four, three, and mismatched (reference level); simScore: similarity score.

Akamatsu, C. T. (1985). Fingerspelling formulae: A word is more or less the sum of its letters. SLR, 83, 126–132. Brentari, D. (1998). A prosodic model of sign language phonology. The MIT Press. Burnham, K. P. & Anderson, D. R. (2004). Multimodel inference understanding AIC and BIC in model selection. Sociological methods & research, 33(2), 261–304. Johnson, P. C. (2014). Extension of Nakagawa & Schielzeth's R2GLMM to random slopes models. Methods in Ecology and Evolution, 5(9), 944–946. Keane, J. (2014). Towards an articulatory model of handshape: What fingerspelling tells us about the phonetics and phonology of handshape in American Sign Language. Ph.D. dissertation, University of Chicago. Stungis, J. (1981). Identification and discrimination of handshape in American Sign Language. Perception & Psychophysics, 29(3), 261–276. Lane, H., Boyes-Braem, P., & Bellugi, U. (1976). Preliminaries to a distinctive feature analysis of handshapes in American Sign Language. Cognitive Psychology, 8(2), 263–289. Locke, J. L. (1970). Short-term memory encoding strategies of the deaf. Psychonomic Science, 18(4), 233–234. Nakagawa, S. & Schielzeth, H. (2013). A general and simple method for obtaining R2 from generalized linear mixed-effects models. Methods in Ecology and Evolution, 4(2), 133–142. Richards, J. T. & Hanson, V. L. (1985). Visual and production similarity of the handshapes of the American manual alphabet. Perception & psychophysics, 38(4), 311–319.