CATEGORICAL VS. GRADIENT

WHAT ASL FINGERSPELLING TEACHES US ABOUT THE PHONETICS-PHONOLOGY INTERFACE

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Broad Questions

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

- environment?
- signer?
- phonological properties?

What is the best type of explanation to capture this variation?

- phonetic?
- phonological?
- both?

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.

Why fingerspelling?

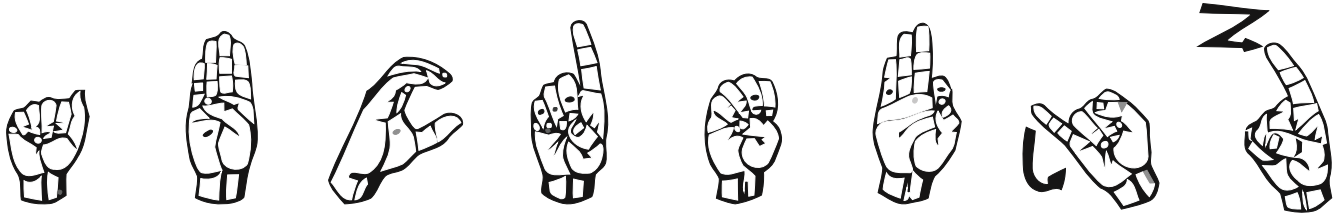
Fingerspelling involves quick and sequential handshape changes, unlike signing.

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

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

Phenomena of interest

- **Pinky extension**
- **Ulnar flexion**
  more accurately: increased ulnar digit flexion

phonology *phonetics*

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orientation

handshape

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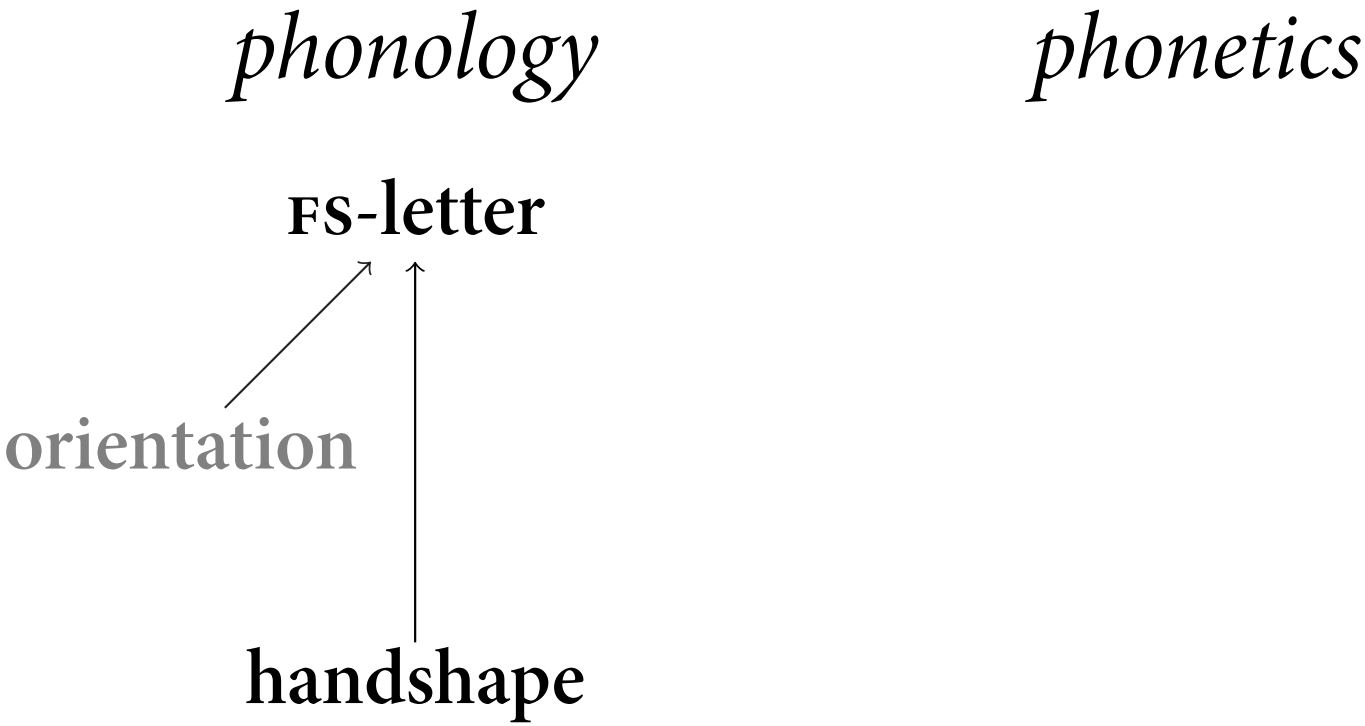

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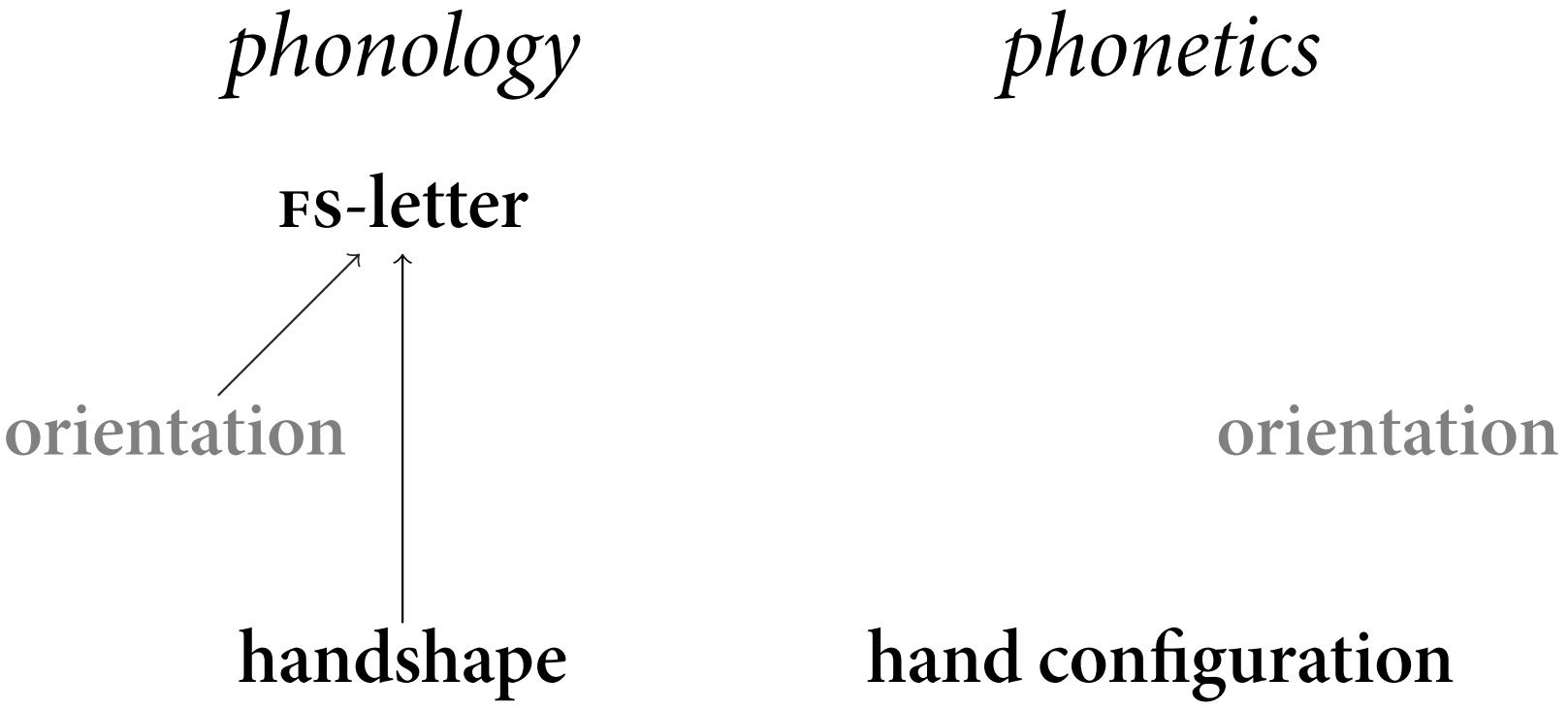

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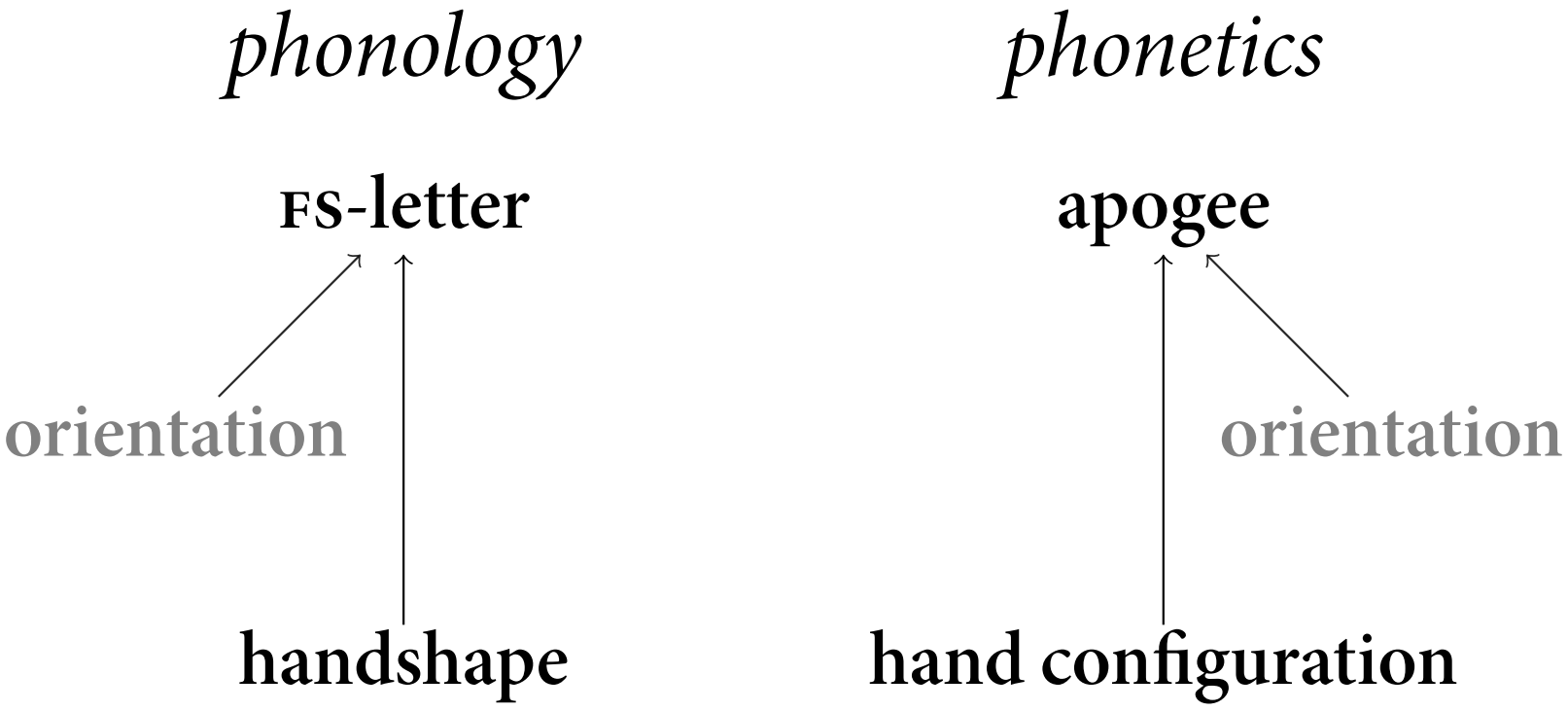

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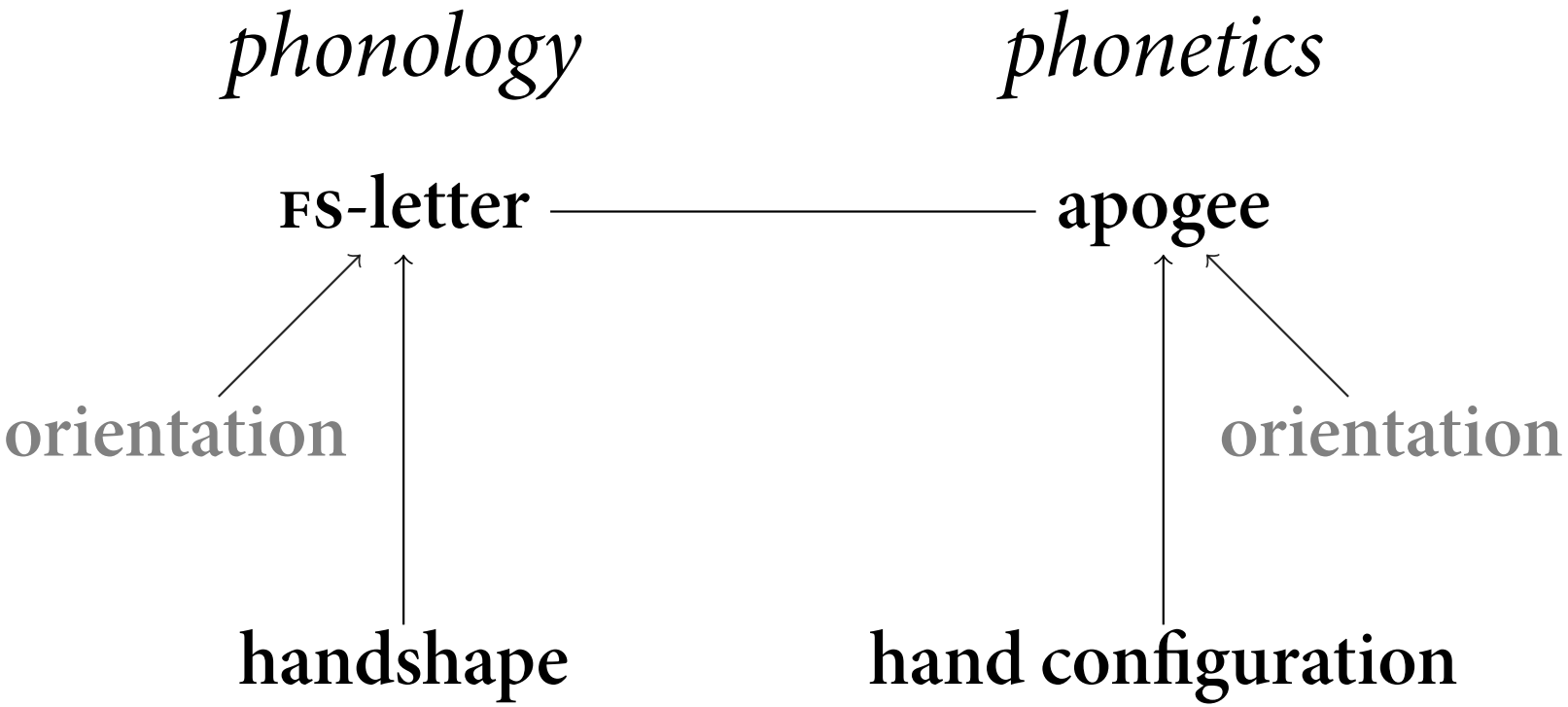

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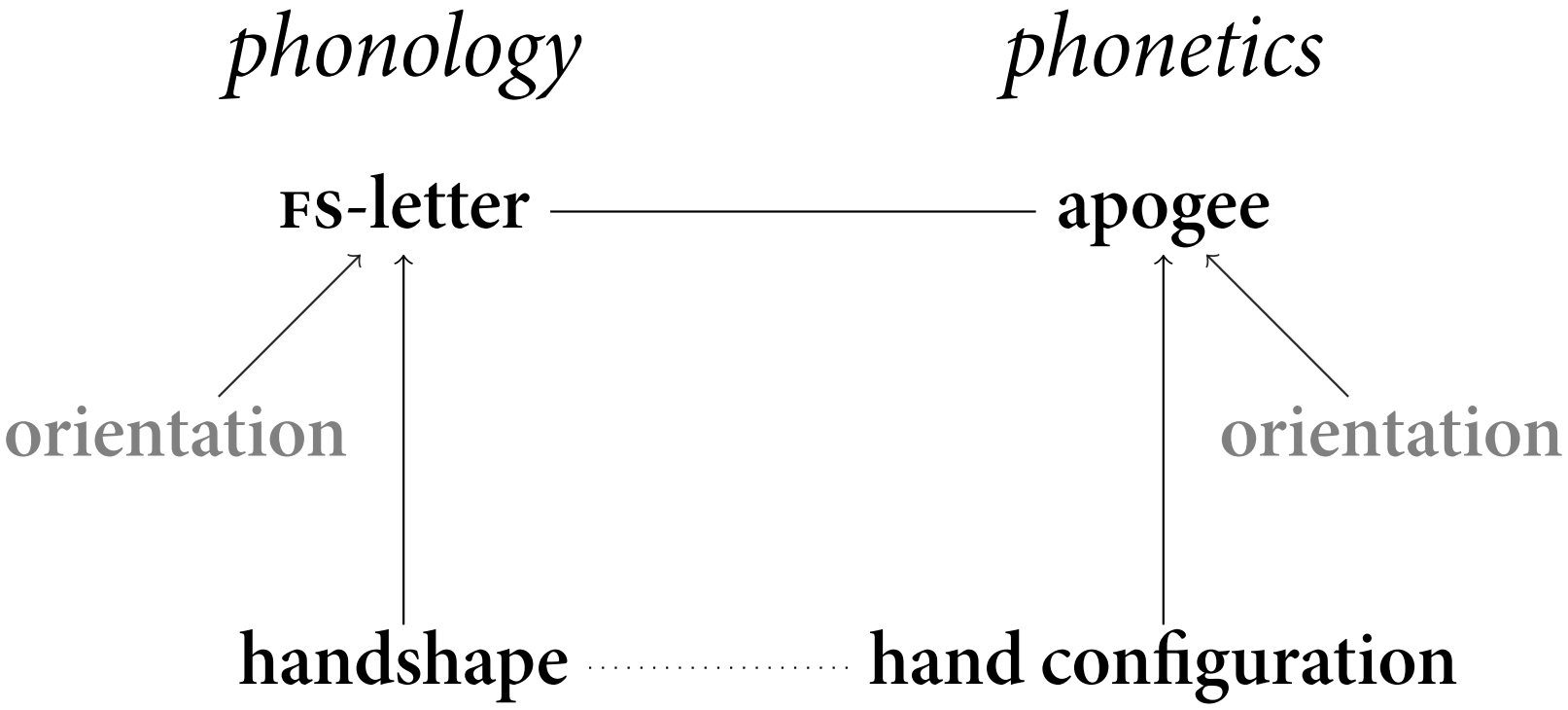
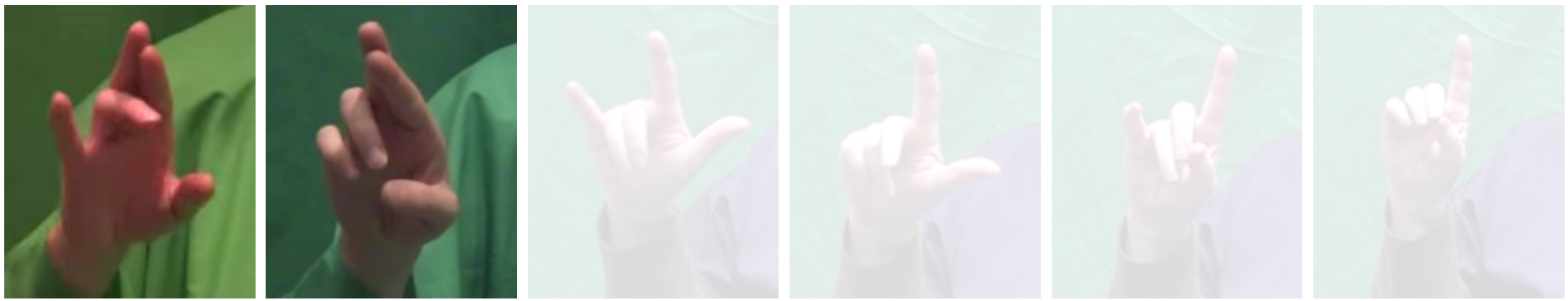


Pinky extension

- The tip of the pinky was above the plane perpendicular to the palmar plane, at the base of the pinky finger (the MCP joint).
- The proximal interphalangeal joint (PIP) was more than half extended.



-R- [+ext] -R- [−ext] -L- [+ext] -L- [−ext] -D- [+ext] -D- [−ext]

Apogees from C-H-R-I-S, D-I-N-O-S-A-U-R, O-I-L, W-O-R-L-D, B-U-I-L-D-I-N-G, W-O-R-L-D

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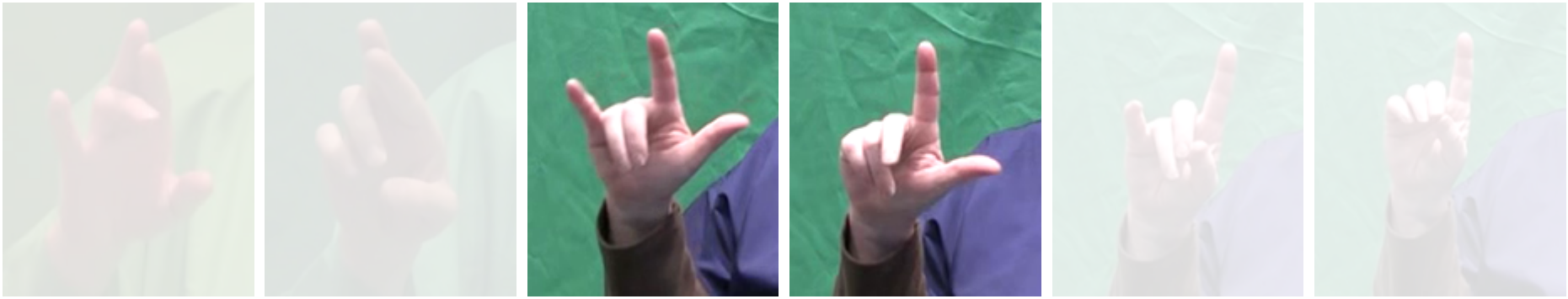

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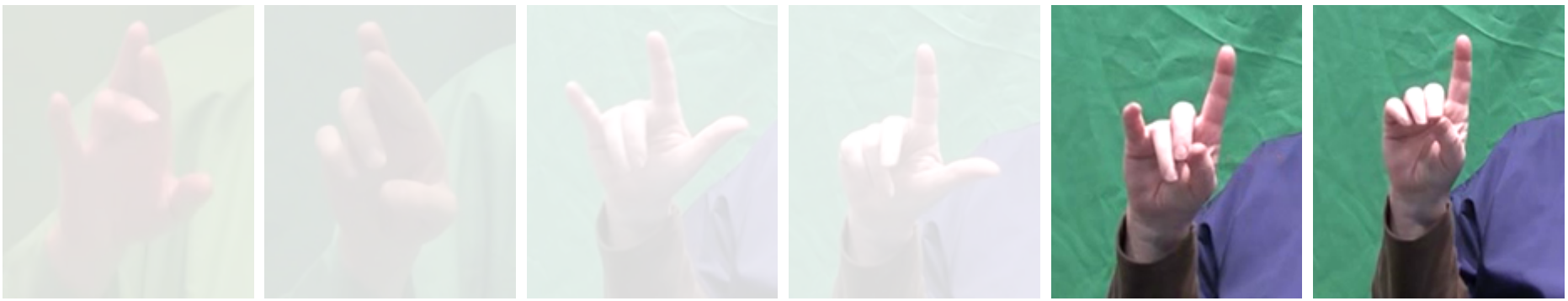

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Ulnar flexion

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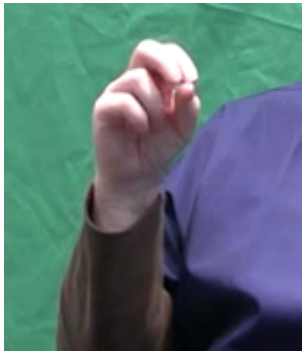
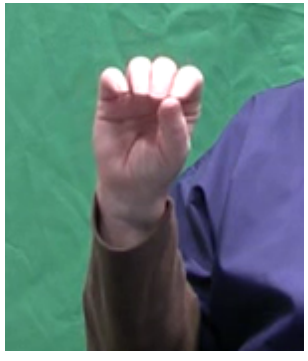

-O- [+flex]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-E- [−flex]

-D- [+flex]

-D- [−flex]

Apogees from A-U-T-H-O-R-I-T-Y, C-O-U-P-L-E, I-N-T-E-R-E-S-T, D-E-C-I-S-I-O-N, G-R-O-U-N-D, and D-A-Y-S,

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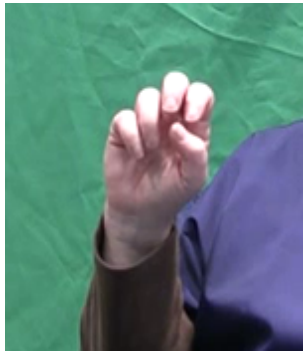
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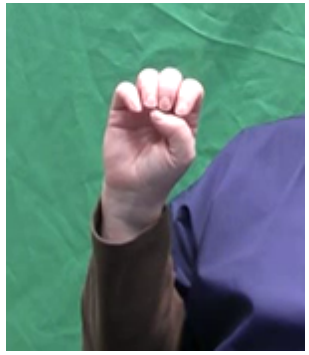
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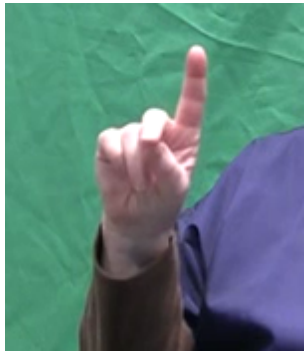
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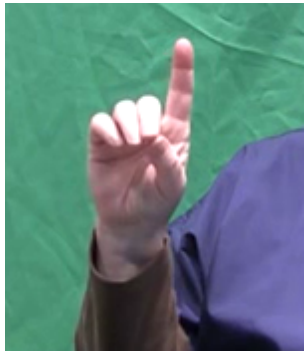
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Why these phenomena?

They are similar in many ways; both:

- involve (most of) the same articulators.
- are conditioned by surrounding context.
- are conditioned by time.

The conditioning articulators are different:

- **Pinky extension** Nonselected fingers become more like surrounding selected fingers.
- **Ulnar flexion** Selected fingers become more like surrounding nonselected fingers.

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

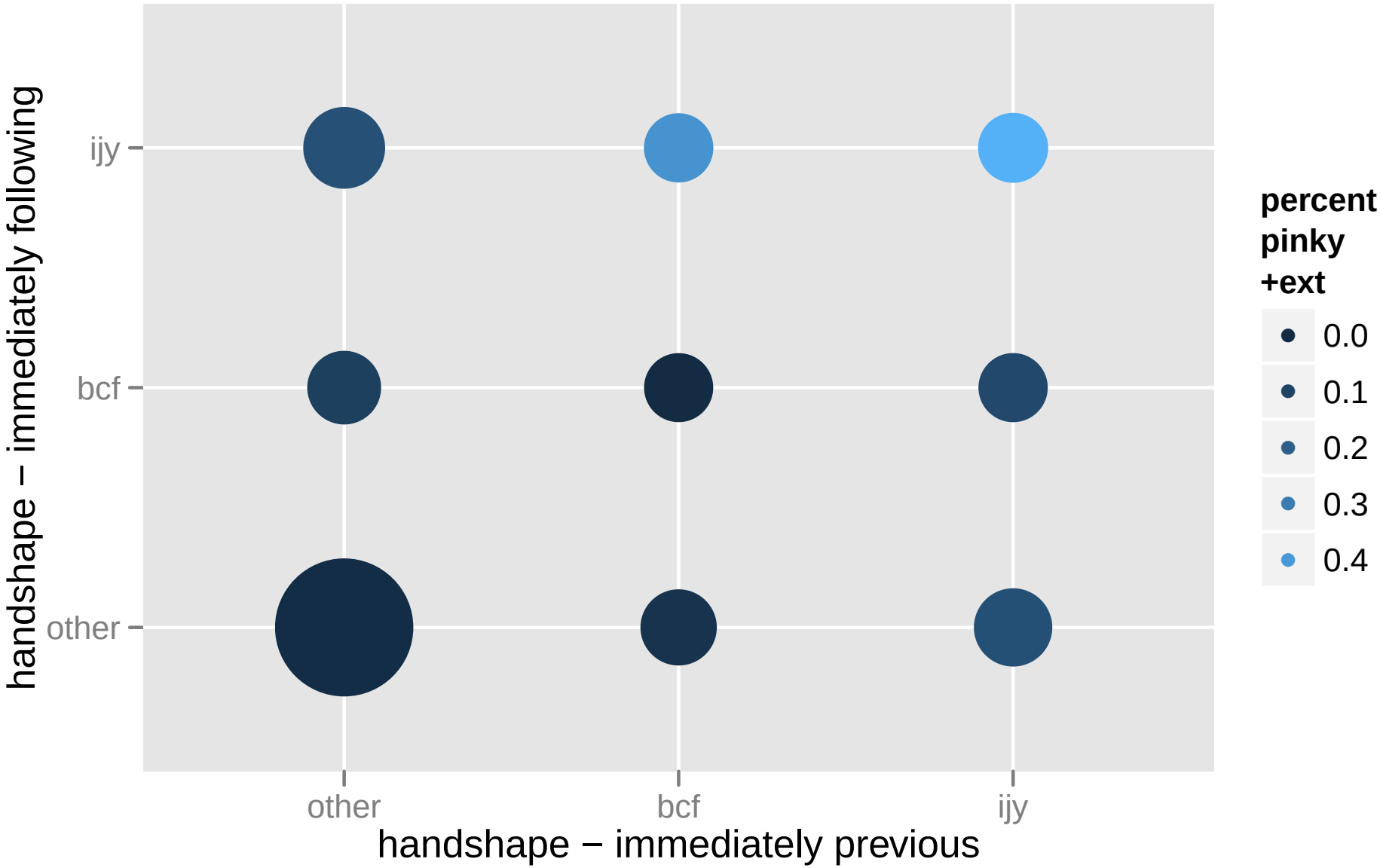
Feature annotation

- We extracted still images from the data that has been coded.
- We hand coded features of hand configuration:
  - all apogees for pinky extension.
  - 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

Pinky extension by surrounding handshape



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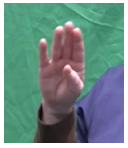
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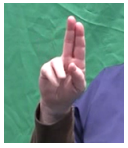
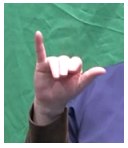

-U-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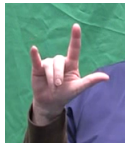
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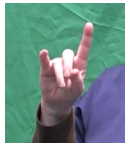
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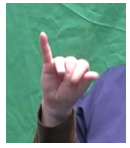
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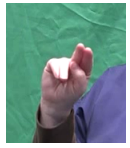
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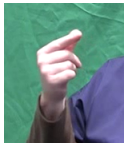
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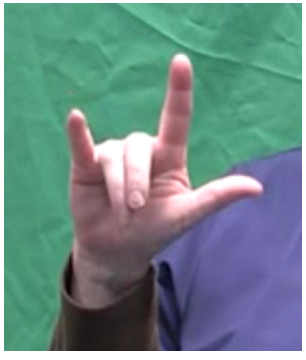

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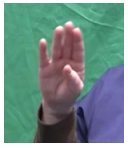
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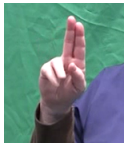
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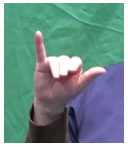
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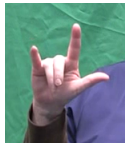
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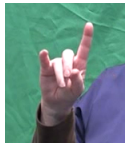
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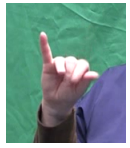
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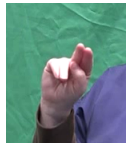
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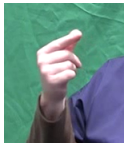
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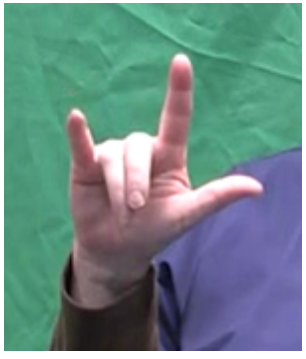

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apogee handshape

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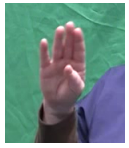
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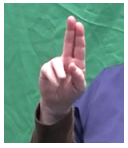
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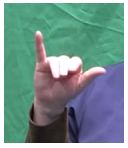
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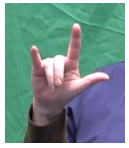
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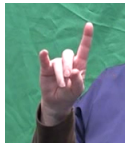
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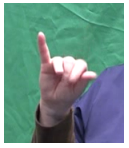
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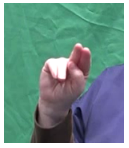
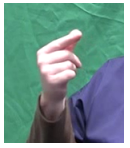

-N-

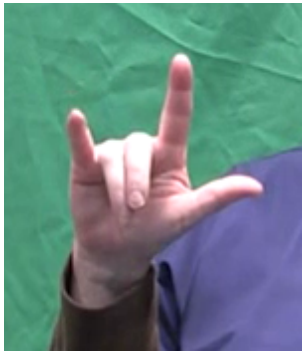

-G-

word type

name, noun, non-English

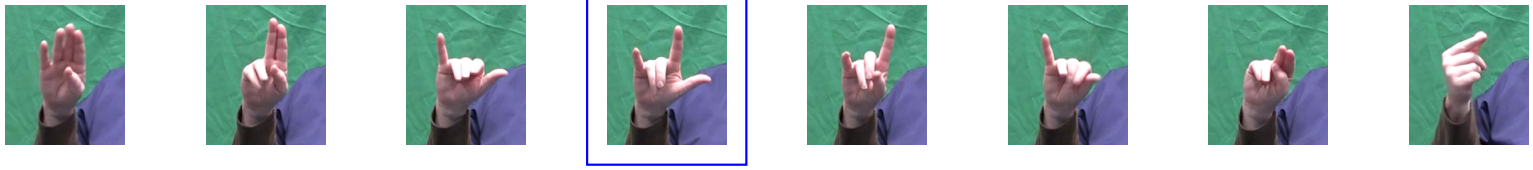
signer

s1, s2



apogee handshape

What effects the -L- handshape?



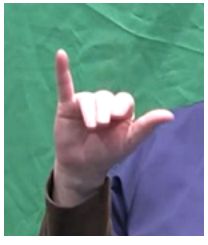
-B- -U- -I- -L- -D- -I- -N- -G-

word type

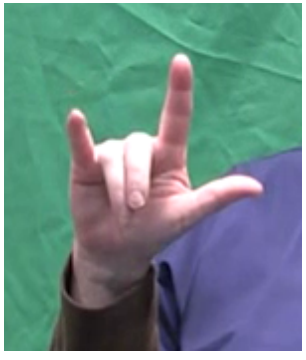
name, noun, non-English

signer

s1, s2

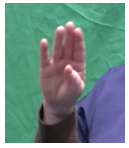


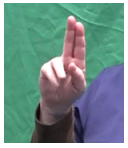
previous handshape ⟶

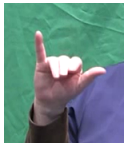


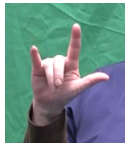
apogee handshape

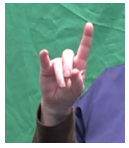
What effects the -L- handshape?

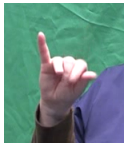

-B-

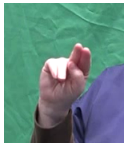

-U-

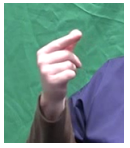

-I-


-L-


-D-


-I-


-N-

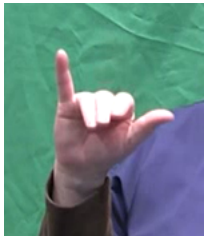

-G-

word type

name, noun, non-English

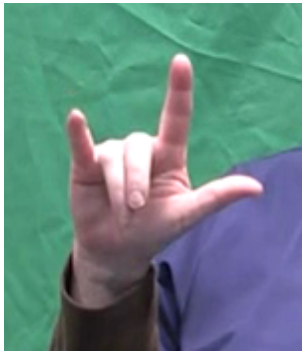
signer

s1, s2



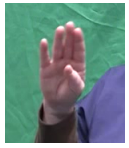
previous handshape

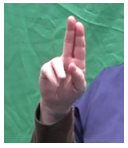
previous transition time

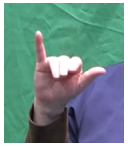


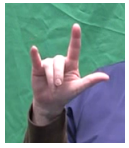
apogee handshape

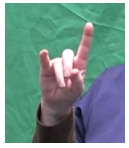
What effects the -L- handshape?

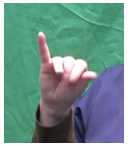

-B-

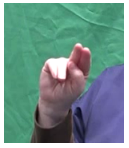

-U-

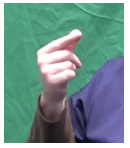

-I-


-L-


-D-


-I-


-N-

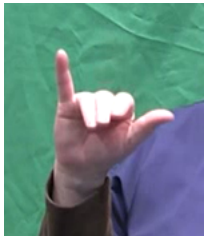

-G-

word type

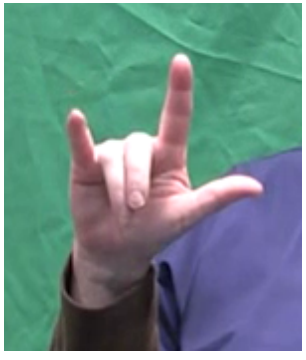
name, noun, non-English

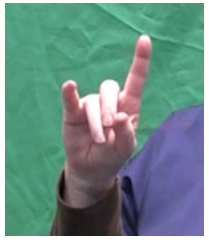
signer

s1, s2



previous handshape





following handshape

previous transition time

apogee handshape

What effects the -L- handshape?

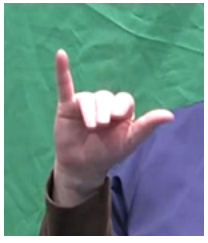
-B- -U- -I- -L- -D- -I- -N- -G-

word type

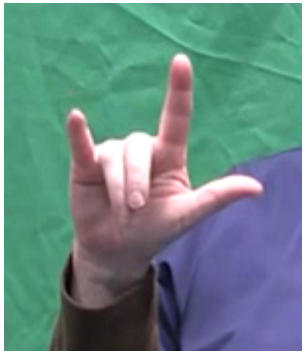
name, noun, non-English

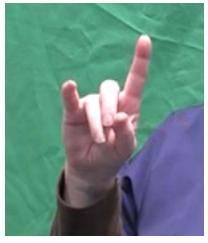
signer

s1, s2



previous handshape





following handshape

previous transition time

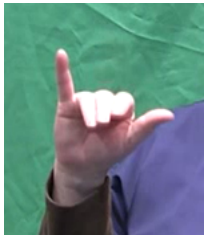
following transition time

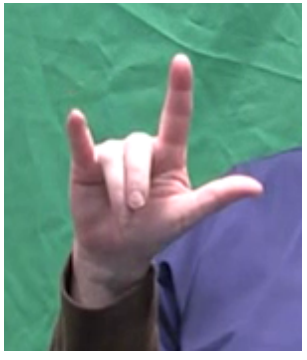
apogee handshape

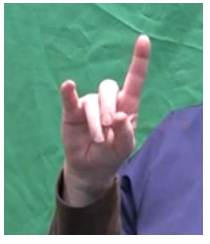
Significant effects for pinky extension

word type
name, noun, non-English

signer
s1, s2







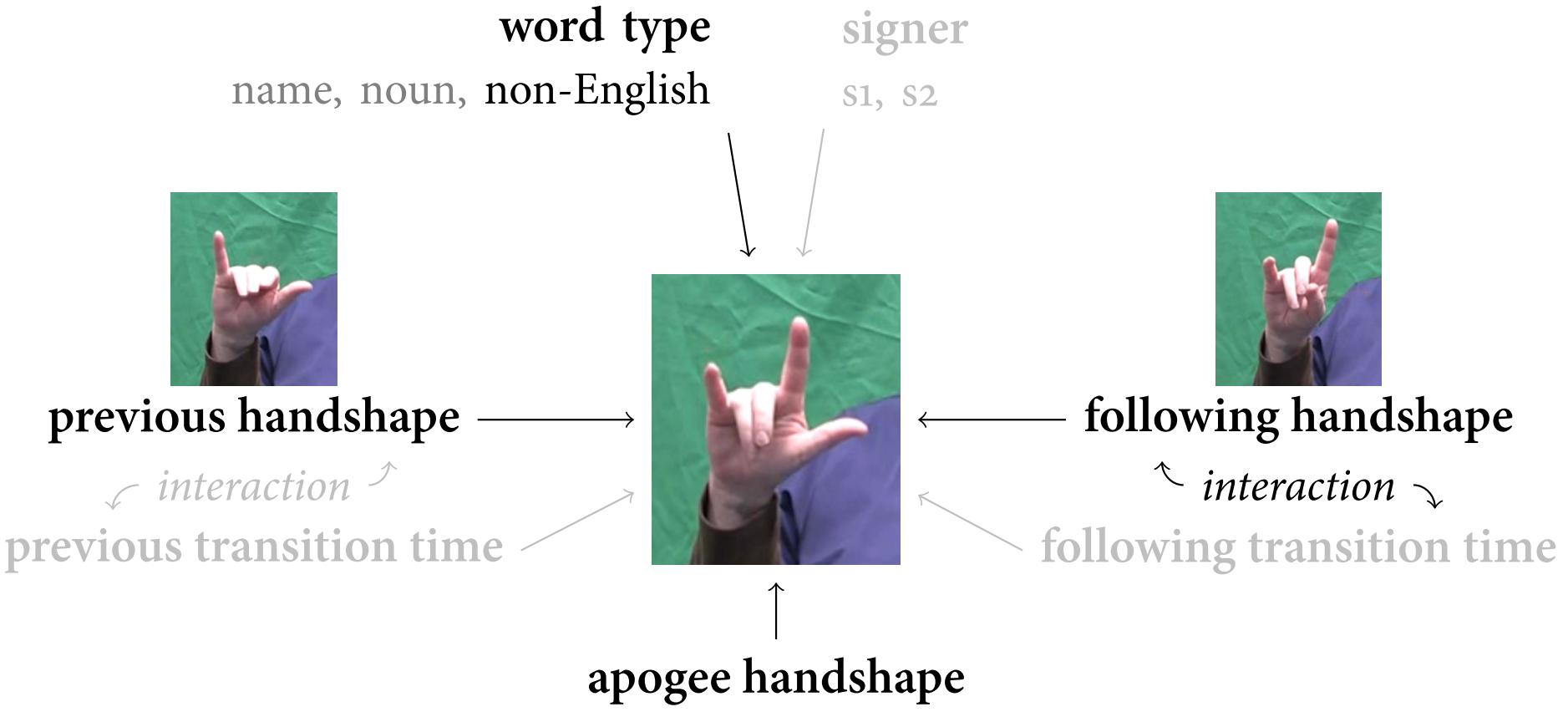
previous handshape → ← **following handshape**

previous transition time ↔ *interaction* ↔ **following transition time**

apogee handshape

(Keane et al., 2012b)

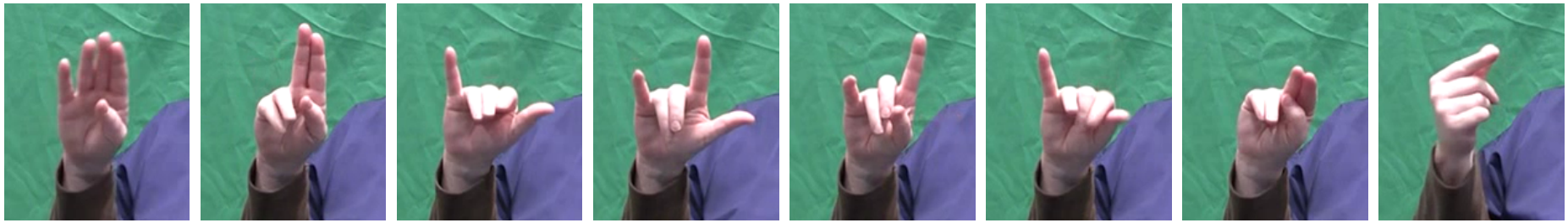
Significant effects for pinky extension



(Keane et al., 2012b)

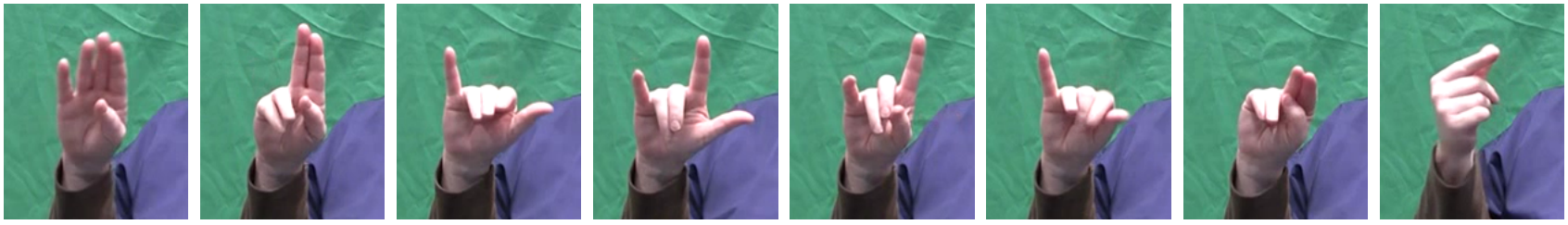
B-U-I-L-D-I-N-G; half speed

building.mp4

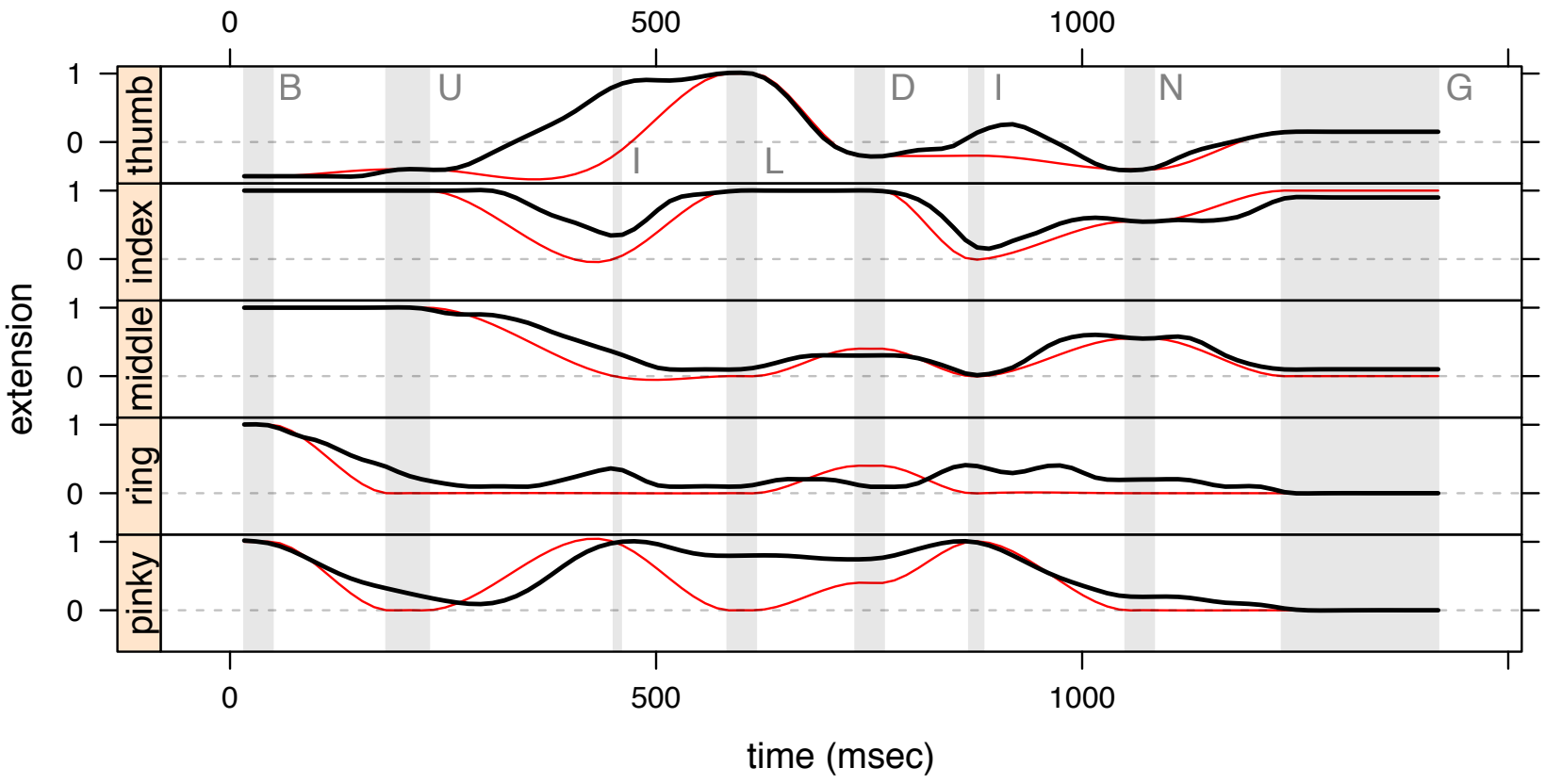


-B- -U- -I- -L- -D- -I- -N- -G-

Articulator trajectories



-B- -U- -I- -L- -D- -I- -N- -G-



Explanation of pinky extension

- Extended and selected pinky fingers spread from surrounding handshapes.
- Pinky extension is physiologically based gestural overlap (or coarticulation):
  - When extended alone, a single extensor pulls on the pinky.
  - The pinky extension gesture is slower and less controlled.
- Pinky extension is more time dependent when it is anticipatory coarticulation.

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.

one finger	two fingers	three fingers
-G-, -L-, -Q-, -T-, -X-, and -Z-	-H-, -K-, -N-, -P-, -R-, -U-, and -V-	-M-, -W-, and -D-

all fingers	others (ulnar)
-A-, -B-, -C-, -E-, -O-, and -S-	-F-, -I-, -J-, and -Y-

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radial: [−flex] (>extension)
ulnar: [+flex]

all fingers	others (ulnar)
-A-, -B-, -C-, -E-, -O-, and -S-	-F-, -I-, -J-, and -Y-

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one finger	two fingers	three fingers	
-G-, -L-, -Q-, -T-, -X-, and -Z-	-H-, -K-, -N-, -P-, -R-, -U-, and -V-	-M-, -W-, and -D-	radial: [−flex] (>extension) ulnar: [+flex]

all fingers	others (ulnar)	
-A-, -B-, -C-, -E-, -O-, and -S-	-F-, -I-, -J-, and -Y-	all: [±flex] or radial: [+flex] ulnar: [−flex]

What features encourage ulnar digit flexion?

Selected Fingers

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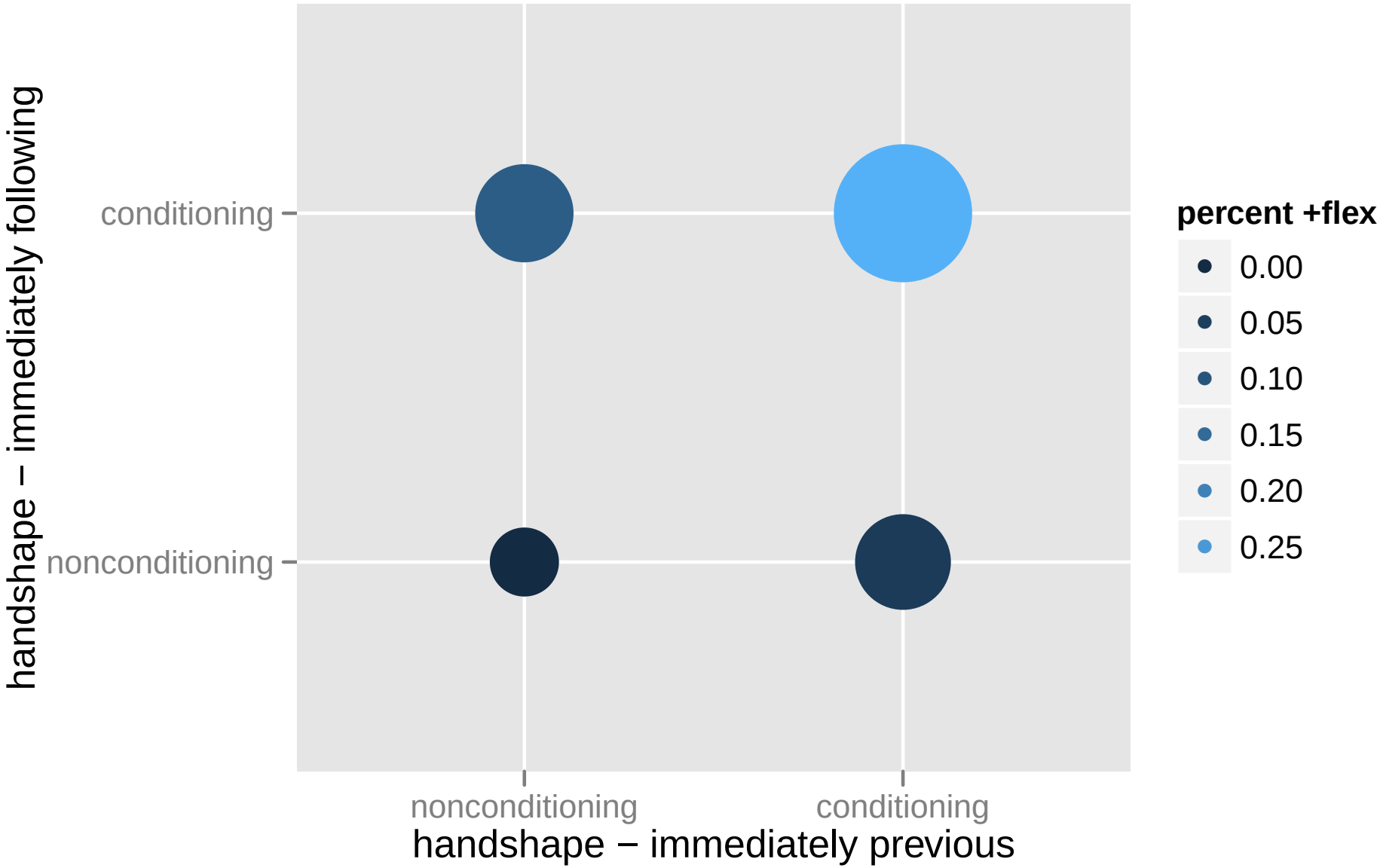
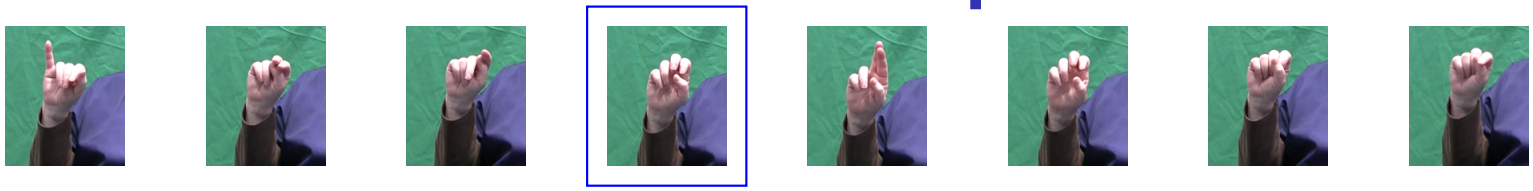
one finger	two fingers	three fingers	
-G-, -L-, -Q-, -T-, -X-, and -Z-	-H-, -K-, -N-, -P-, -R-, -U-, and -V-	-M-, -W-, and -D-	conditioning
all fingers	**others (ulnar)**		
-A-, -B-, -C-, -E-, -O-, and -S-	-F-, -I-, -J-, and -Y-		non-conditioning

Flexion based on surrounding handshapes



What effects the -E- handshape?



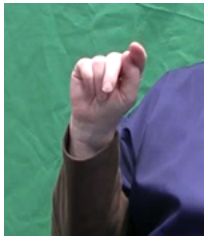
-I- -N- -T- -E- -R- -E- -S- -T-

word type

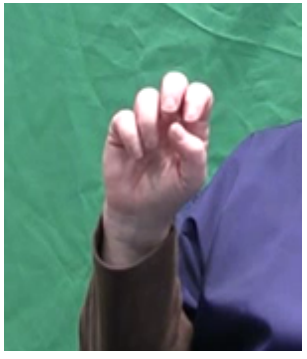
name, noun, foreign

signer

s1, s2



previous handshape



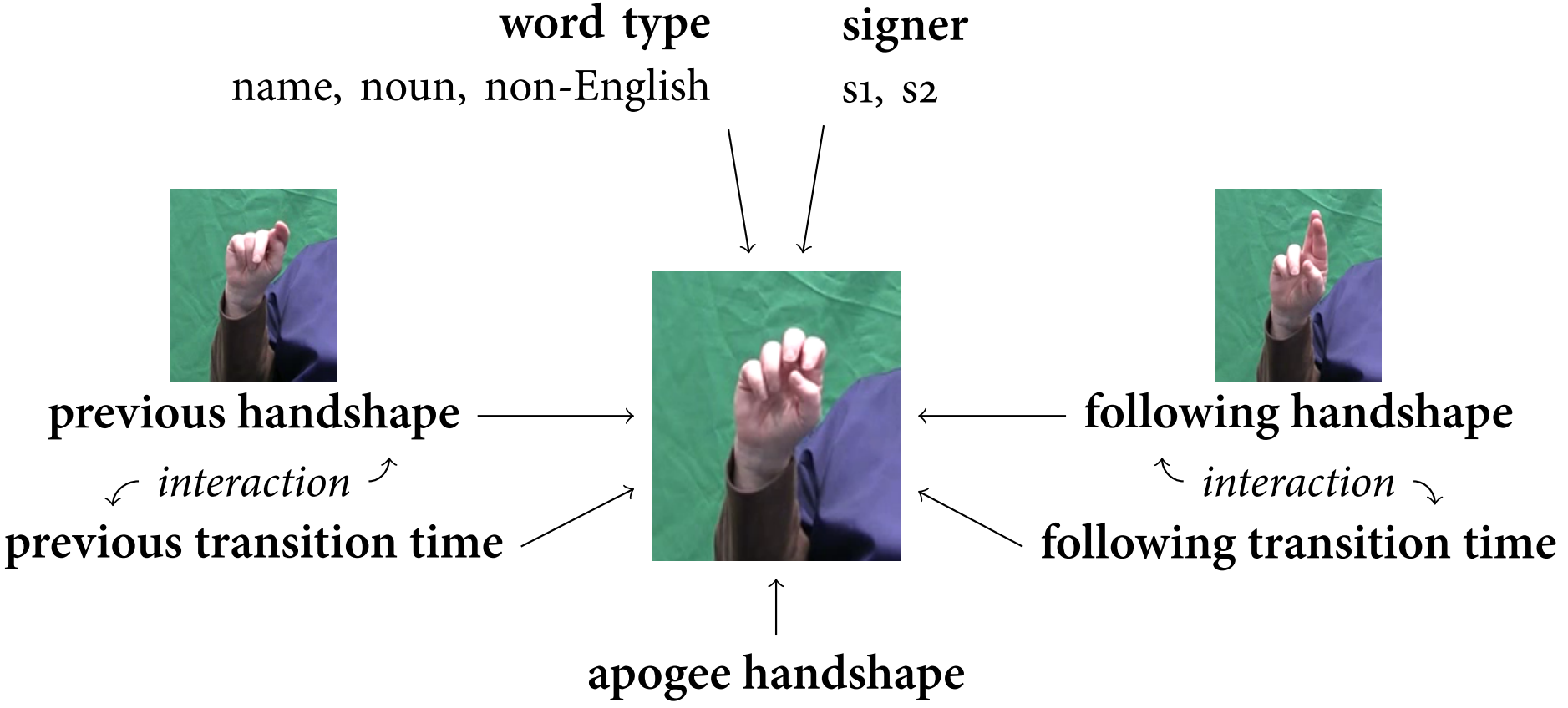
following handshape

previous transition time

following transition time

apogee handshape

Significant effects for ulnar flexion

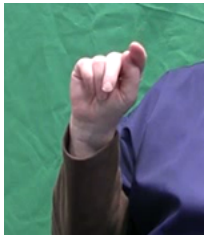


(Keane et al., 2012a)

Significant effects for ulnar flexion

word type
name, noun, non-English

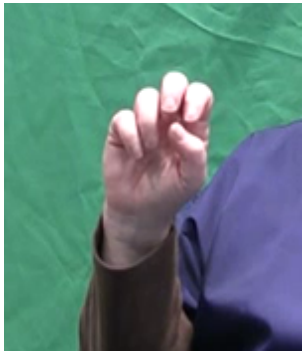
signer
s1, s2



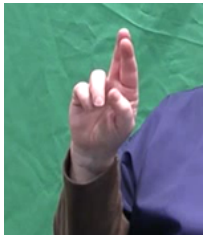
previous handshape

interaction

previous transition time



apogee handshape



following handshape

interaction

following transition time

(Keane et al., 2012a)

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-.

-T- -E- -R- -R- -O- -U-

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

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- It seems that flexed, nonselected ulnar fingers are spreading from surrounding apogees to -E- and -O-.

-T- -E- -R- -R- -O- -U-

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)).

Pushing the boundaries

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-).

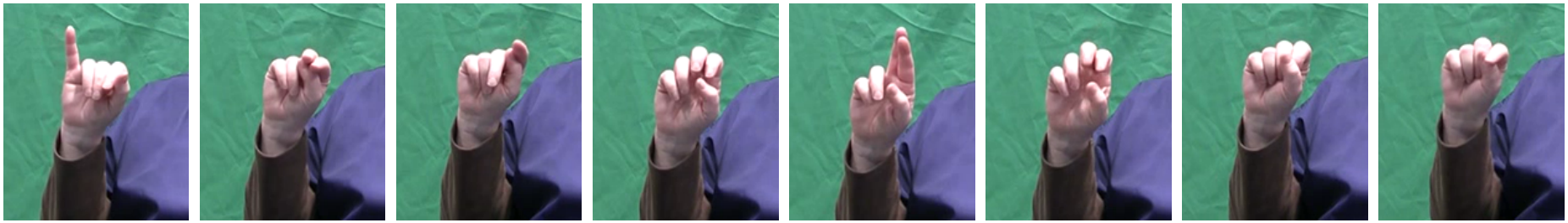
Predictions

If this phenomenon is the result of the assimilation of a phonological feature, and not the result of a gestural constraint at the phonetic level, we expect:

- no temporal variation
- no effect of word category

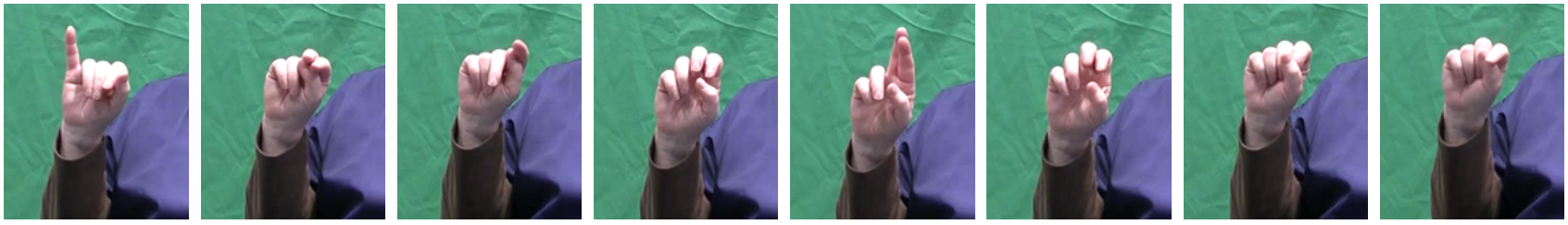
I-N-T-E-R-E-S-T; half speed

Clipsinterest.mp4

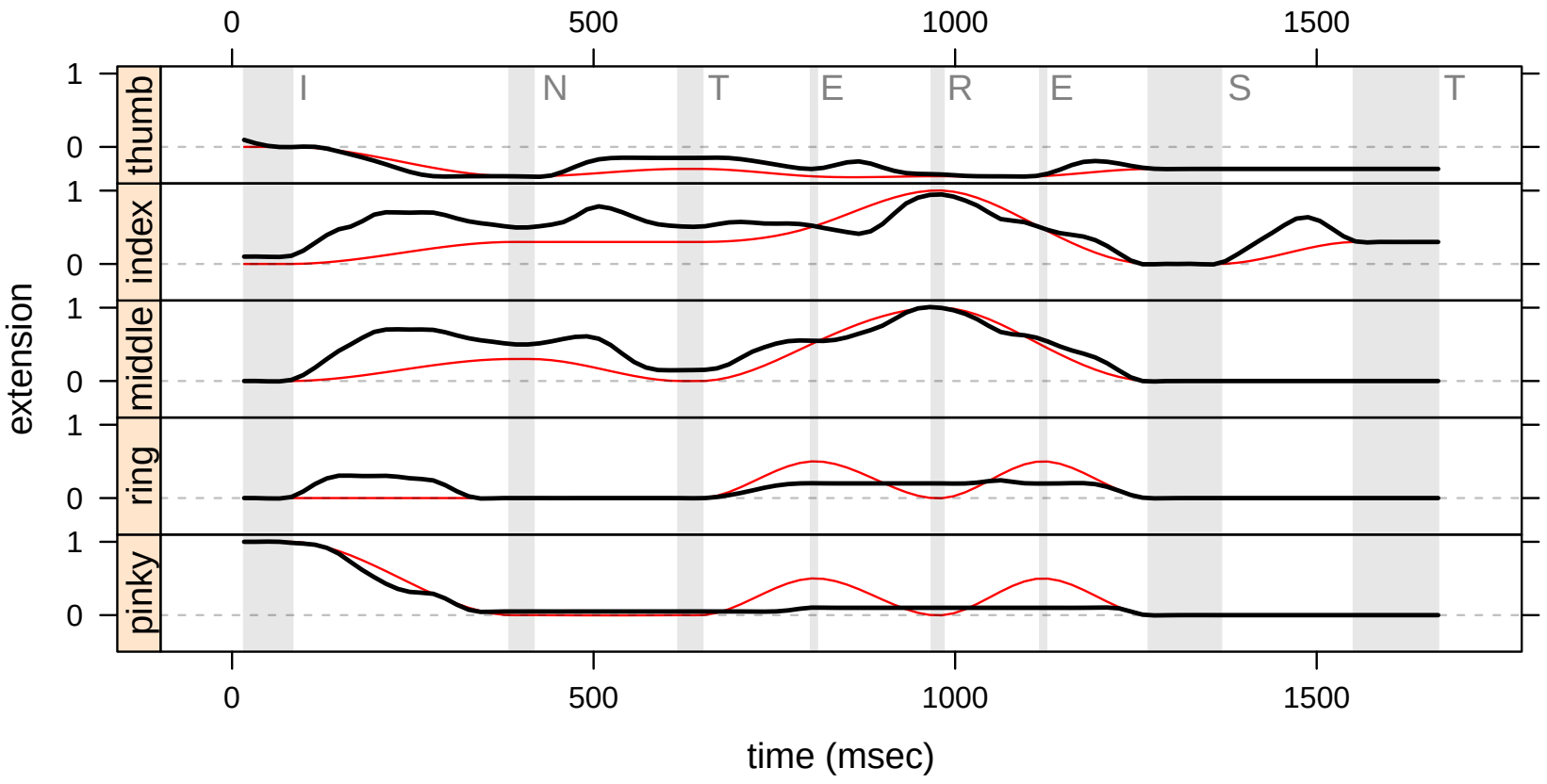


-I- -N- -T- -E- -R- -E- -S- -T-

Articulator trajectories



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

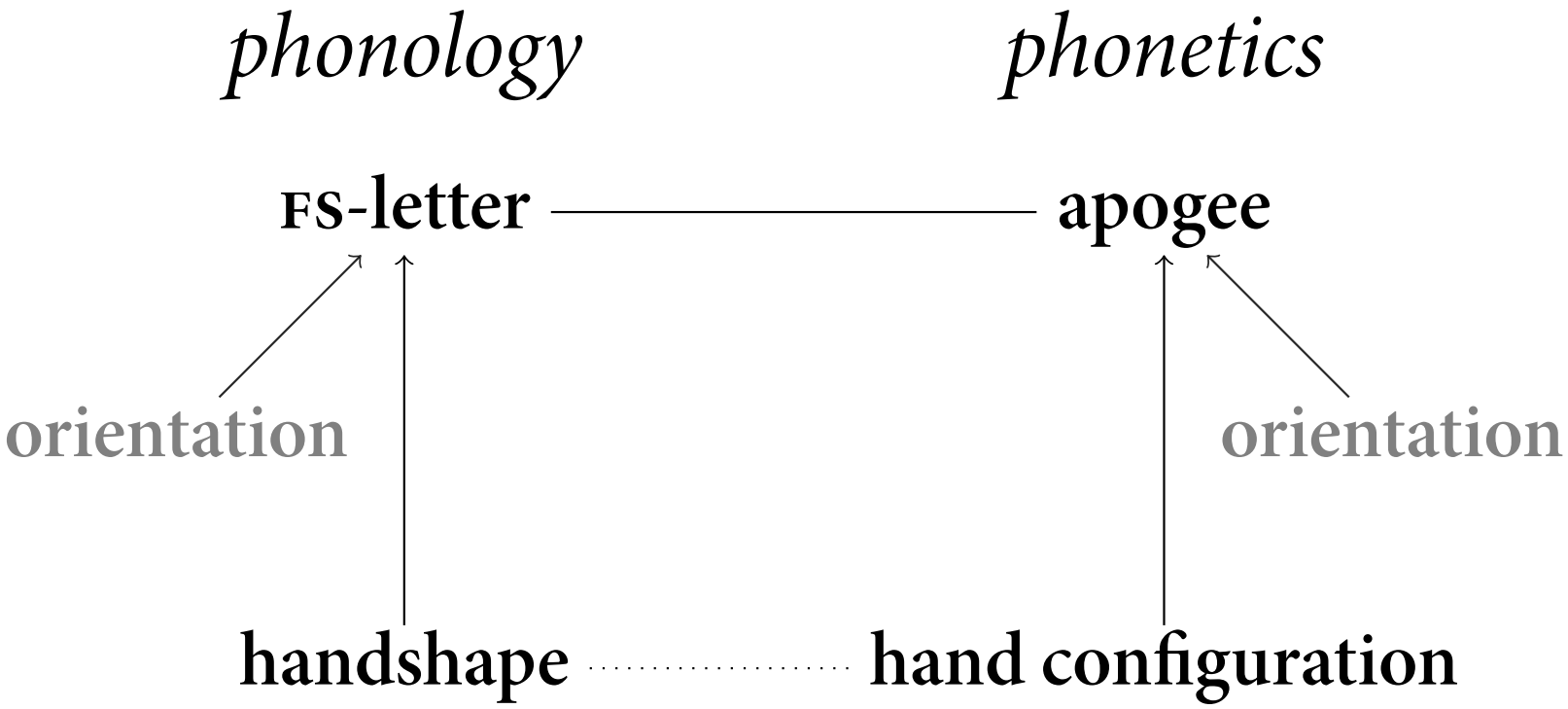


Same articulators, different explanations

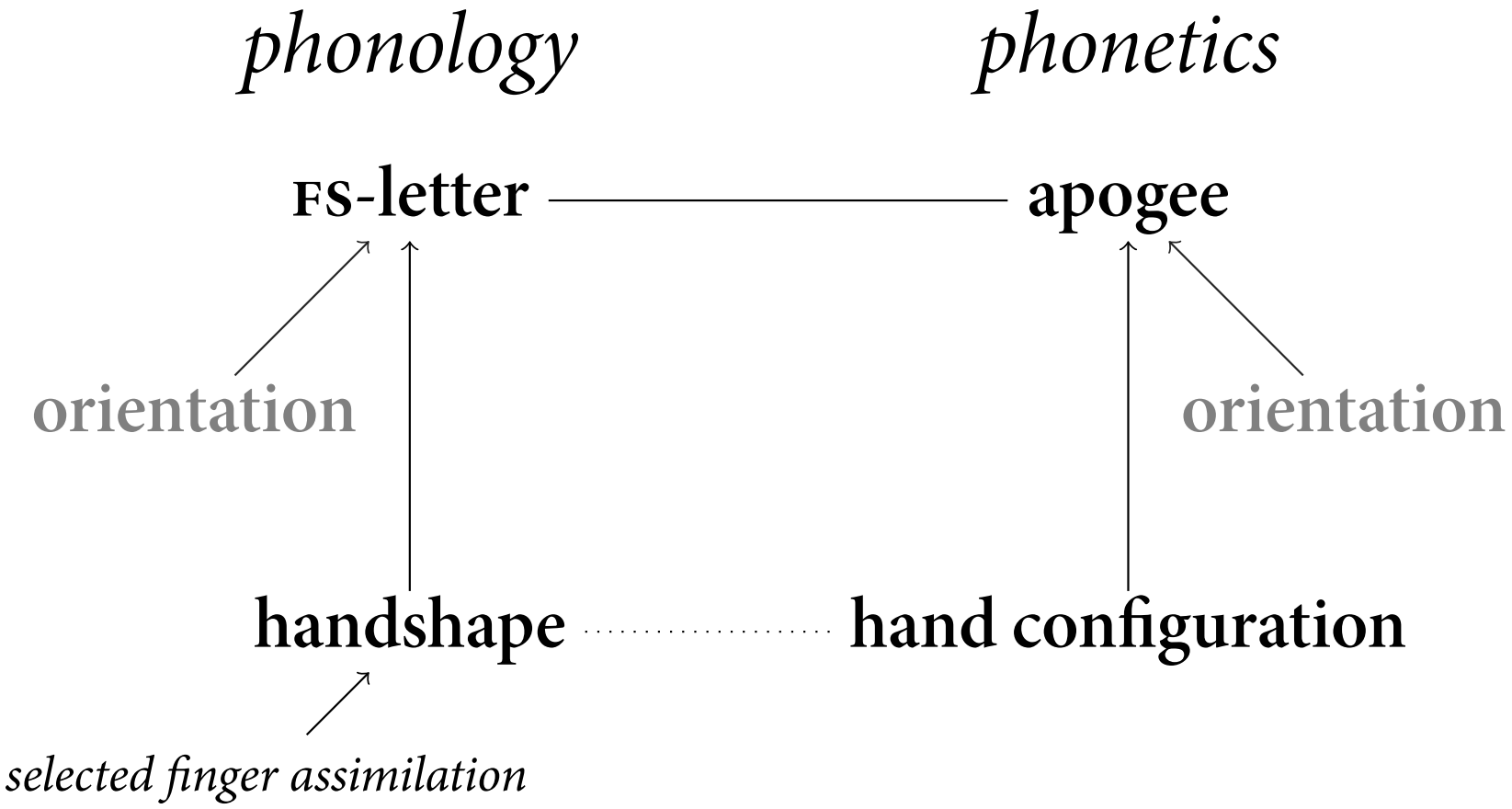
Pinky extension has a phonetic explanation: **gestural overlap (coarticulation)**.

Ulnar flexion has a phonological explanation: **selected finger assimilation**.

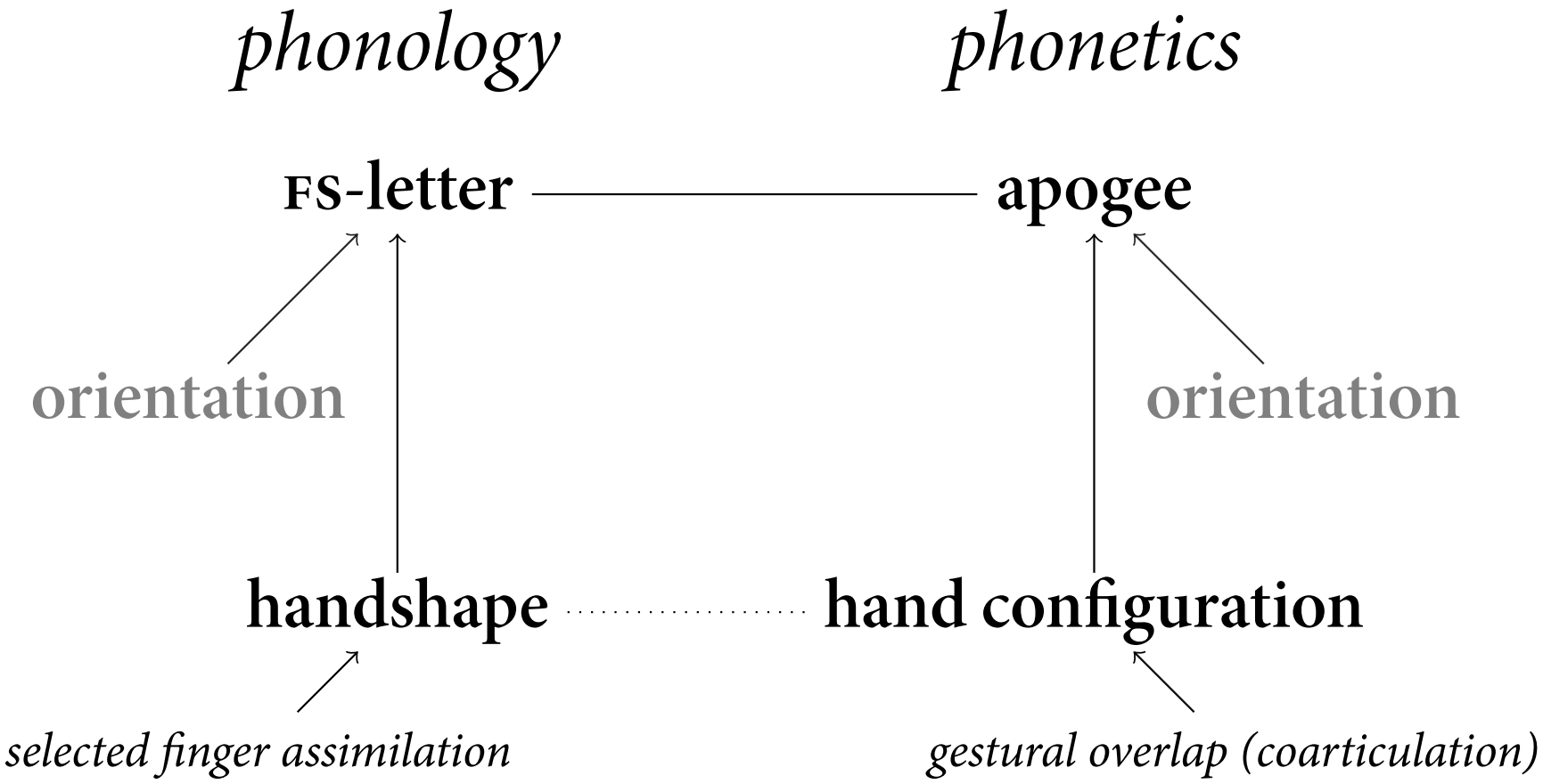
Levels of representation



Levels of representation



Levels of representation



Same articulators, different levels

Pinky extension has a phonetic explanation: gestural overlap. Which results in:

- temporal variation (gradience).
- variation based on word type.

Ulnar flexion has a phonological explanation: selected finger assimilation. Which results in:

- no temporal variation (categorical across segments).
- no variation based on word type.

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

Susan Rizzo, Karen Livescu, Greg Shakhnarovich, Raquel Urtasun, Erin Dahlgren, and Katie Henry.

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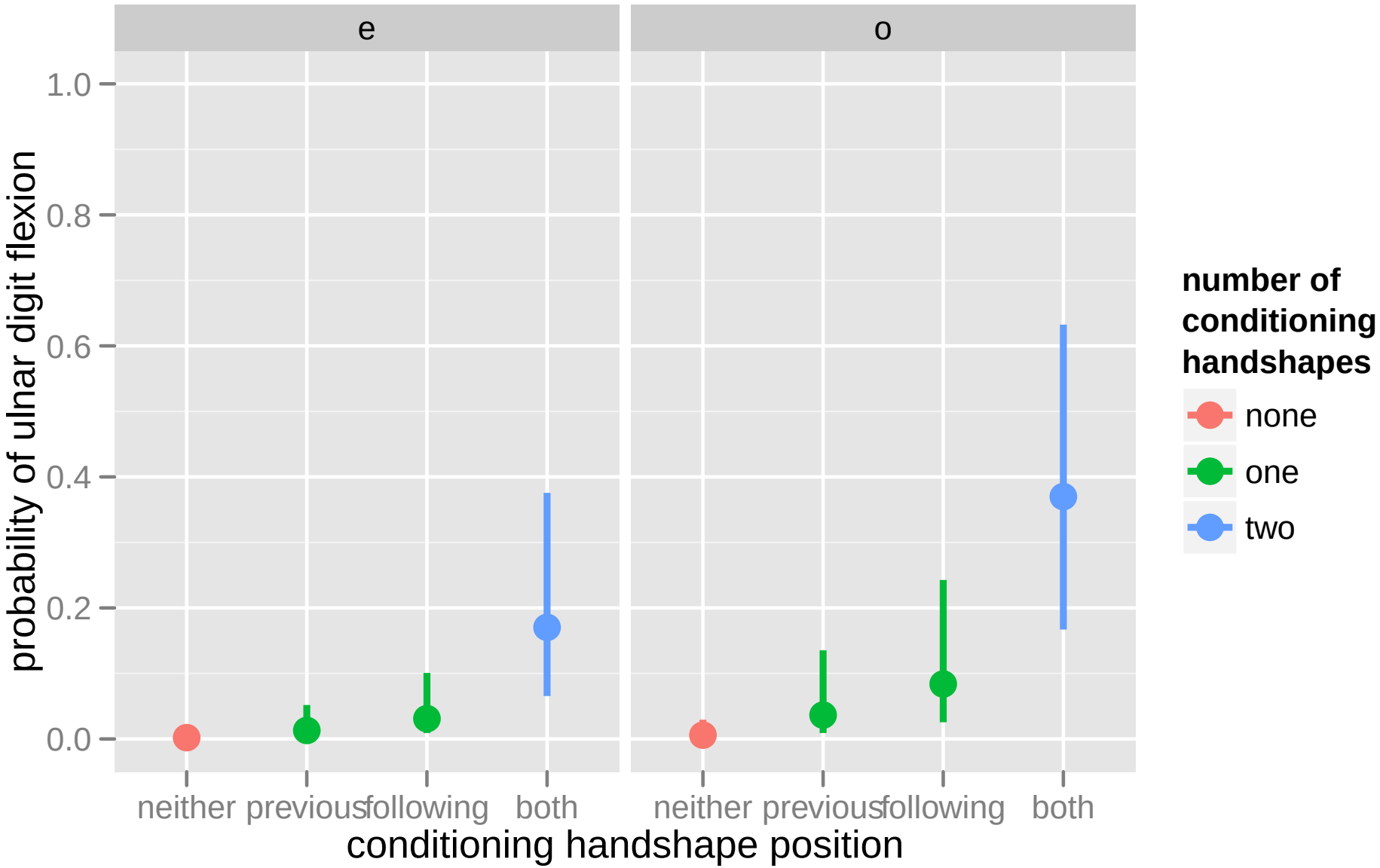
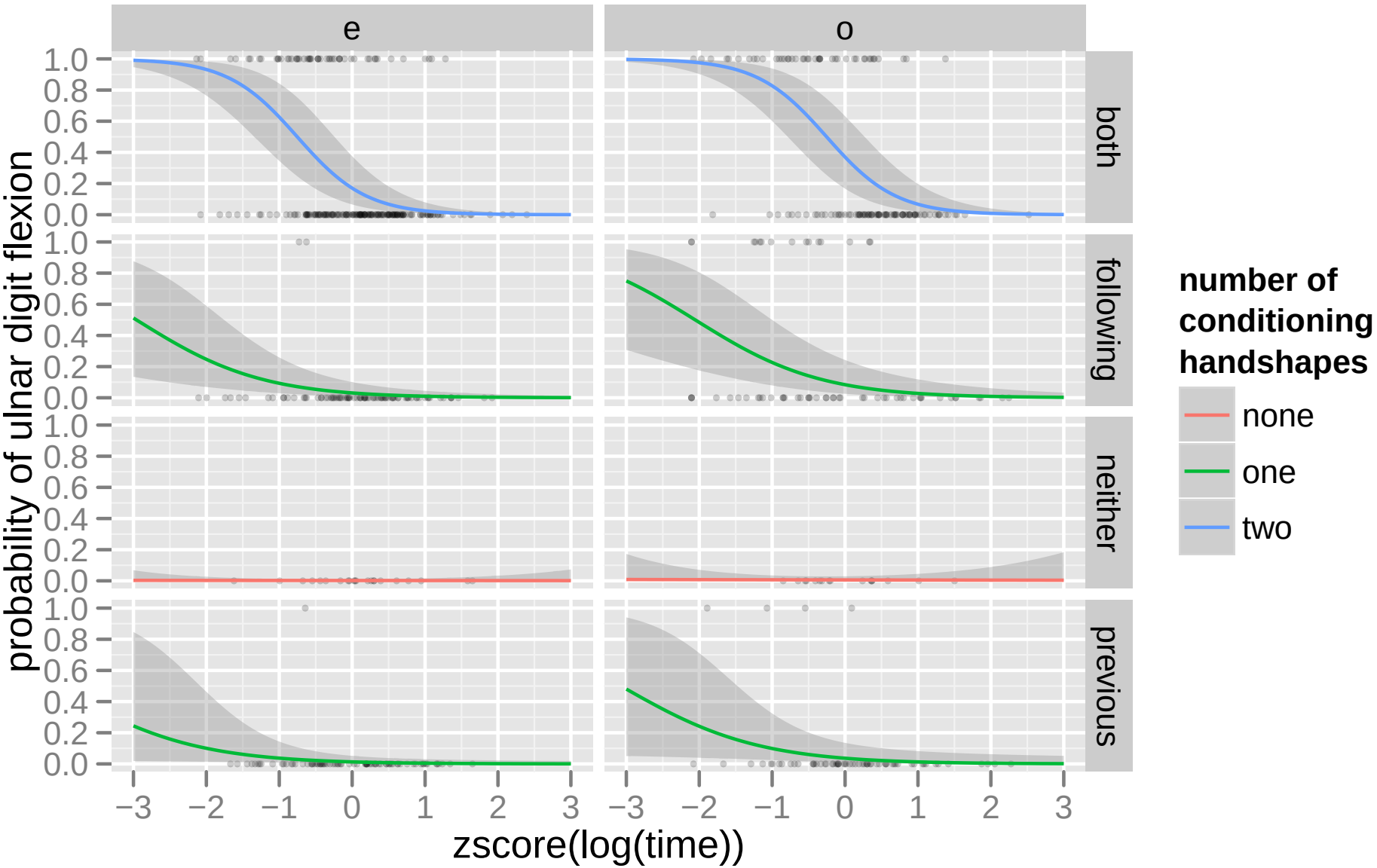
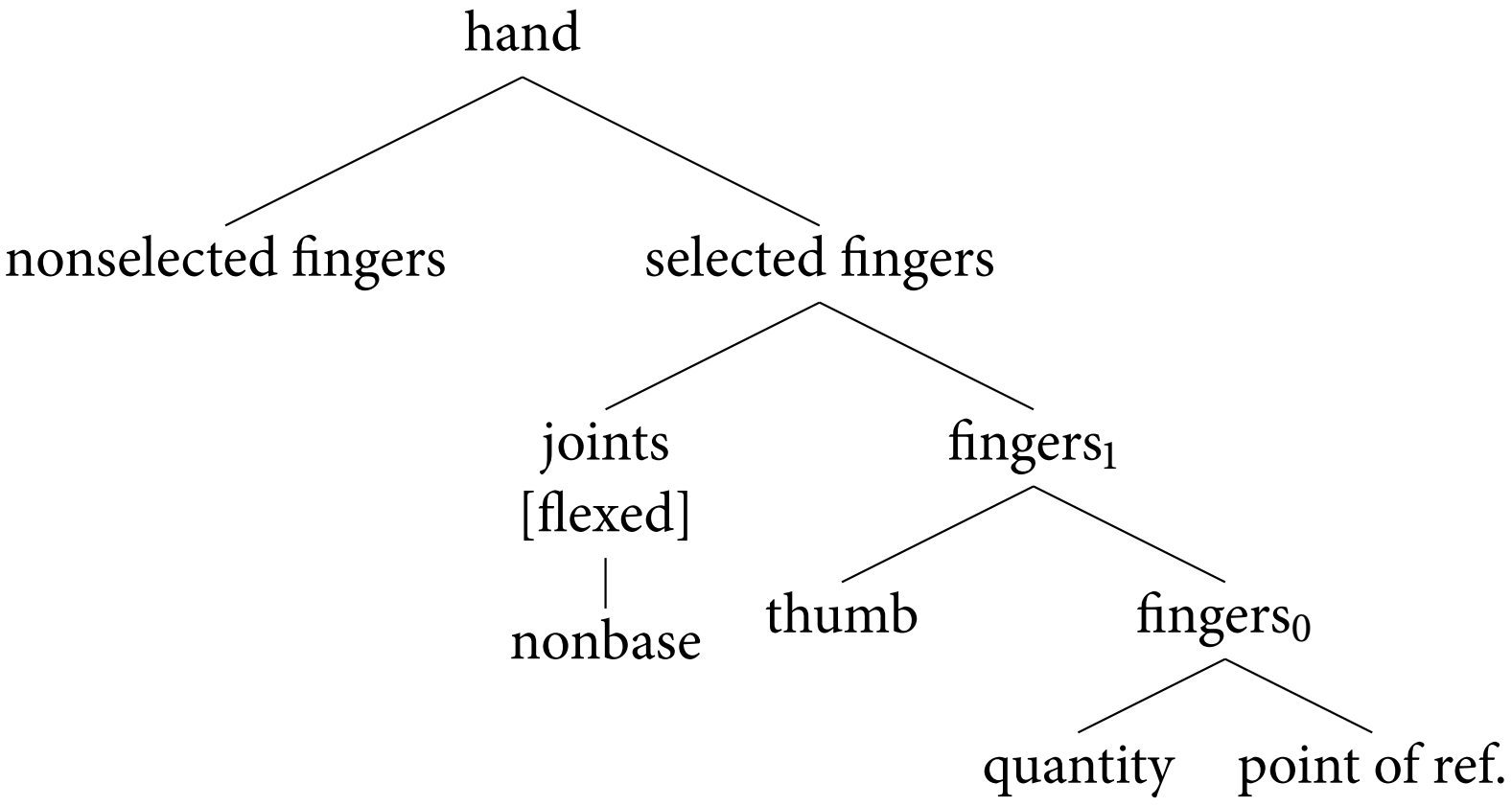
Model predictions for ulnar flexion (mean transition times)



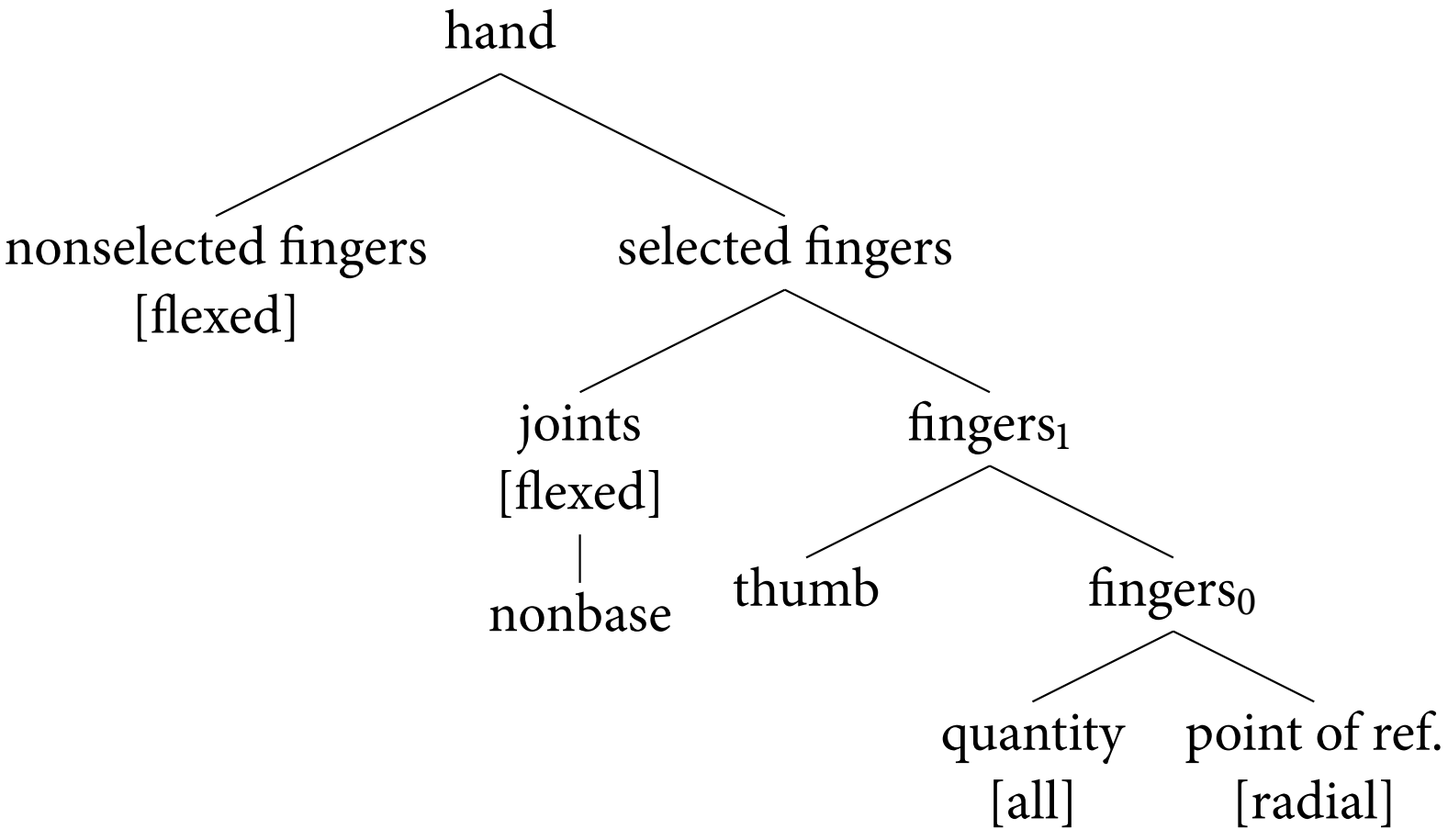
Model predictions based on transition time



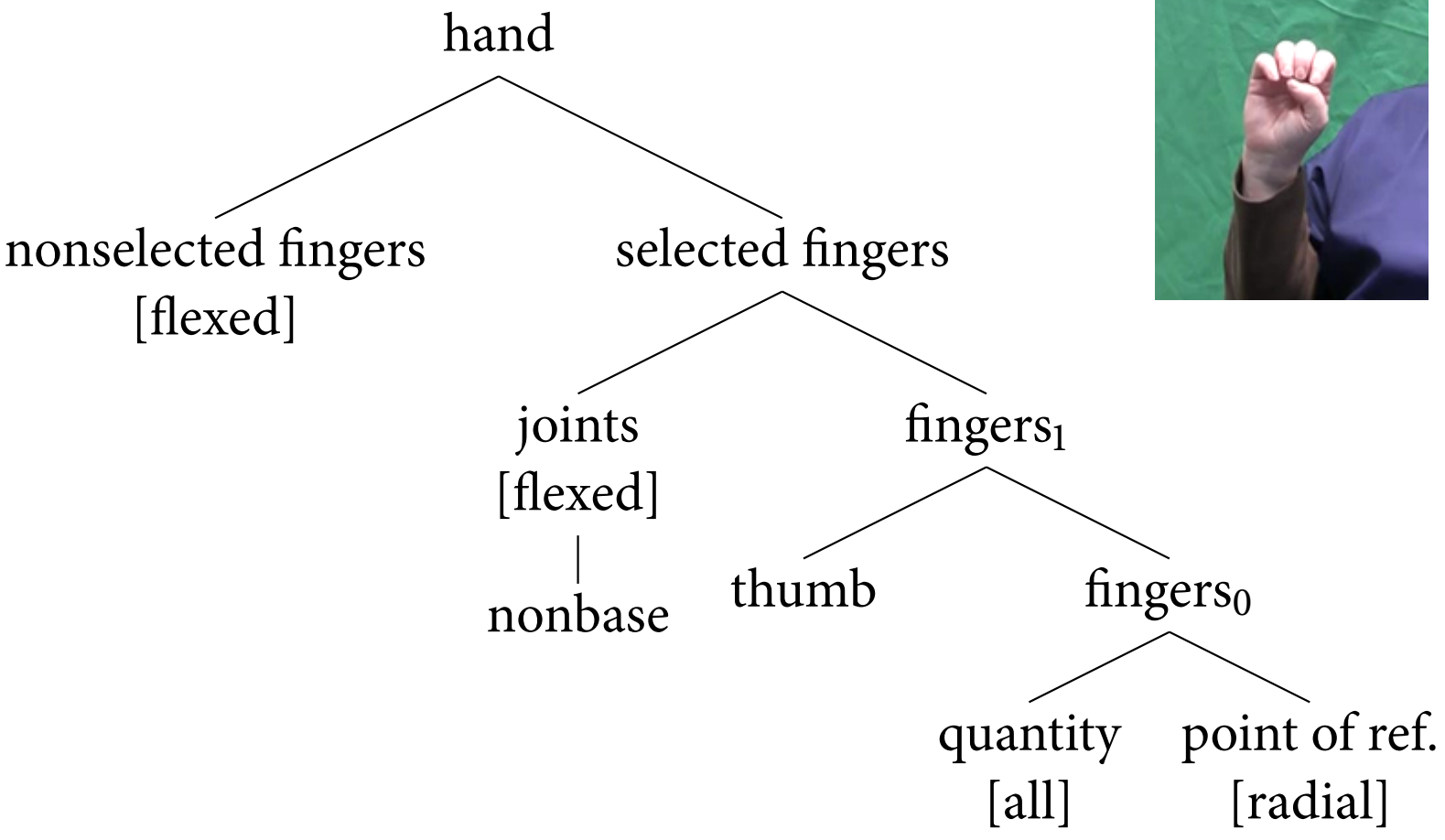
Canonical -E- (no increased ulnar digit flexion)



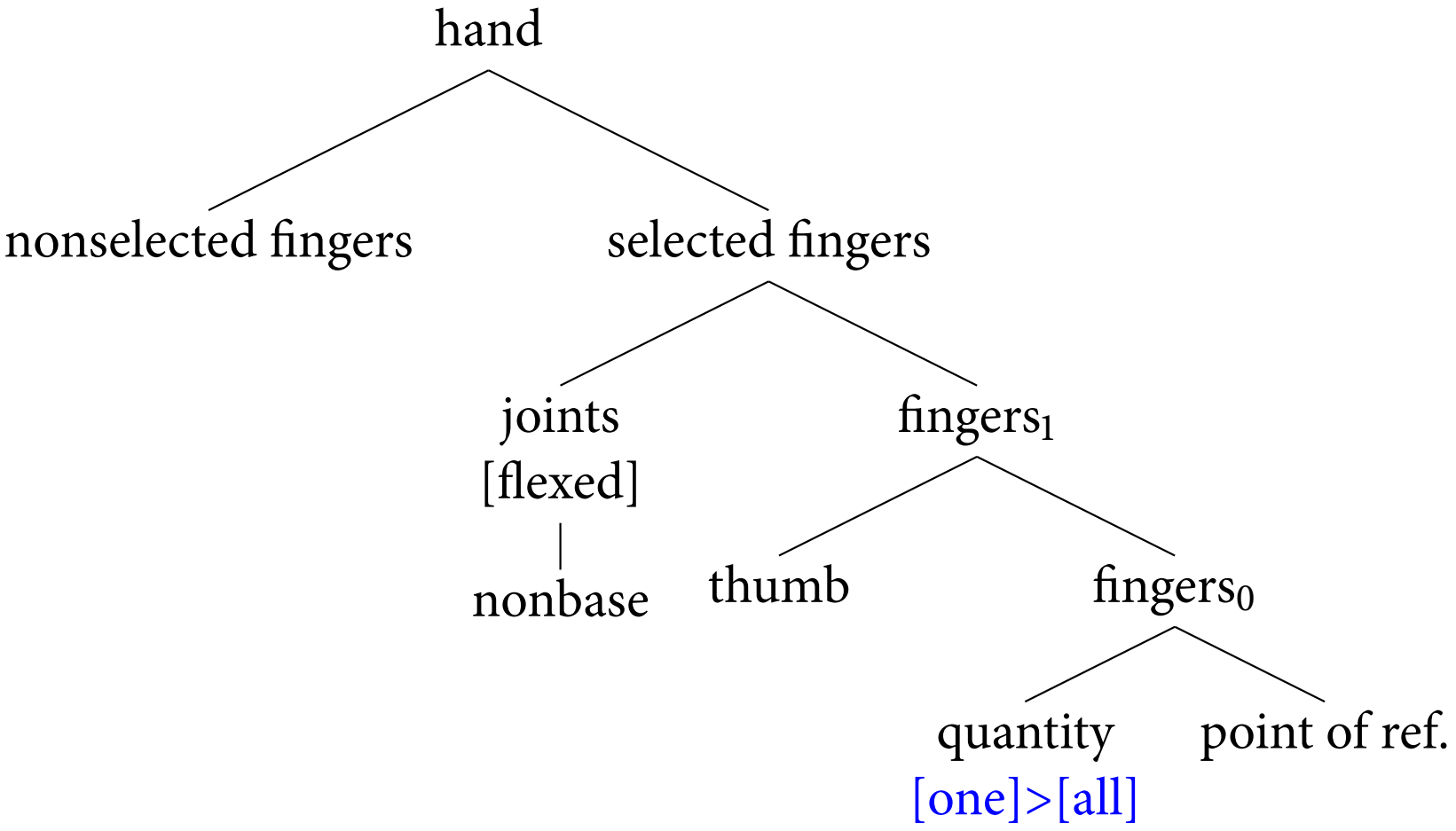
Canonical -E- (no increased ulnar digit flexion)



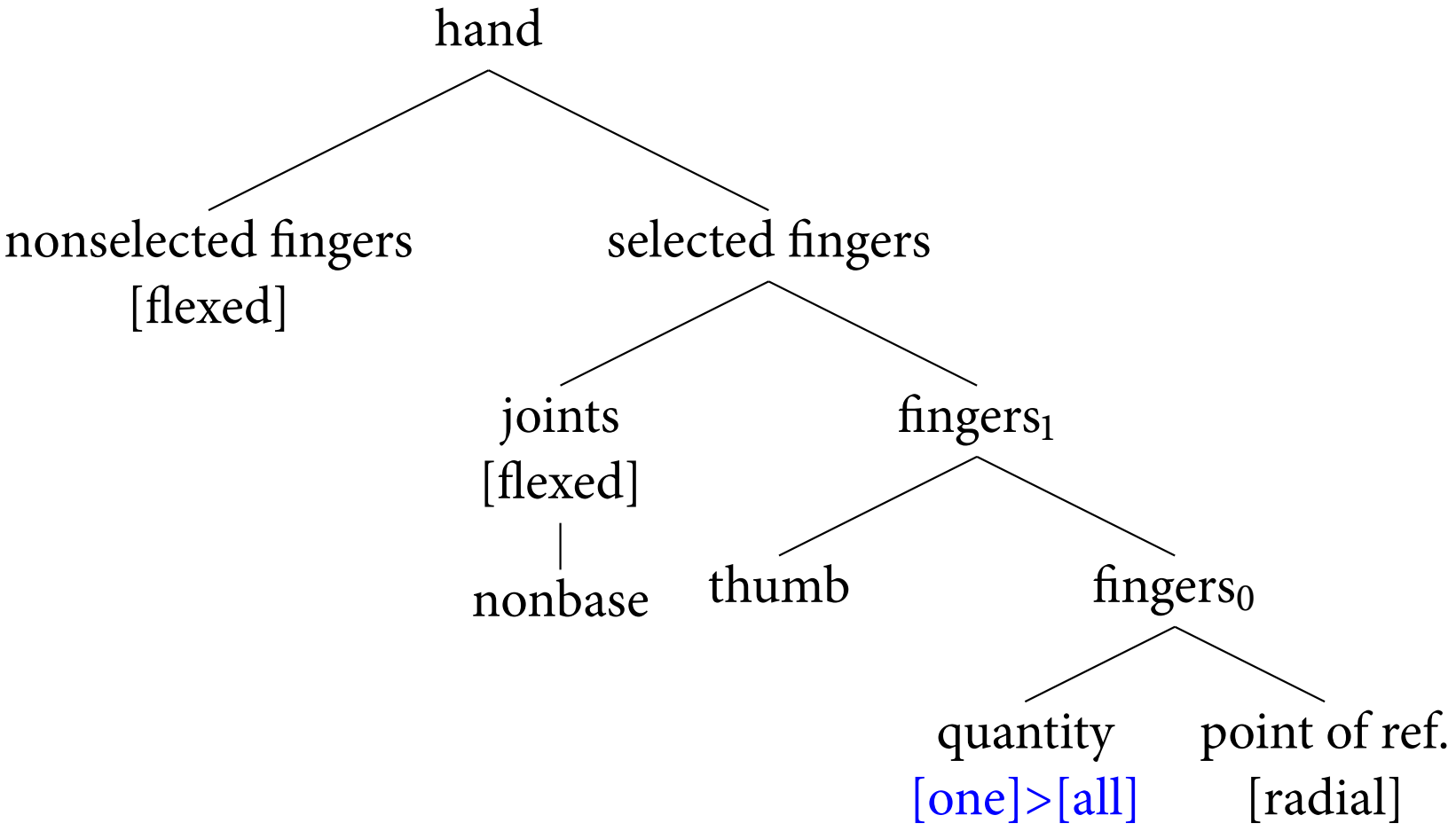
Canonical -E- (no increased ulnar digit flexion)



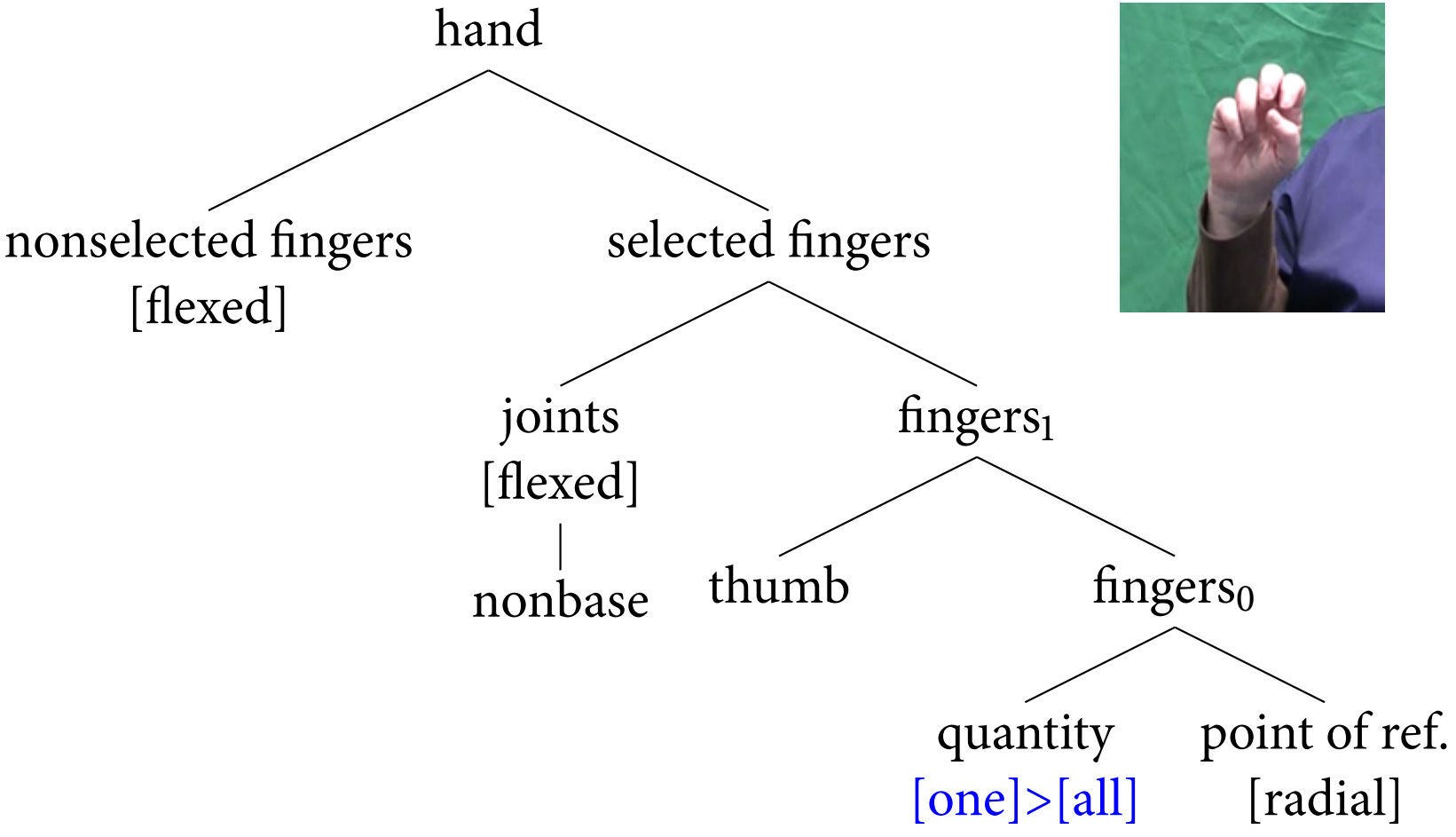
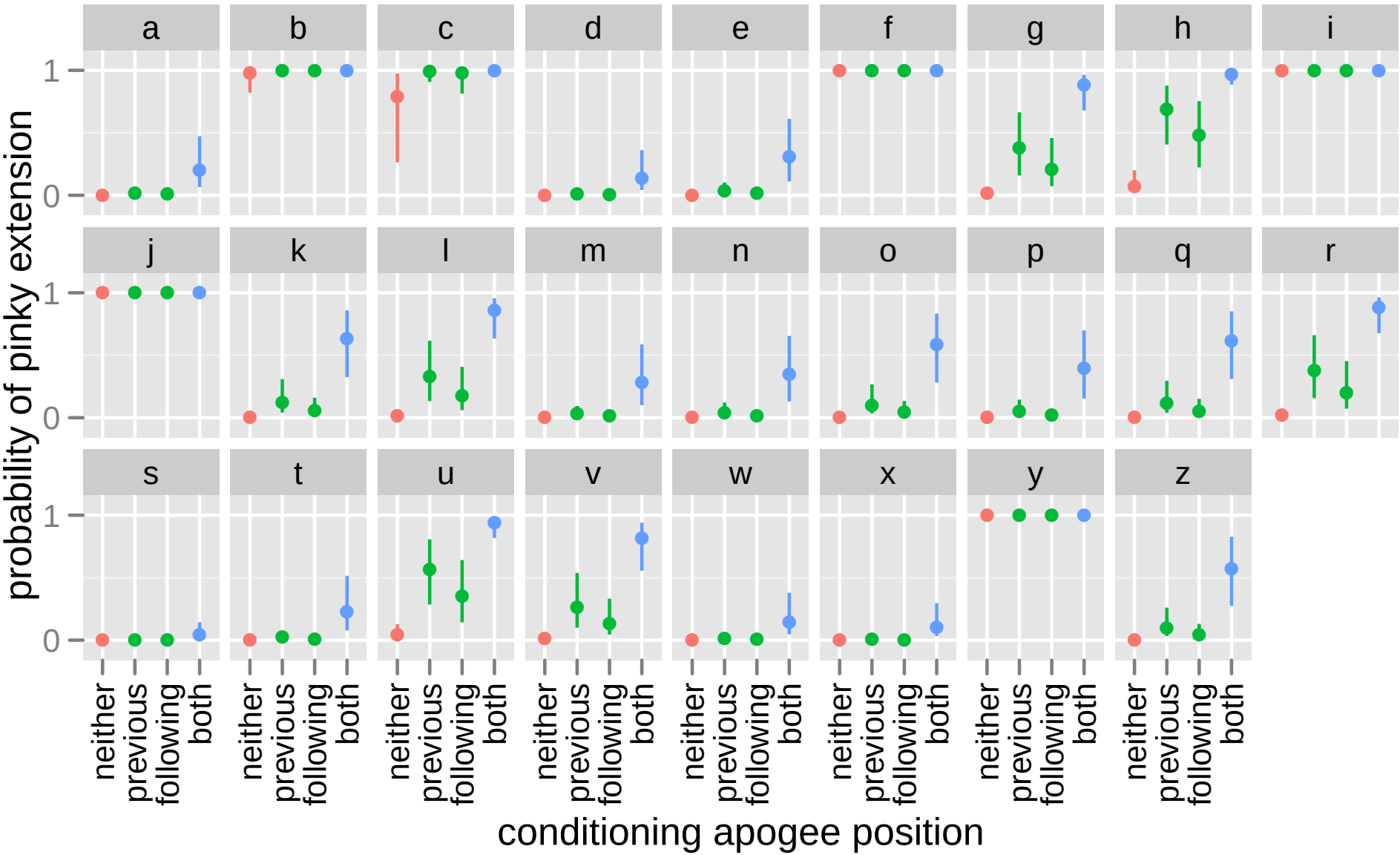
-E- with increased ulnar digit flexion



-E- with increased ulnar digit flexion



-E- with increased ulnar digit flexion



Model predictions for pinky extension (mean transition times)