# HANDSHAPE AND COARTICULATION IN ASL FINGERSPELLING

Jonathan Keane, Diane Brentari, Jason Riggle

*University of Chicago*

2012 LSA Annual Meeting: Portland, OR

# Outline

Introduction
- Background

Methods
- Data collection
- Coding method

Data
- Descriptive
- Conditioning variables

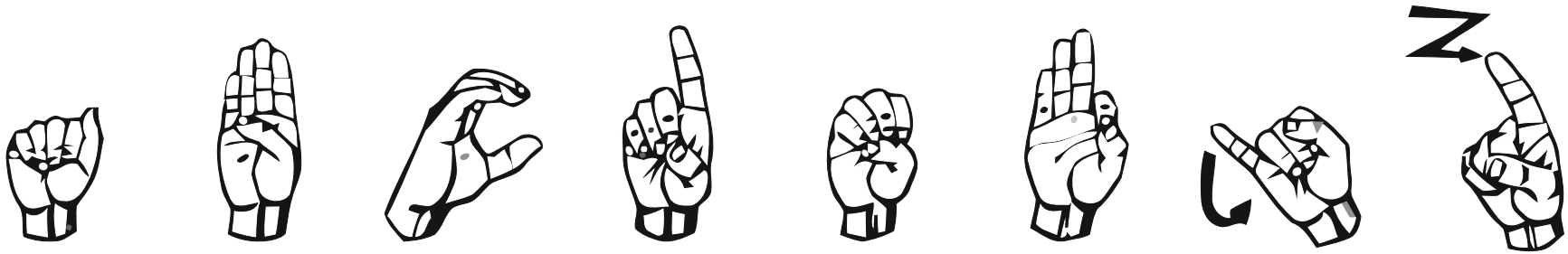
Results
- Model

Phonology of handshape
- Variation
- The Prosodic Model
- Selected finger quantity assimilation

Conclusions

# 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; half speed

data.mp4

# Broad question

**How do handshapes in fingerspelling vary across environments, and what is the best explanation for this variation?**

Specifically, what can increased ulnar digit flexion (AKA baby handshapes) in fingerspelling tell us?

Fingerspelling is an especially good phenomenon to look at handshape variation because it is quick and sequential, unlike handshape in signing.

# Recording specifications

- 4 native signers, 1 early leaner (2 (native) coded so far) produced
- 300 words
  - 100 names
  - 100 nouns
  - 100 non-English
- repeating each word twice
- being recorded by 2 or 3 video cameras
- recording at 60 FPS
- for a total of 8115 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)

# Increased ulnar digit flexion annotation

Handshape coding

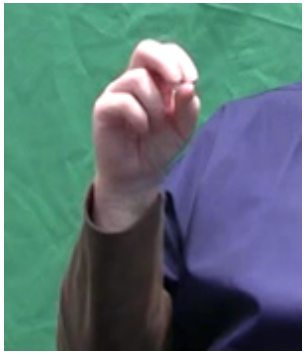
- We extracted still images from the data that has been coded.
- We hand coded increased ulnar digit flexion for all -C-, -D-, -E-, and -O- apogees.
- There are a total of 1,827 word medial apogees annotated.

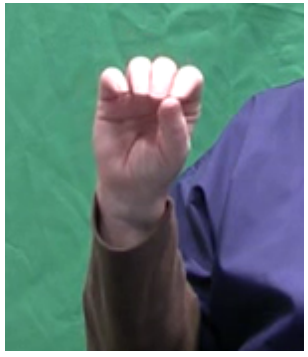
Two goals

- A simple task with only a minimal amount of training necessary
- A task that would apply to these four handshapes

# Increased ulnar digit flexion

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


-O- [+flex]


-O- (–flex)


-E- [+flex]


-E- (–flex)

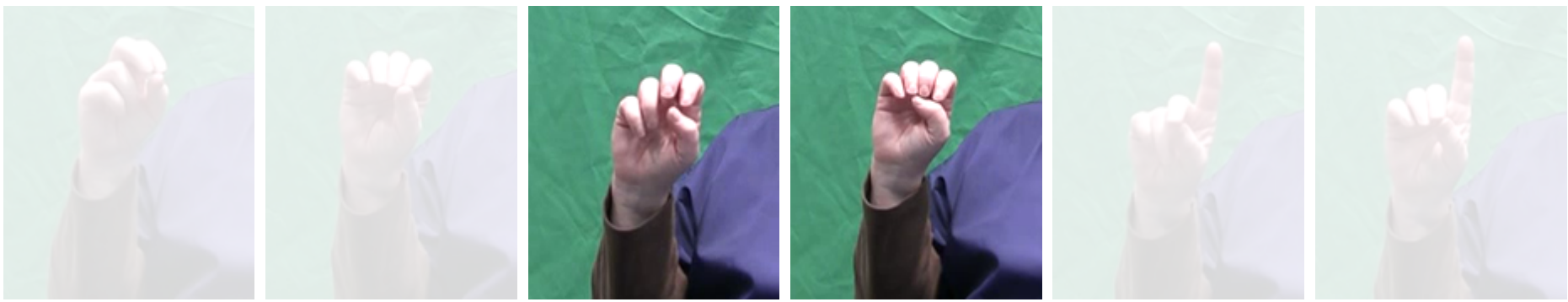

-D- [+flex]


-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,

# Increased ulnar digit flexion

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



-O- [+flex] -O- (–flex) -E- [+flex] -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,

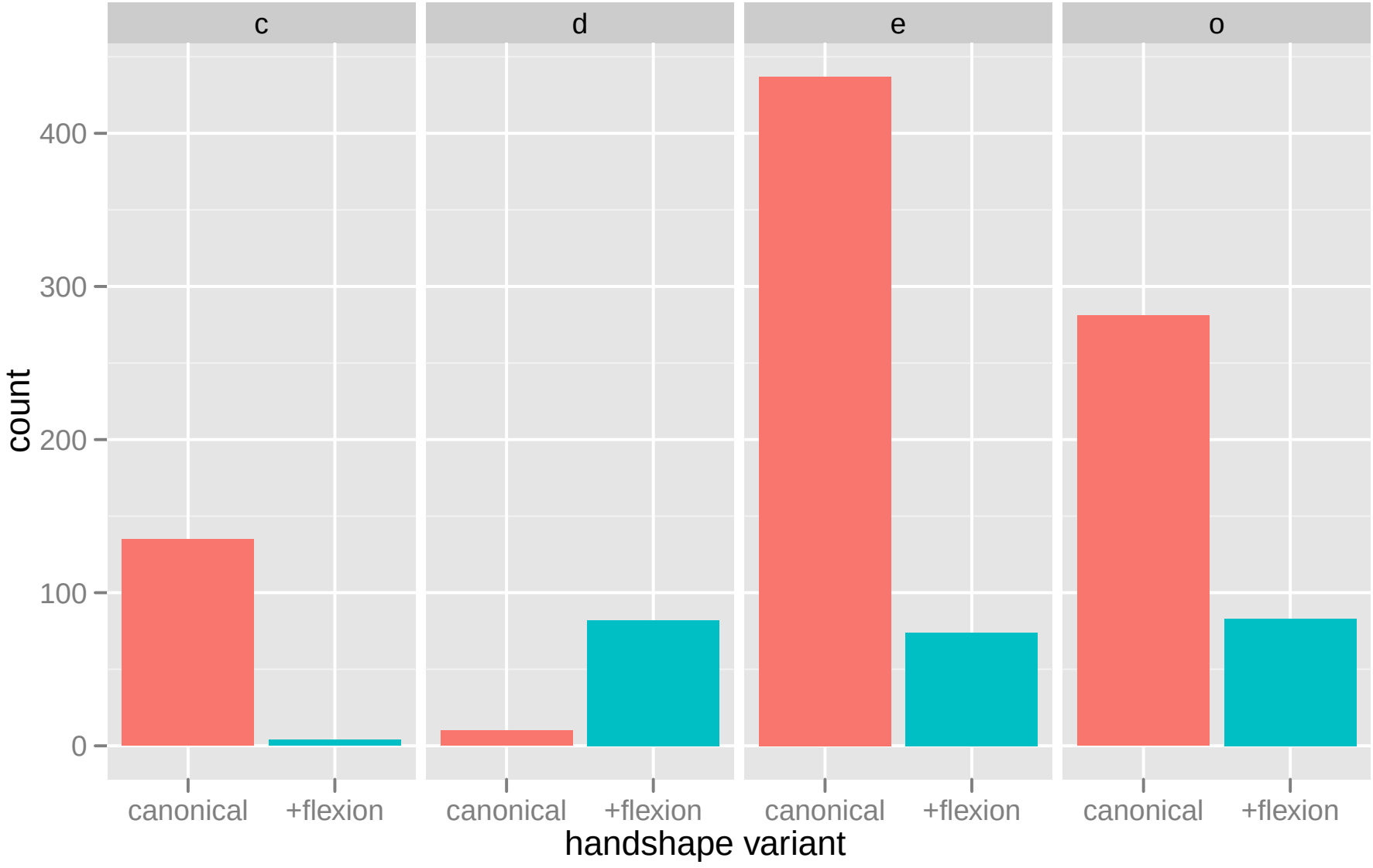
# Increased ulnar digit flexion

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

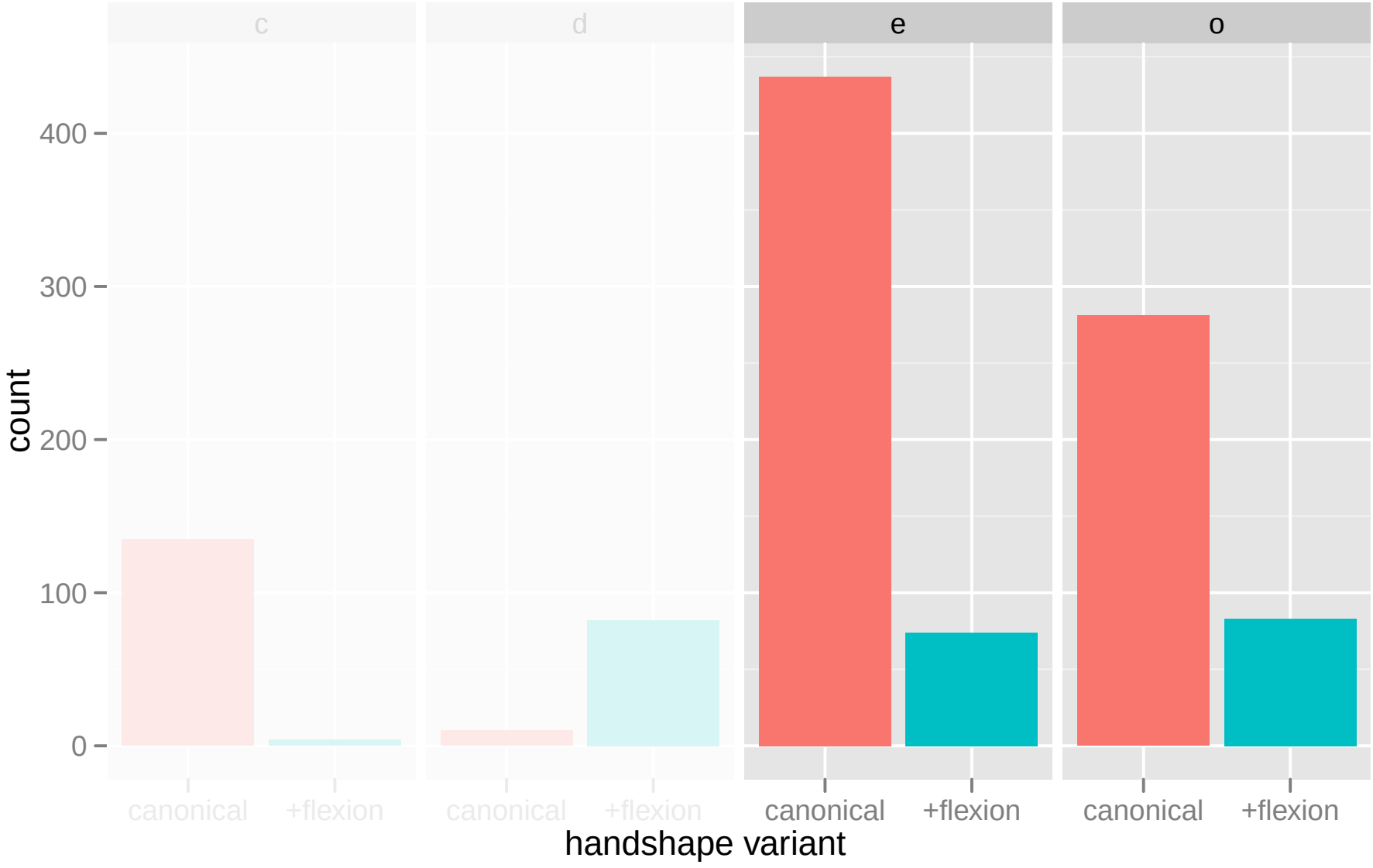
-O- [+flex] -O- (–flex) -E- [+flex] -E- (–flex) -D- [+flex] -D- (–flex)

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,

# Handshape variation

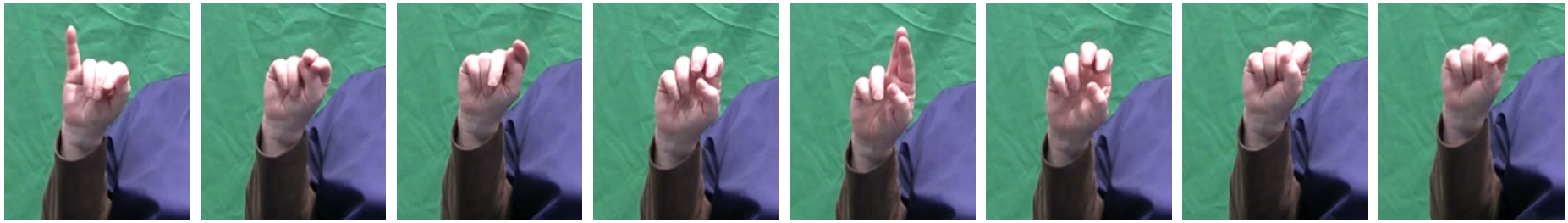


# Handshape variation



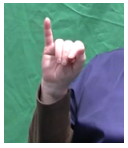
# I-N-T-E-R-E-S-T; half speed

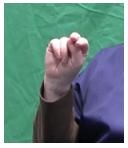
Clipsinterest.mp4

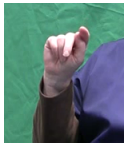


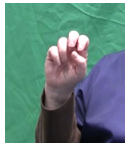
-I- -N- -T- -E- -R- -E- -S- -T-

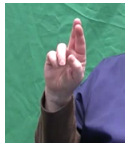
# What affects the -E- handshape?

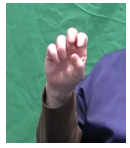

-I-

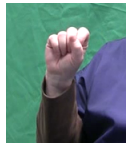

-N-

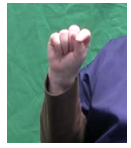

-T-

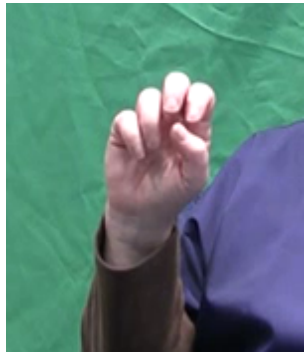

-E-


-R-

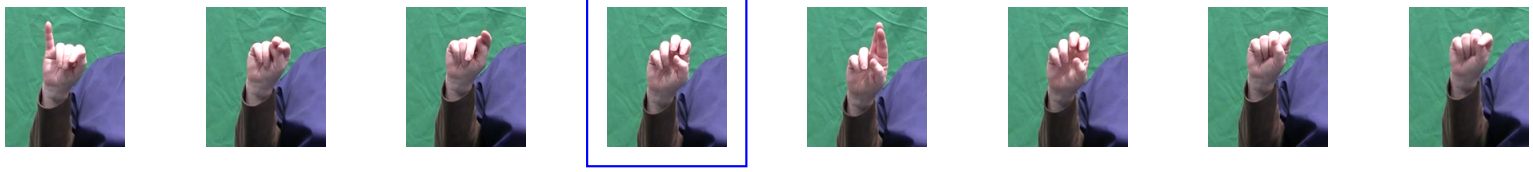

-E-


-S-


-T-



# What affects the -E- handshape?



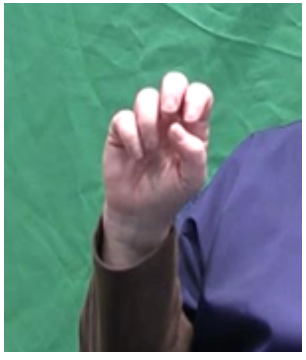
-I- -N- -T- -E- -R- -E- -S- -T-

**word type**

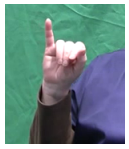
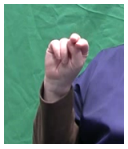
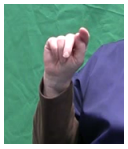
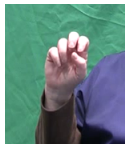
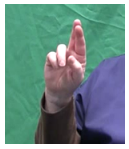
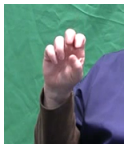
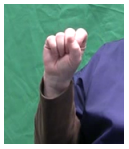
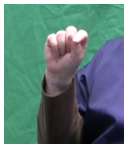
name, noun, foreign

**signer**

s1, s2



# What affects the -E- handshape?

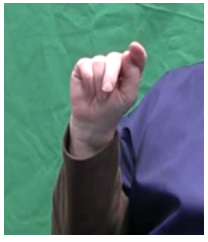
-I- -N- -T- -E- -R- -E- -S- -T-

**word type**

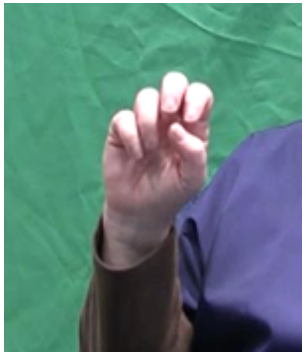
name, noun, foreign

**signer**

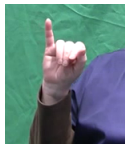
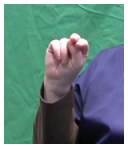
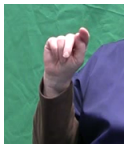
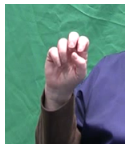
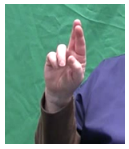
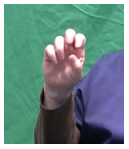
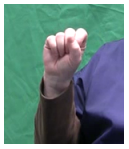
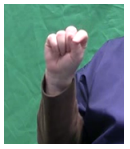
s1, s2



**previous handshape** →



# What affects the -E- handshape?

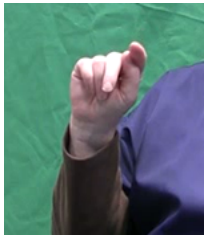
-I- -N- -T- -E- -R- -E- -S- -T-

**word type**

name, noun, foreign

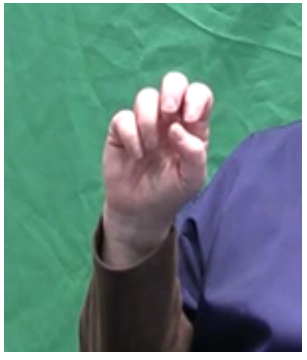
**signer**

s1, s2

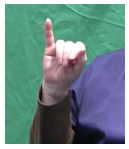
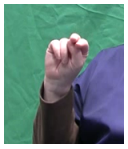
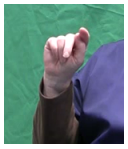
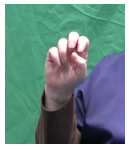
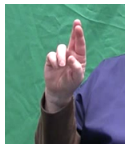
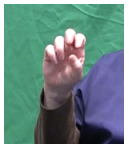
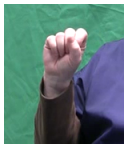
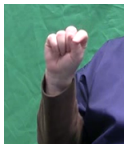


**previous handshape**

**previous transition time**

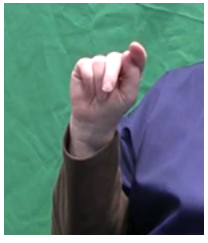


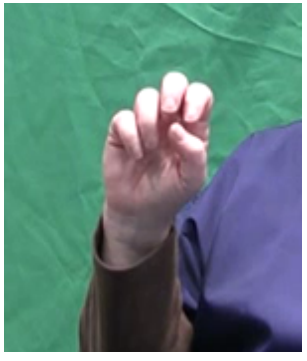
# What affects the -E- handshape?

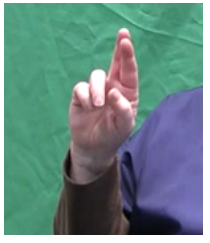

-I-

-N-

-T-

-E-

-R-

-E-

-S-

-T-

**word type**
name, noun, foreign

**signer**
s1, s2

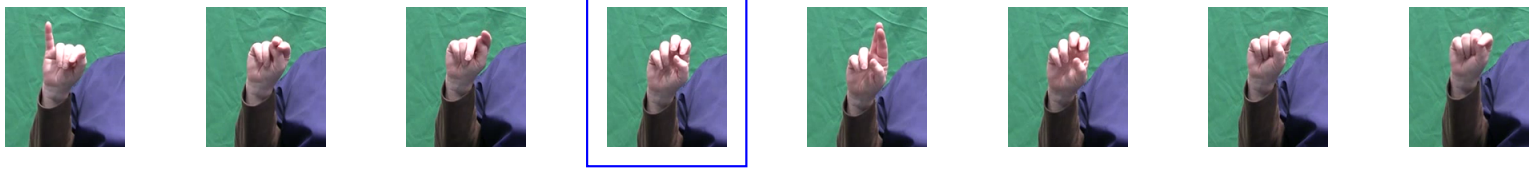

**previous handshape**




**following handshape**

**previous transition time**

# What affects the -E- handshape?



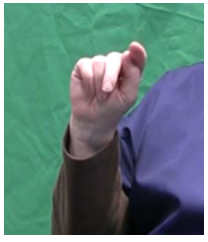
-I- -N- -T- -E- -R- -E- -S- -T-

**word type**

name, noun, foreign

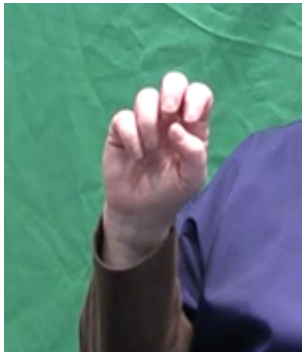
**signer**

s1, s2



**previous handshape**

**previous transition time**



**following handshape**

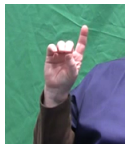
**following transition time**

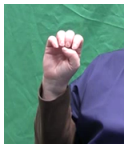
# D-E-C-I-S-I-O-N; half speed

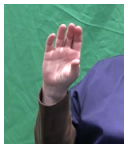
Clipsdecision.mp4

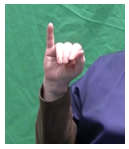
-D- -E- -C- -I- -S- -I- -O- -N-

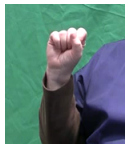
# What affects the -E- handshape?

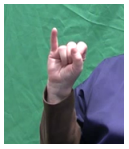

-D-

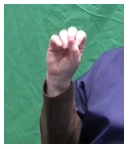

-E-

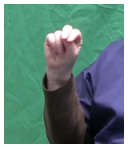

-C-


-I-


-S-


-I-


-O-

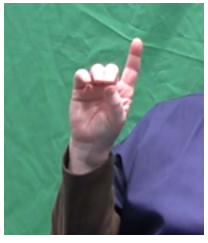

-N-

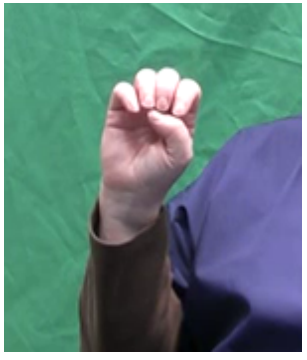
**word type**

name, noun, foreign

**signer**

s1, s2


**previous handshape**




**following handshape**

**previous transition time**

**following transition time**

# 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- |

# 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- |

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

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

# 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- |

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

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

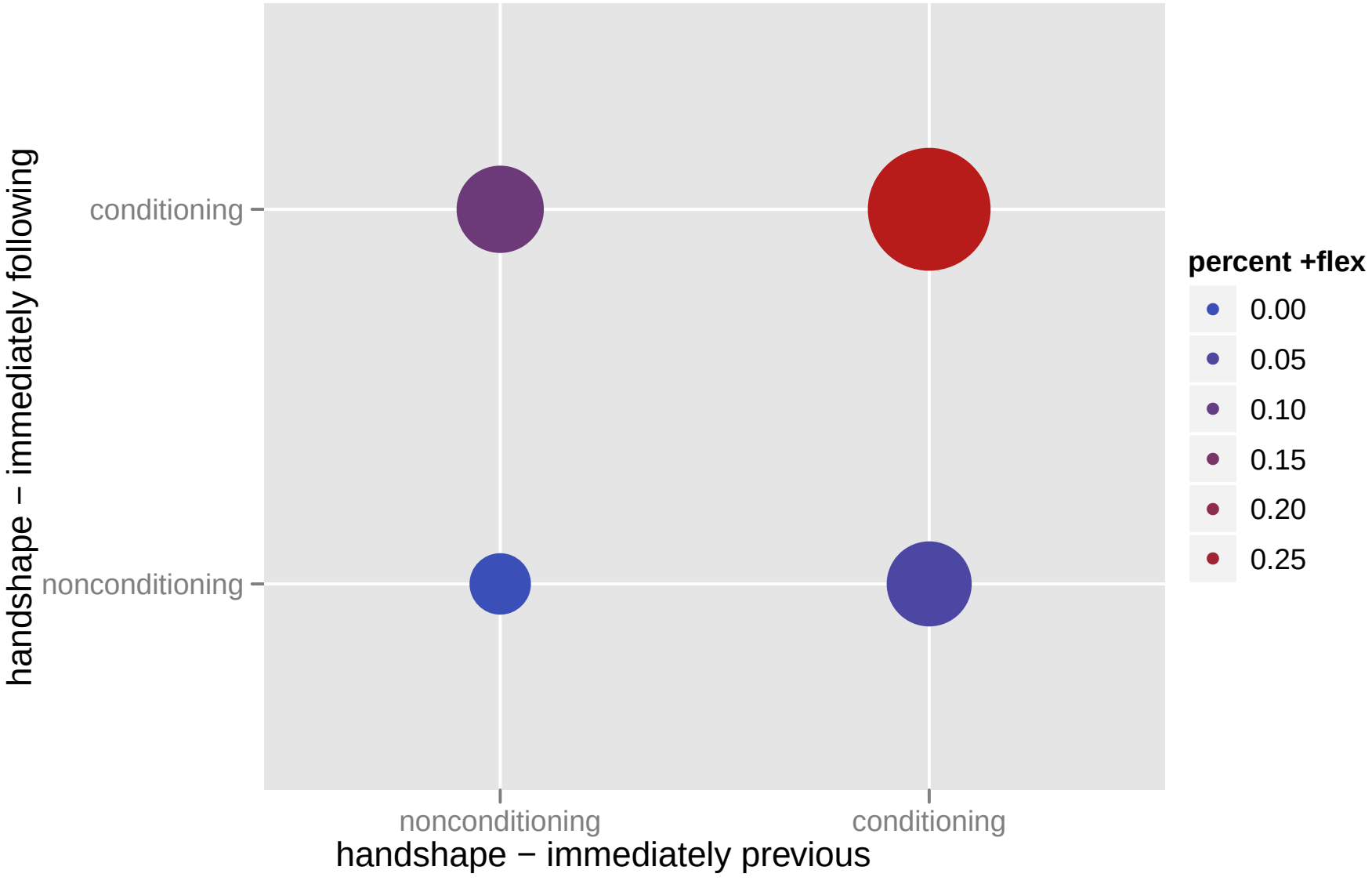
# Specific questions

1. Is there variation with respect to ulnar digit flexion in the handshapes -C-, -D-, -E-, and -O-?
2. What environments condition this? Previous handshape? Following handshape? &c.
3. Is the variation phonetically or phonologically grounded?

# Specific questions

1. Is there variation with respect to ulnar digit flexion in the handshapes -C-, -D-, -E-, and -O-? For -E- and -O-: **yes**
2. What environments condition this? Previous handshape? Following handshape? &c.
3. Is the variation phonetically or phonologically grounded?

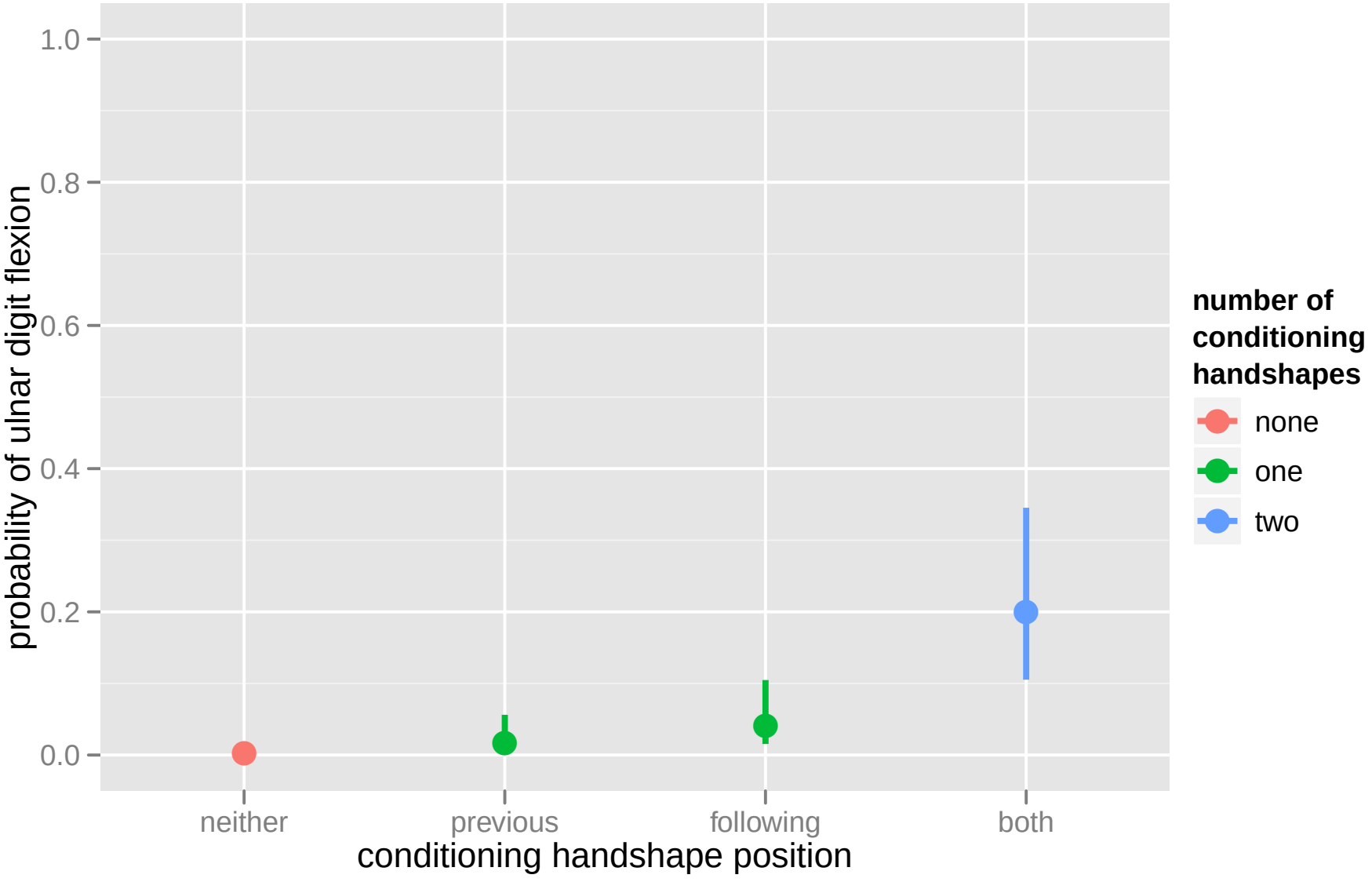
# Flexion based on surrounding handshapes



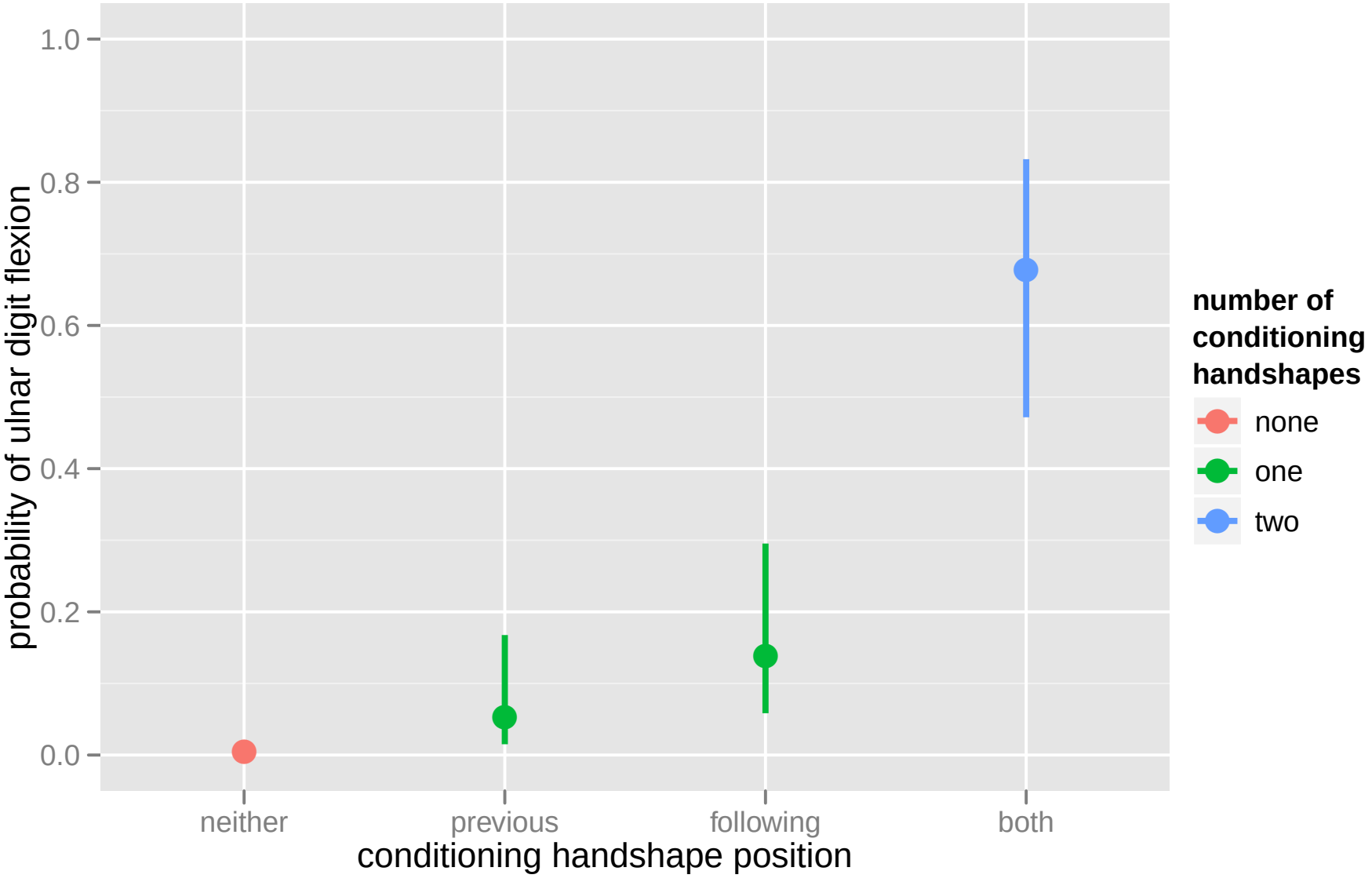
Using a multilevel logistic regression, we determined that the following have a significant effect on ulnar digit flexion:

- handshape of the previous apogee,
- handshape of the following apogee,
- interaction of previous handshape and previous transition time,
- interaction of following handshape and following transition time.

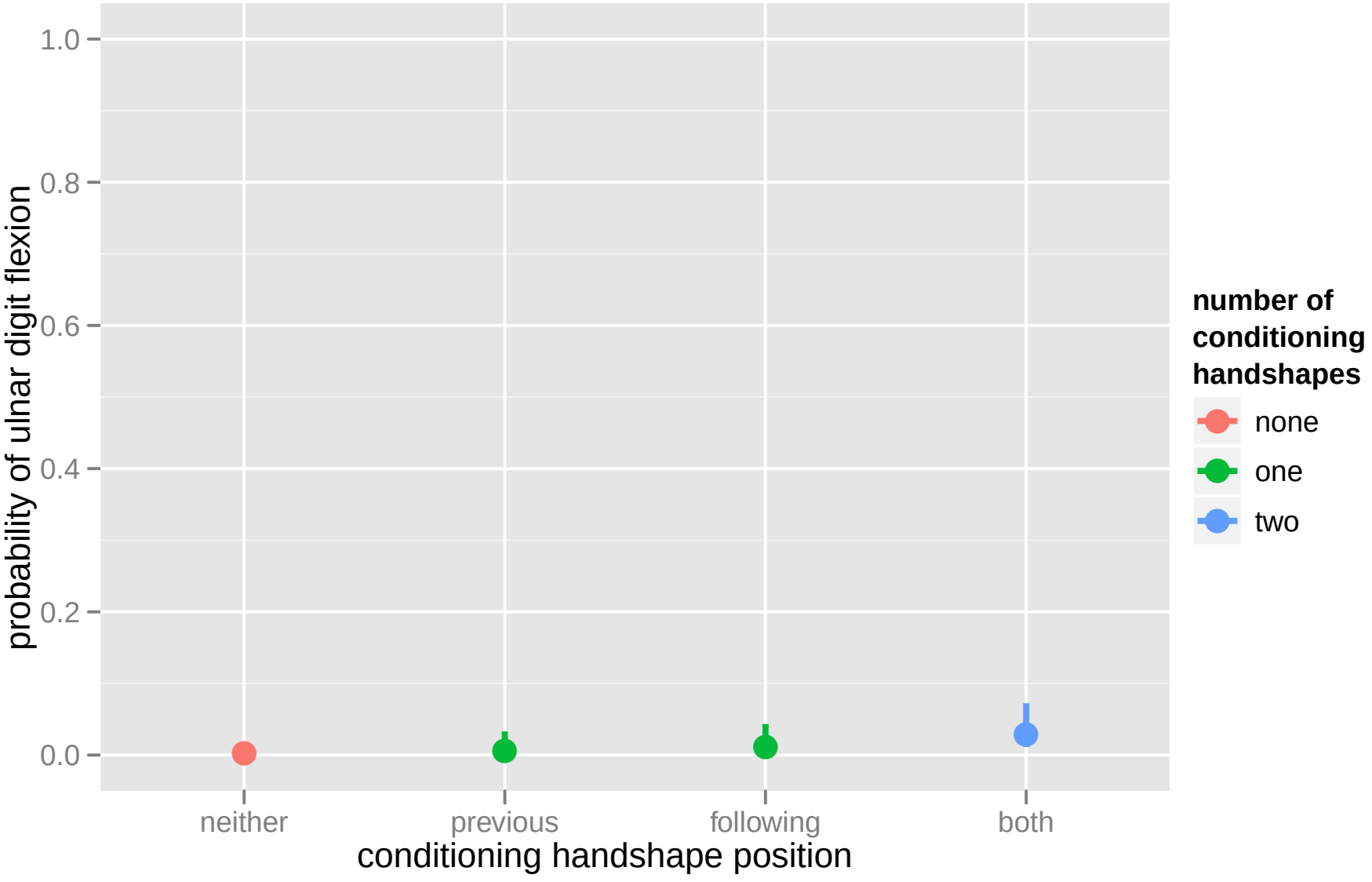
# Near conditioning handshapes, mean trans.



# Near conditioning handshapes, fast (-1 sd)



# Near conditioning handshapes, slow (+1 sd)



In summary, the following increase the probability that an apogee will have increased ulnar digit flexion:

- if the previous handshape has fewer than all selected fingers and
- if the following handshape has fewer than all selected fingers.

Additionally,

- the effect of previous handshape is magnified with smaller previous transition times and
- the effect of following handshape is magnified with smaller following transition times.

# Explaining variation

## -E- and -O-

- Increased ulnar digit flexion occurs in the context of surrounding apogees with handshapes that have extended radial fingers and flexed ulnar fingers.
- Interestingly, the -E- and -O- with increased ulnar digit flexion seem to flex the same fingers that are nonselected (and flexed) in surrounding handshapes.

-P- -E- -R- -R- -O- -U-

Apogees from P-E-R-I-O-D and T-R-O-U-B-L-E

# Explaining variation

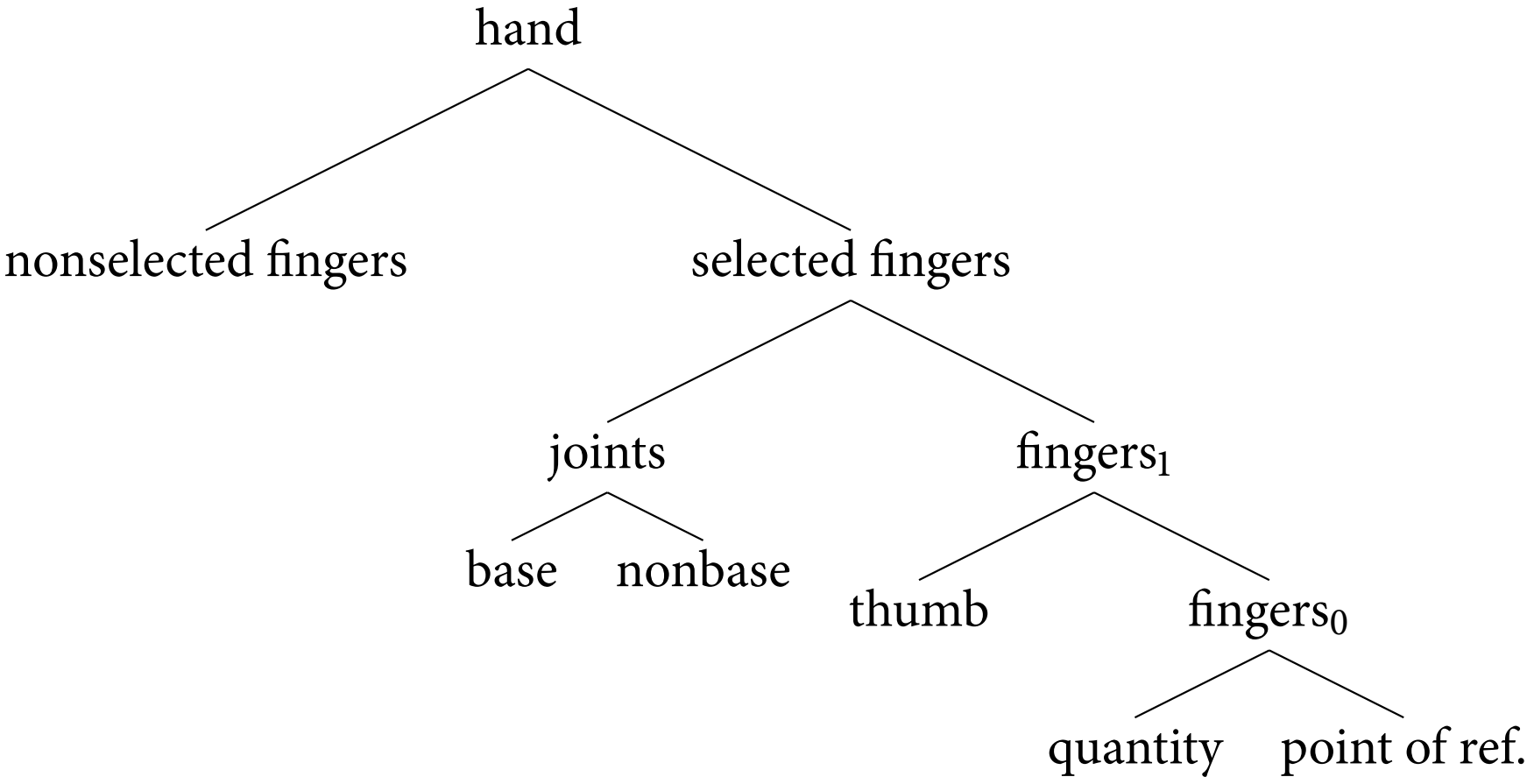
## -E- and -O-

- Increased ulnar digit flexion occurs in the context of surrounding apogees with handshapes that have extended radial fingers and flexed ulnar fingers.
- Interestingly, the -E- and -O- with increased ulnar digit flexion seem to flex the same fingers that are nonselected (and flexed) in surrounding handshapes.

-P- -E- -R- -R- -O- -U-

Apogees from P-E-R-I-O-D and T-R-O-U-B-L-E

# Handshape portion from the Prosodic Model




(Brentari, 1998)

# Default values, dependency relations

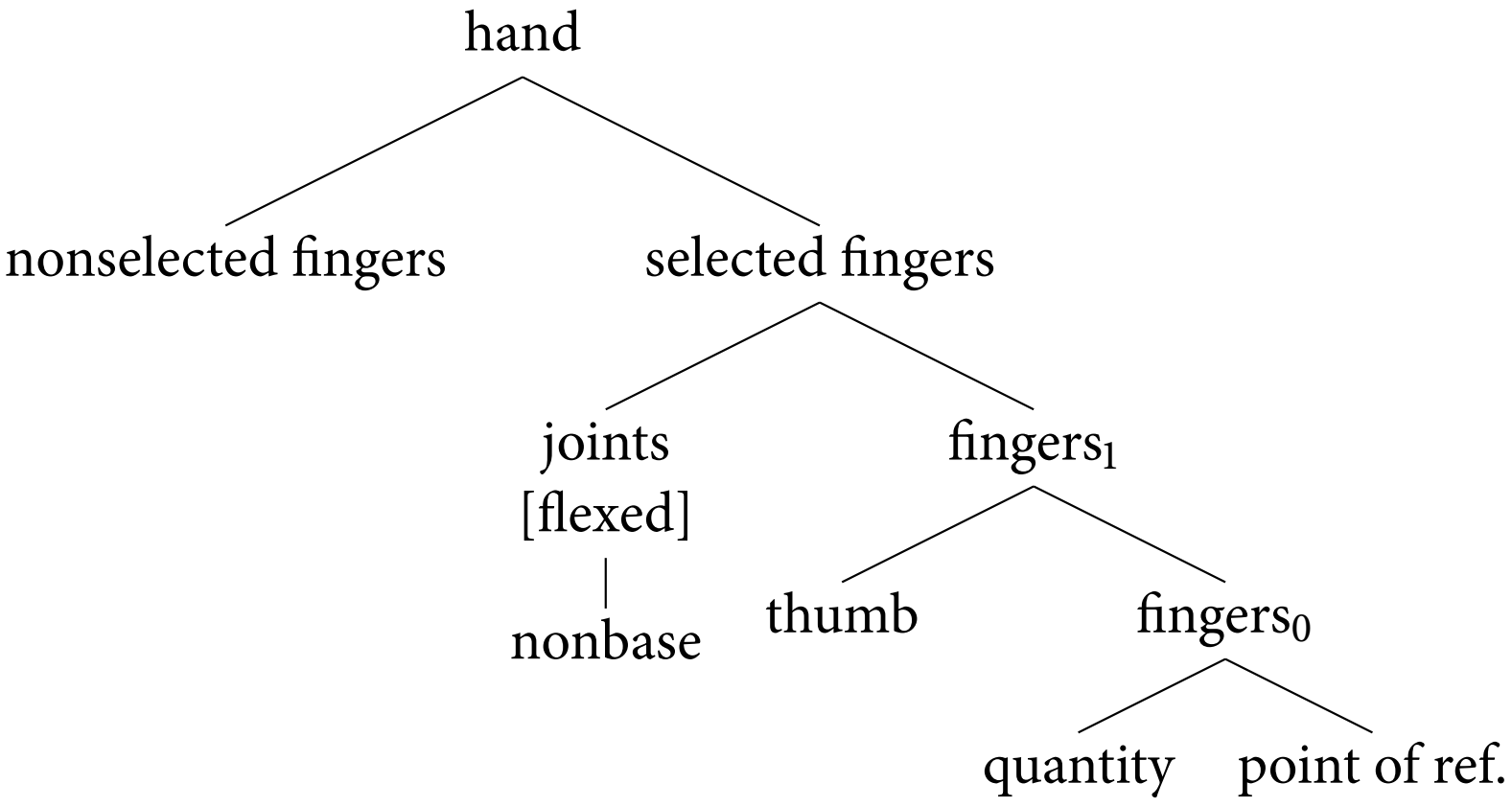
A variety of default values are filled in by redundancy rules:

- **joints:** [-flexed] (extended)
- **quantity:** [all]
- **point of reference:** [radial]
- **nonselected fingers:** [flexed]

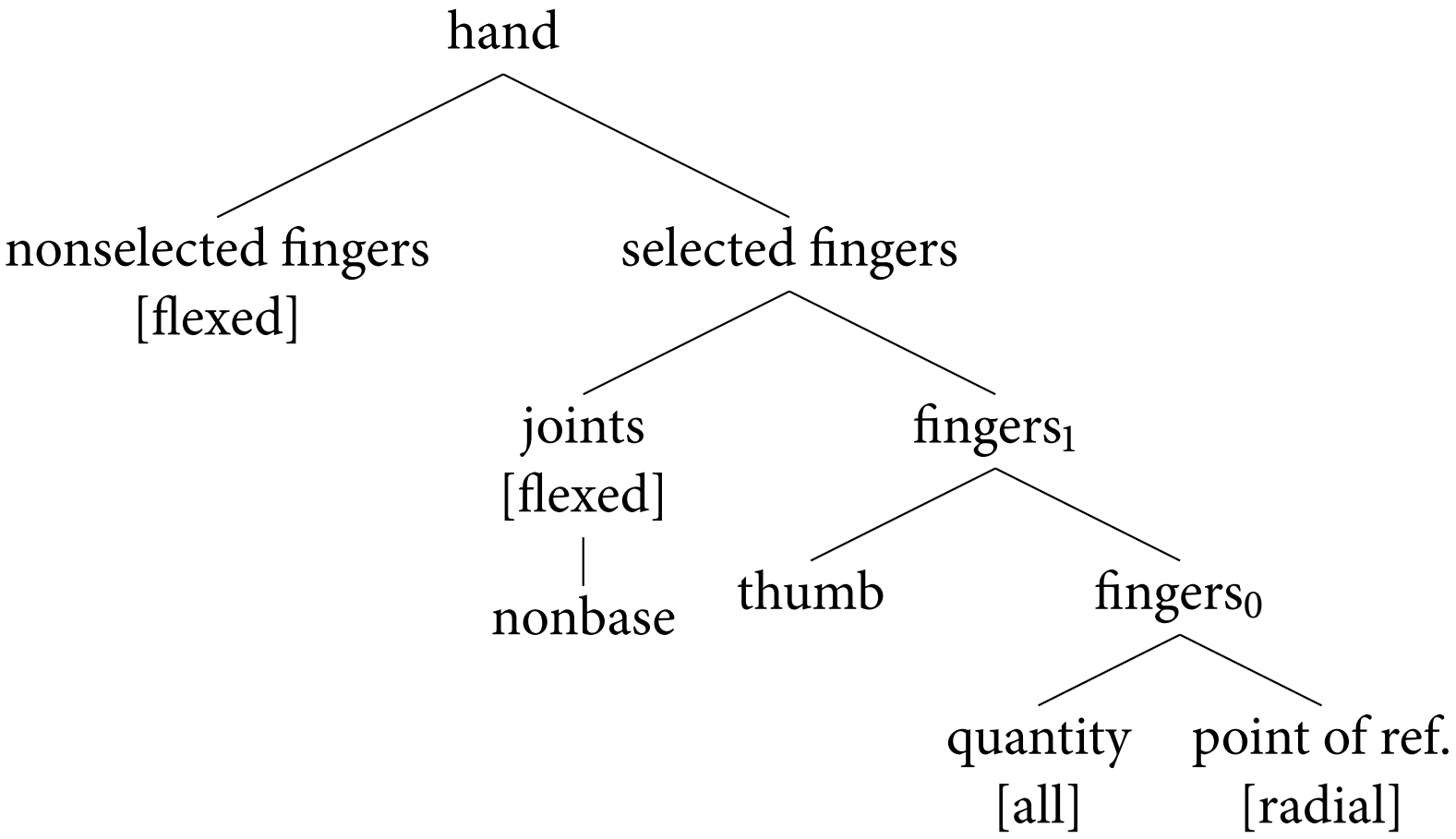
Some features are able to be specified in a dependent relation:

- **quantity**
  - one: [one]
  - two: [one]>[all]
  - three: [all]>[one]
  - four: [all]

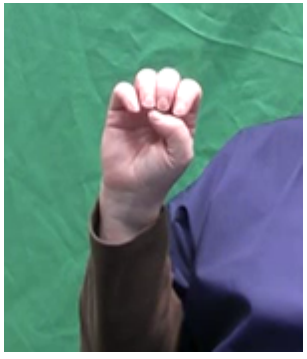
# Canonical -E- (no increased ulnar digit flexion)



# Canonical -E- (no increased ulnar digit flexion)

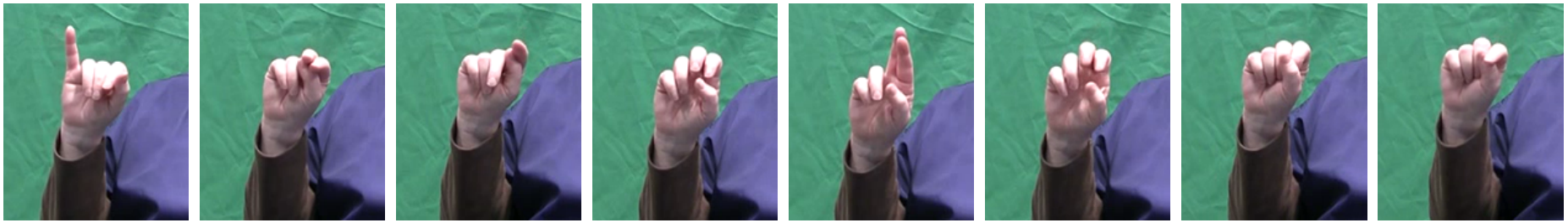


# Canonical -E- (no increased ulnar digit flexion)



# I-N-T-E-R-E-S-T, revisited; 0.3 speed

Clipsinterest.mp4



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

# -E-, revisited

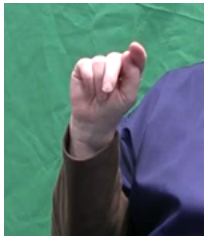
-I- -N- -T- -E- -R- -E- -S- -T-

**word type**

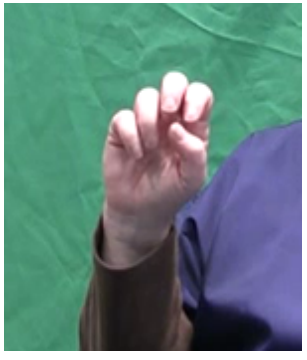
name, noun, foreign

**signer**

s1, s2



**previous handshape** →



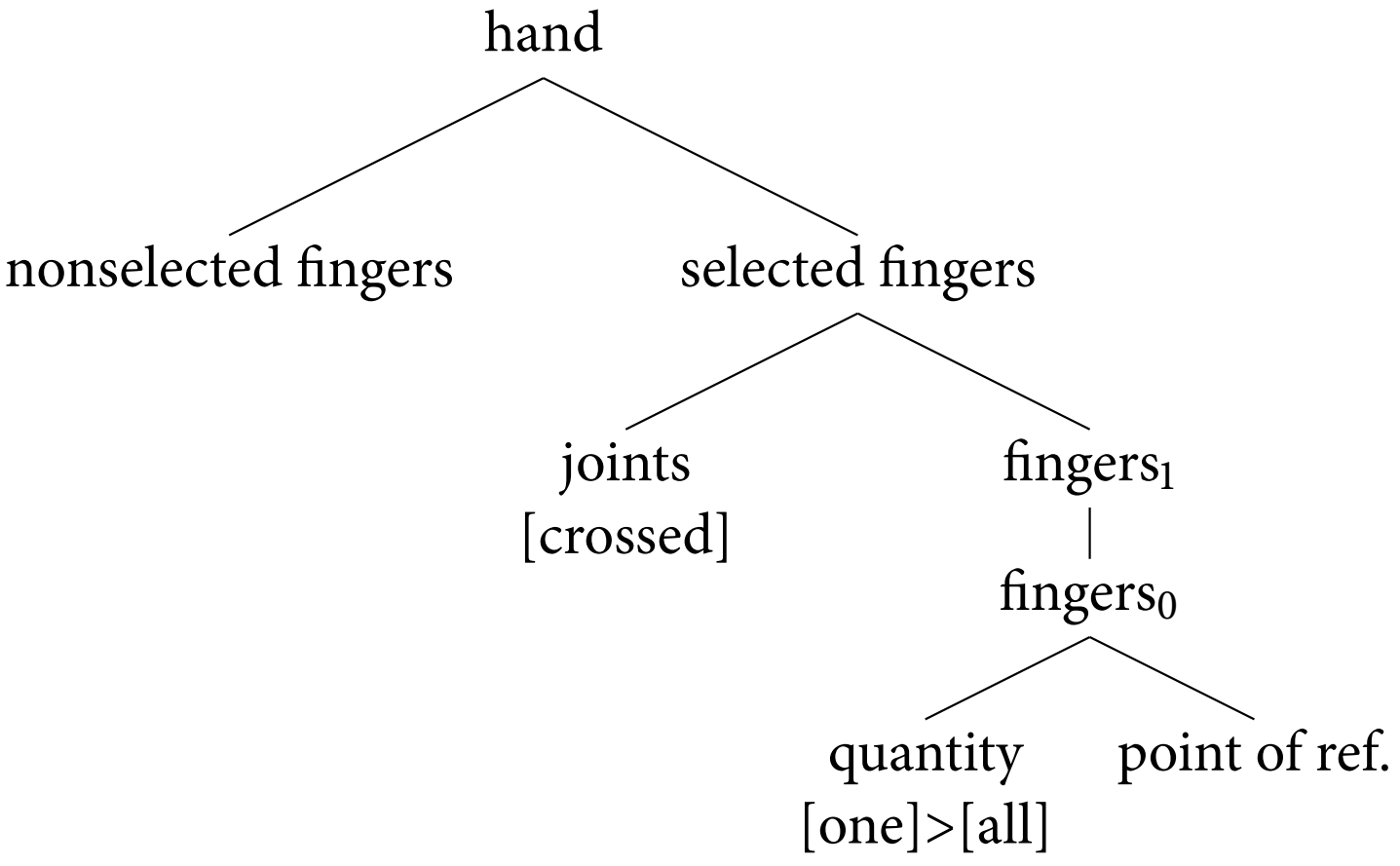
← **following handshape**

**previous transition time** ↗

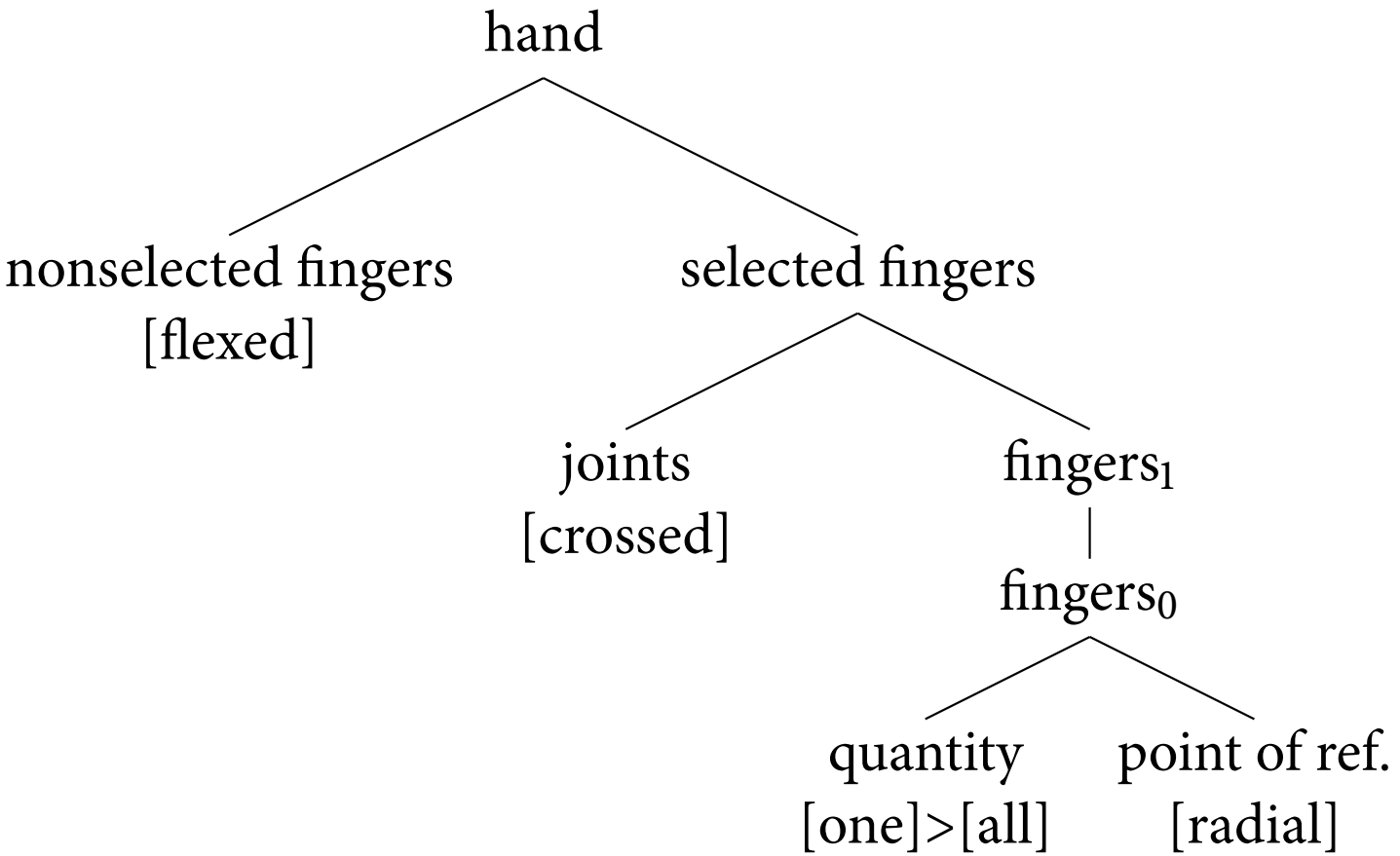
↖ **following transition time**

**[+flex]**

-R-


hand
nonselected fingers
selected fingers
joints
[crossed]
fingers1
fingers0
quantity
[one]>[all]
point of ref.

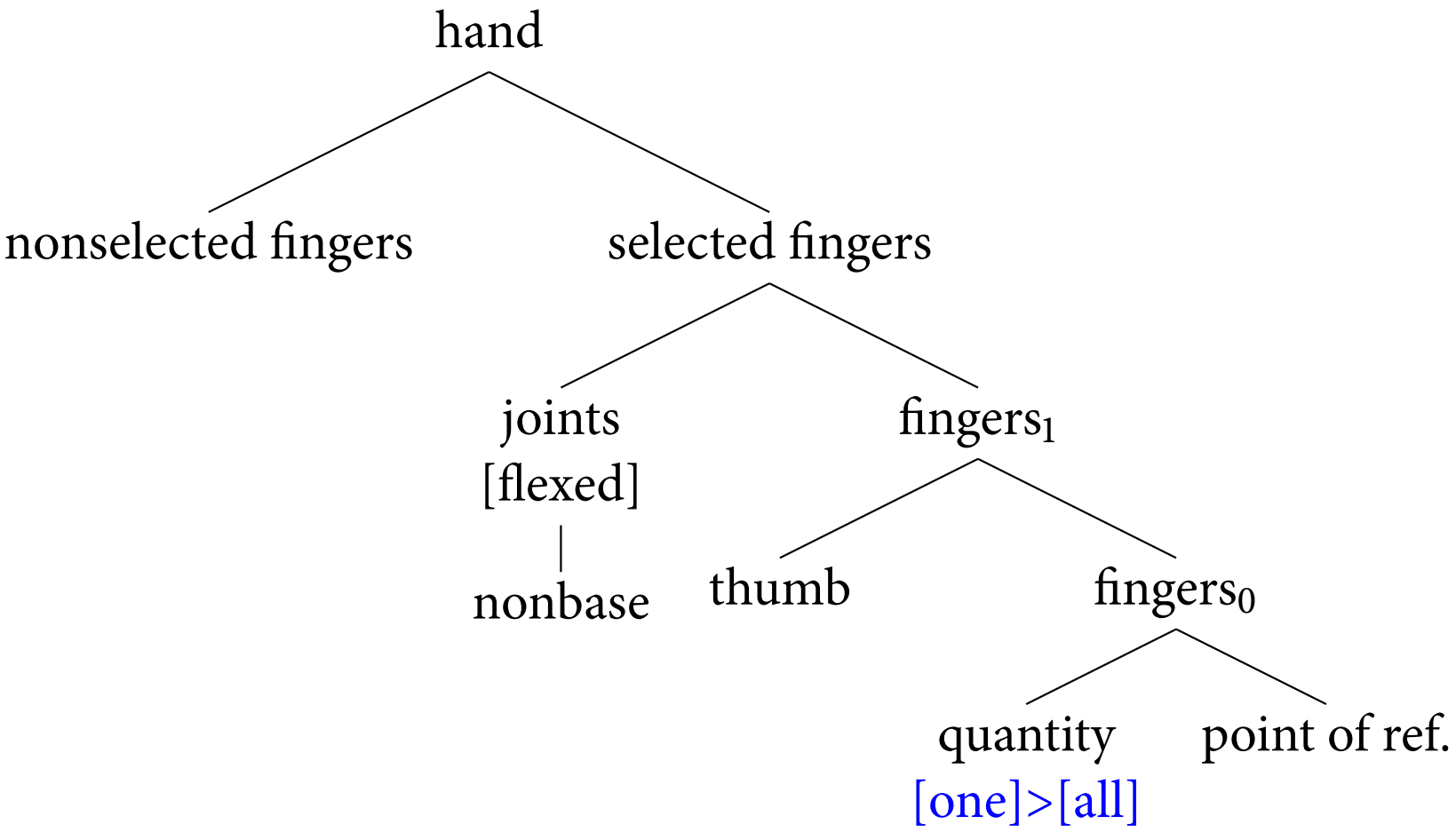
-R-


hand
nonselected fingers
[flexed]
selected fingers
joints
[crossed]
fingers1
fingers0
quantity
[one]>[all]
point of ref.
[radial]

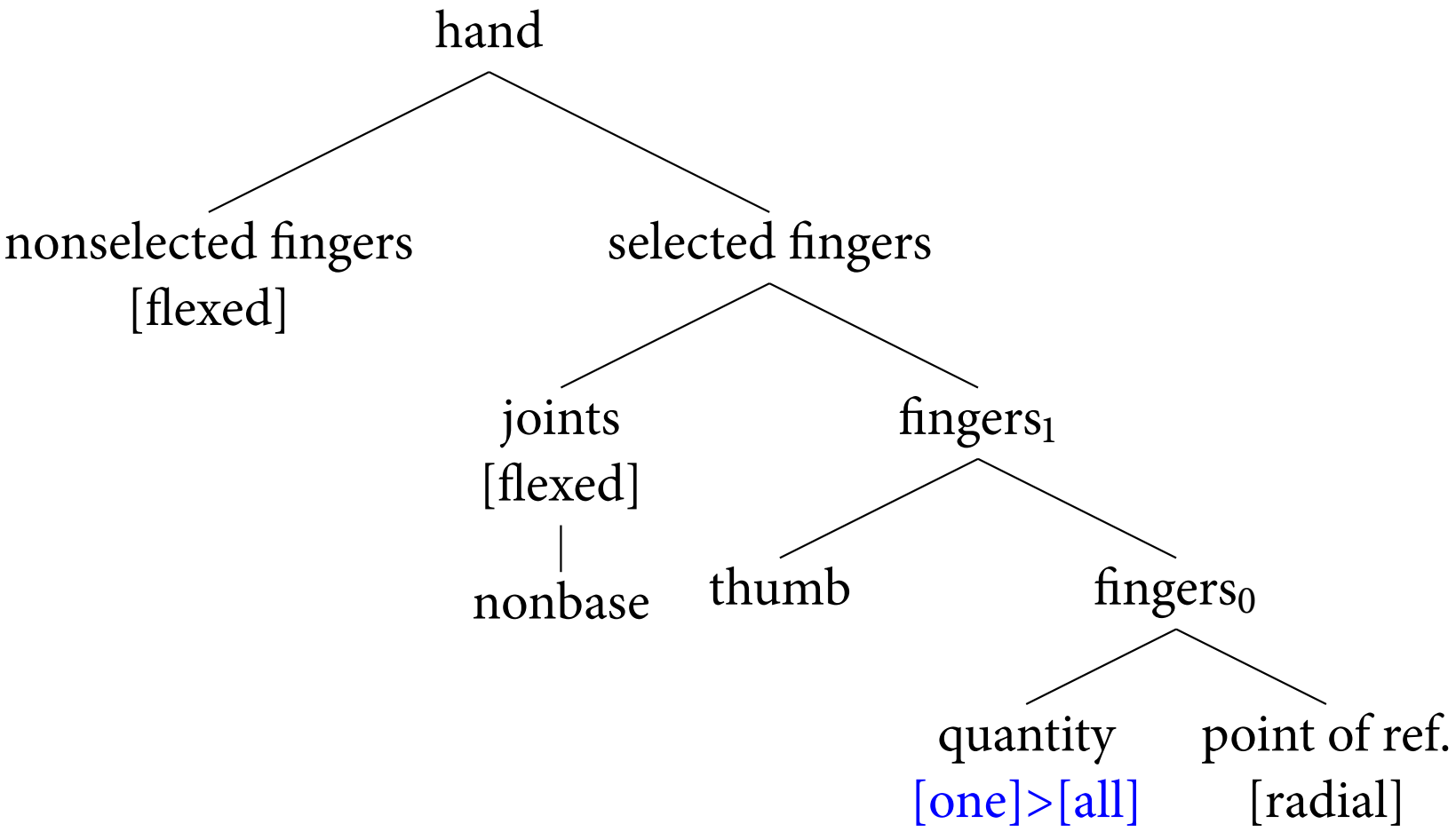
-R-


hand
nonselected fingers
[flexed]
selected fingers
joints
[crossed]
fingers1
fingers0
quantity
[one]>[all]
point of ref.
[radial]

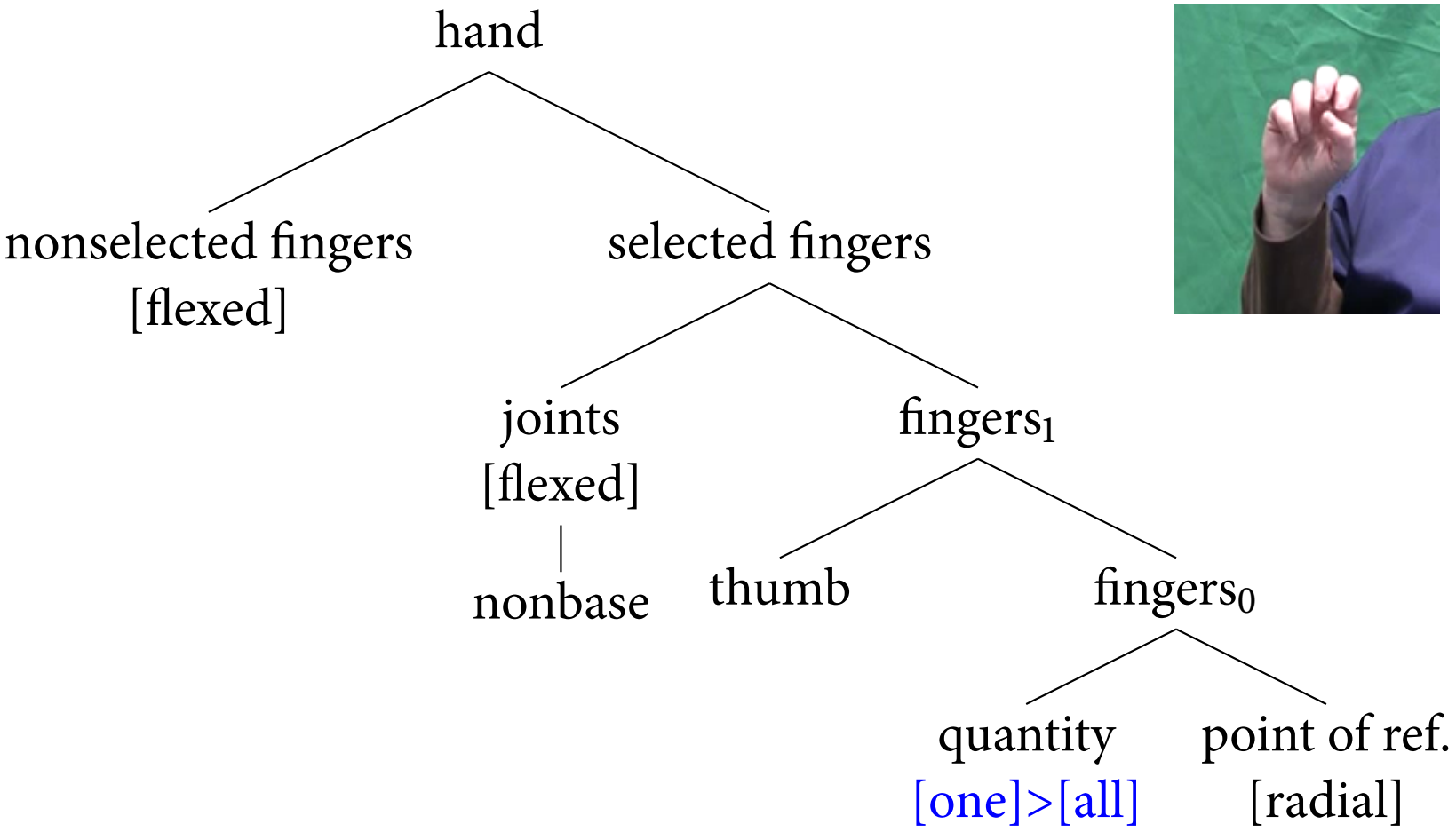
# -E- with increased ulnar digit flexion



# -E- with increased ulnar digit flexion



# -E- with increased ulnar digit flexion



# 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 no variation, but this could be physiological, (CF lexical handshape contours).
- -B- shows no variation, has all fingers extended, this might be physiological or phonological blocking (EG -U-).

# Conclusions

1. Fingerspelled -E- and -O- show signs of assimilating selected finger quantity with the handshapes of the apogees around them.
2. Selected finger quantity must be phonologically separate from joint configuration.
3. Increased ulnar digit flexion appears to be the result of a phonological process: selected finger quantity assimilation.
4. There is little variation in fingerspelled -C- and -D-.
   - -C- shows almost no flexed variants. This could be a physiological constraint.
   - -D- shows almost all flexed variants. This could just be the underlying handshape.

# Future Directions

1. More data with more signers to tease apart differences between one, two, and three selected fingers
2. Annotations at time points other than apogees for a measure of temporal gradience: if a phonological process there should be little temporal gradience.
3. Measure of articulatory ease: or why -C- doesn't vary.

# Thank you for coming.

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, and Katie Henry.

# References

Akamatsu, Carol Tane. 1982. The acquisition of fingerspelling in pre-school children. University of Rochester dissertation.

Brentari, Diane. 1998. A prosodic model of sign language phonology. The MIT Press.

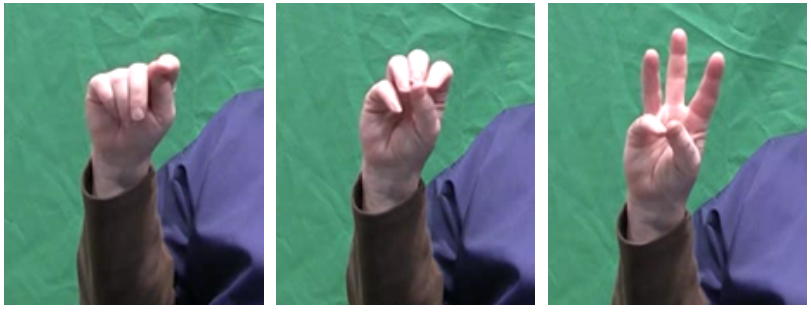
Keane, Jonathan, Susan Rizzo, Diane Brentari, and Jason Riggle. 2011. Phonetic coding of fingerspelling. presented at Building sign language corpora in North America.

Padden, Carol. 1991. Theoretical issues in sign language research, chap. The Acquisition of Fingerspelling by Deaf Children, 191–210. The University of Chicago press.

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

Wilcox, Sherman. 1992. The phonetics of fingerspelling. John Benjamins Publishing Company.

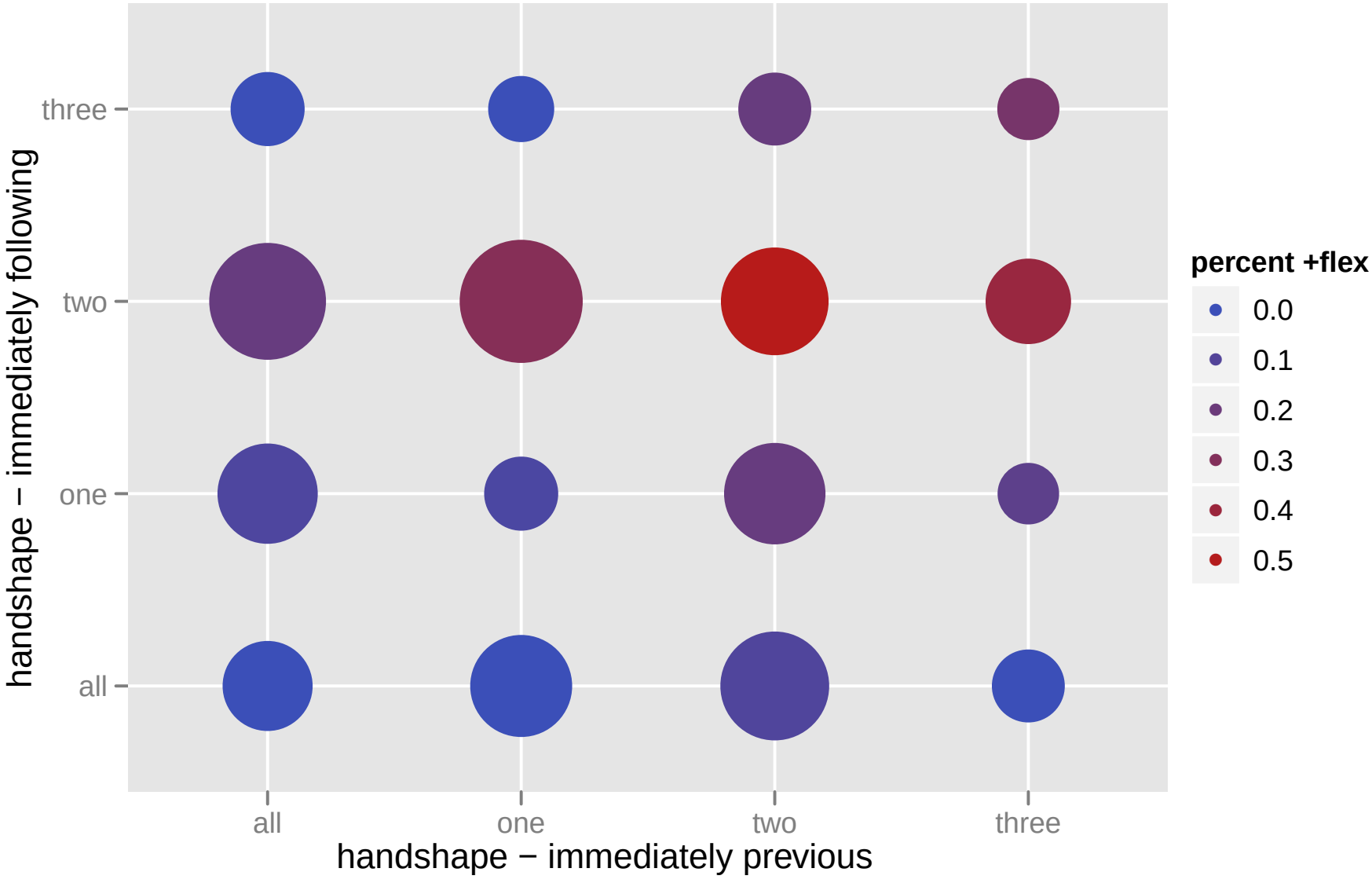
# More examples of variations variation

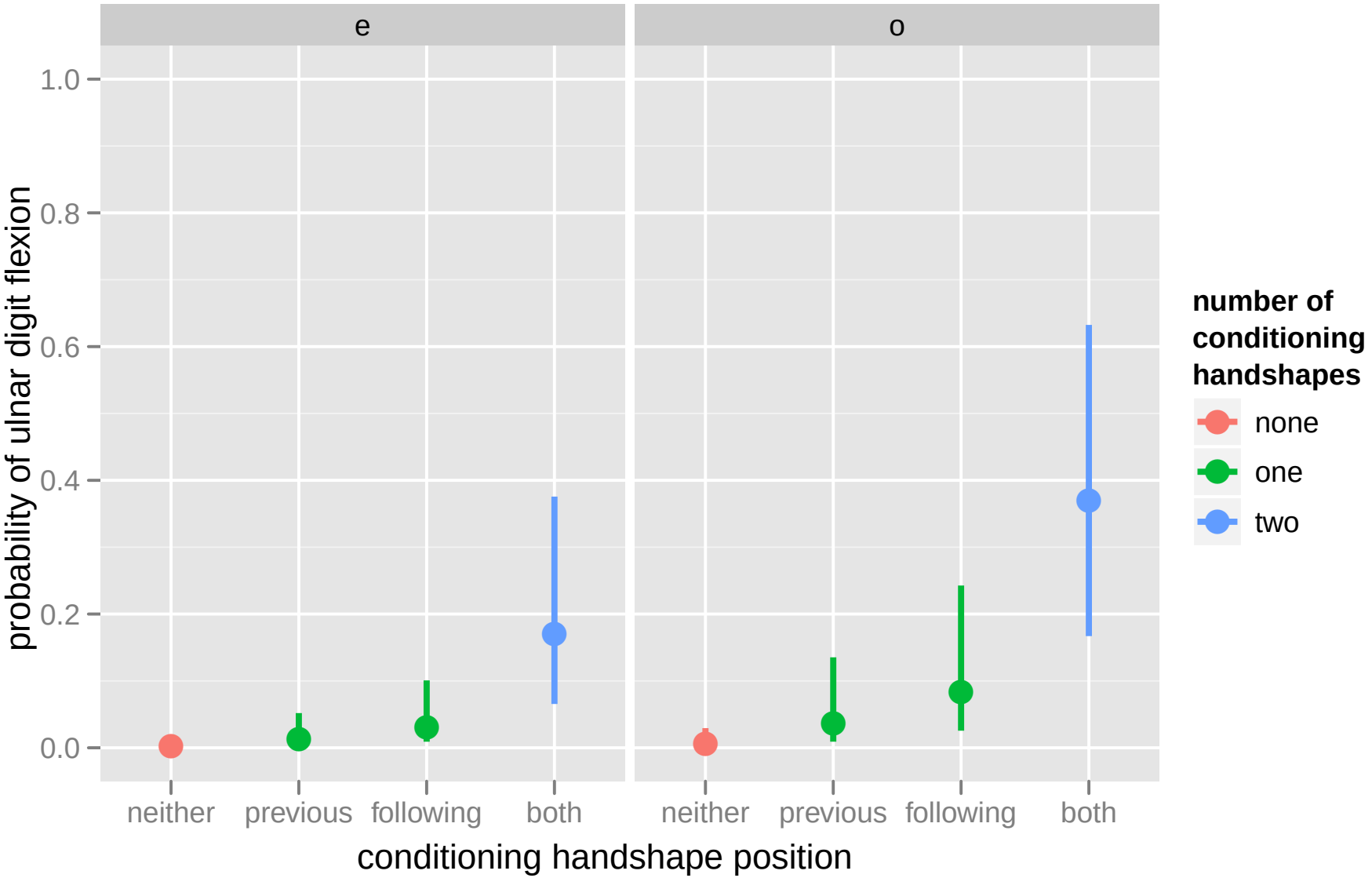


-T- -O- -W-

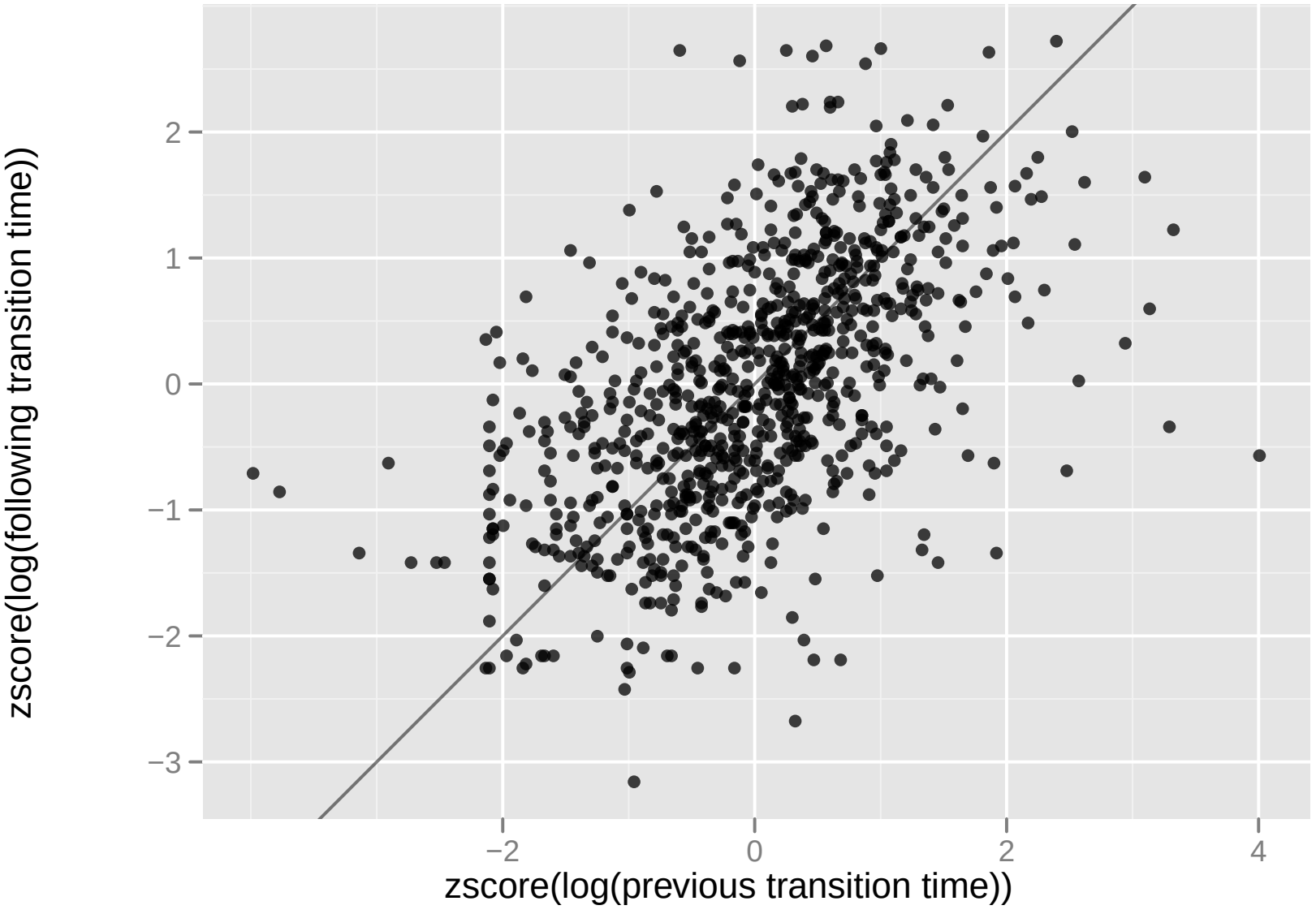
Apogees from T-O-W-N

# Flexion based on surrounding handshapes

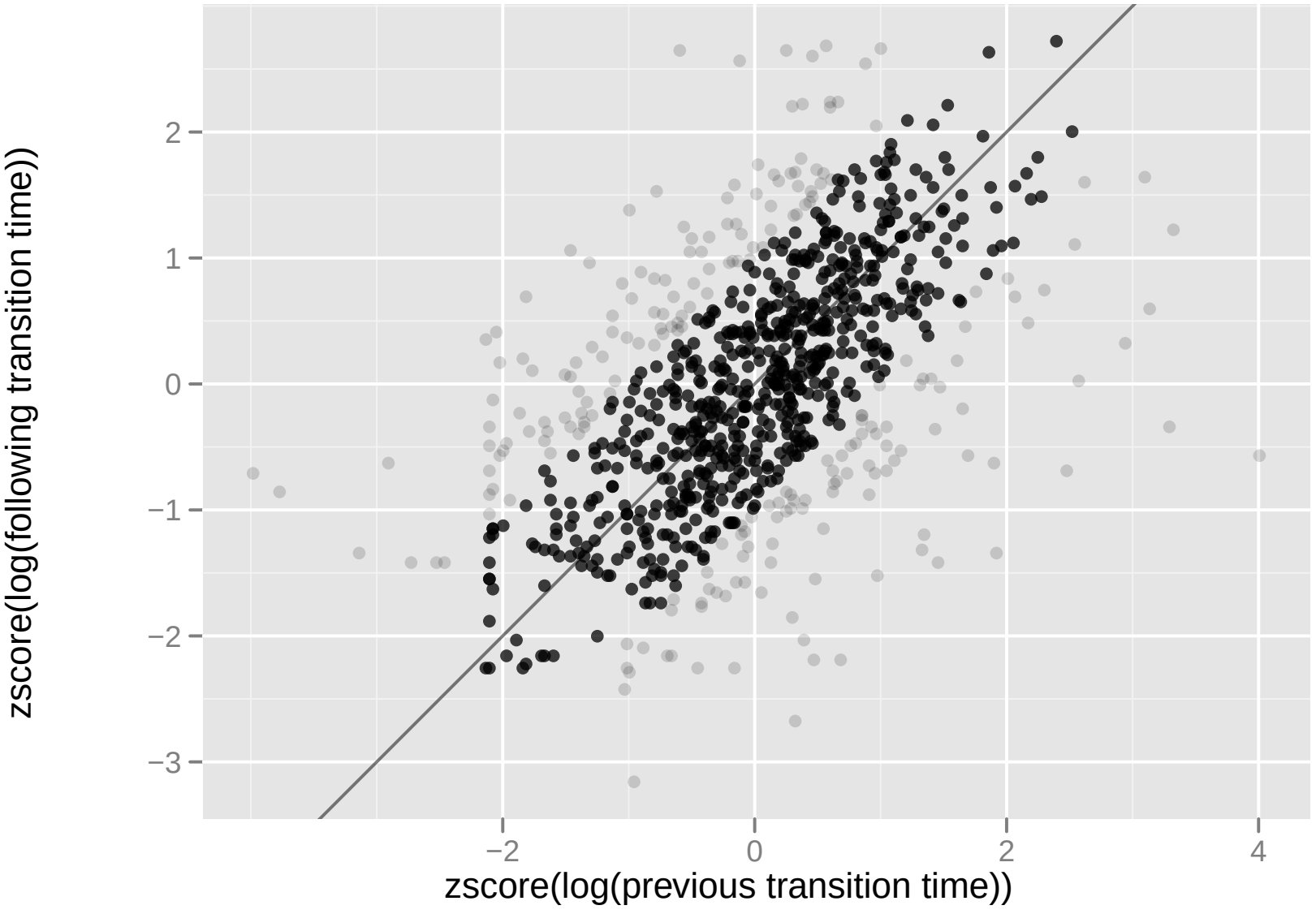



e
o
1.0
0.8
0.6
0.4
0.2
0.0
probability of ulnar digit flexion
neither
previous
following
both
conditioning handshape position
number of conditioning handshapes
none
one
two

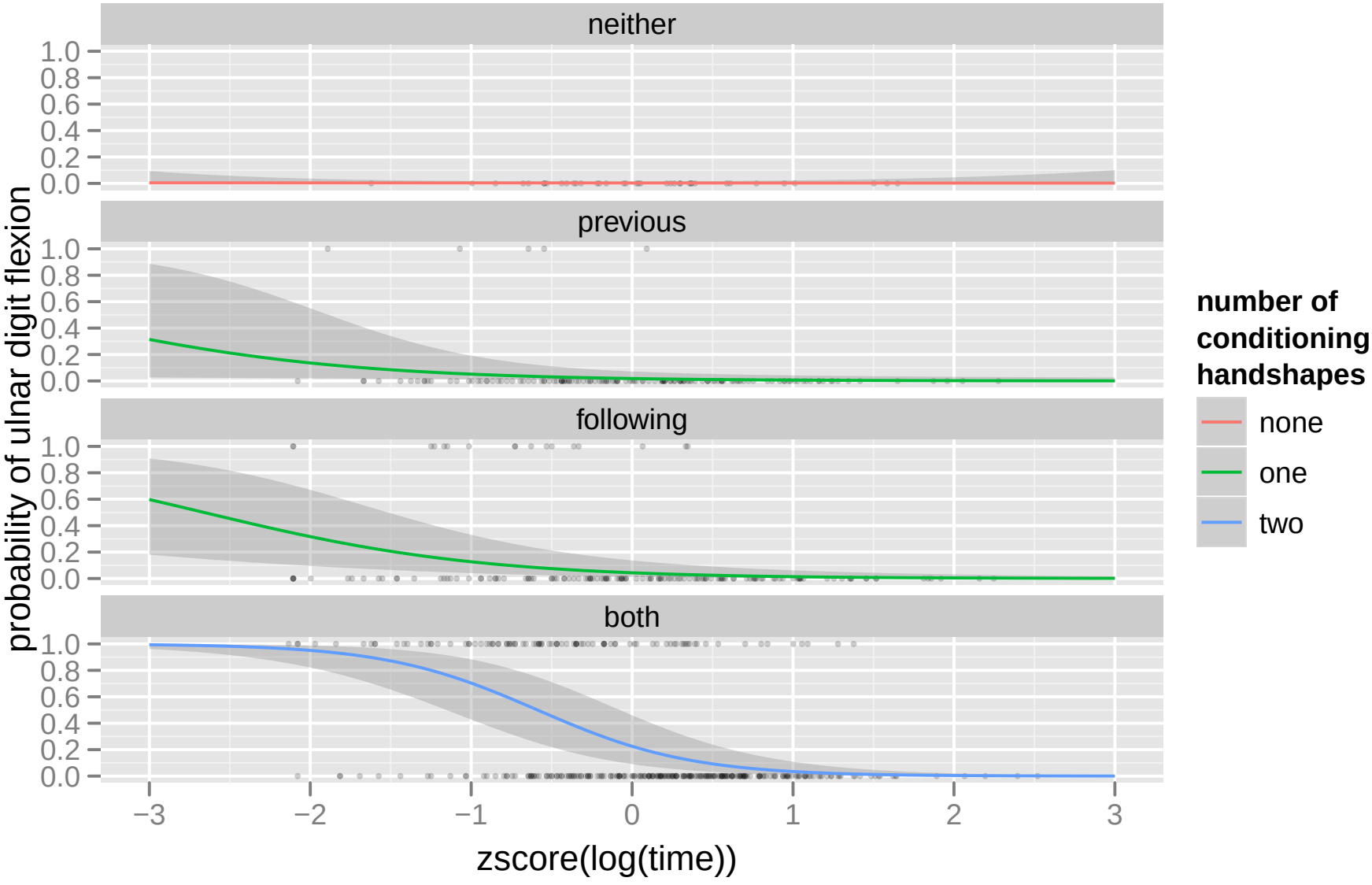
# Distribution of transition times

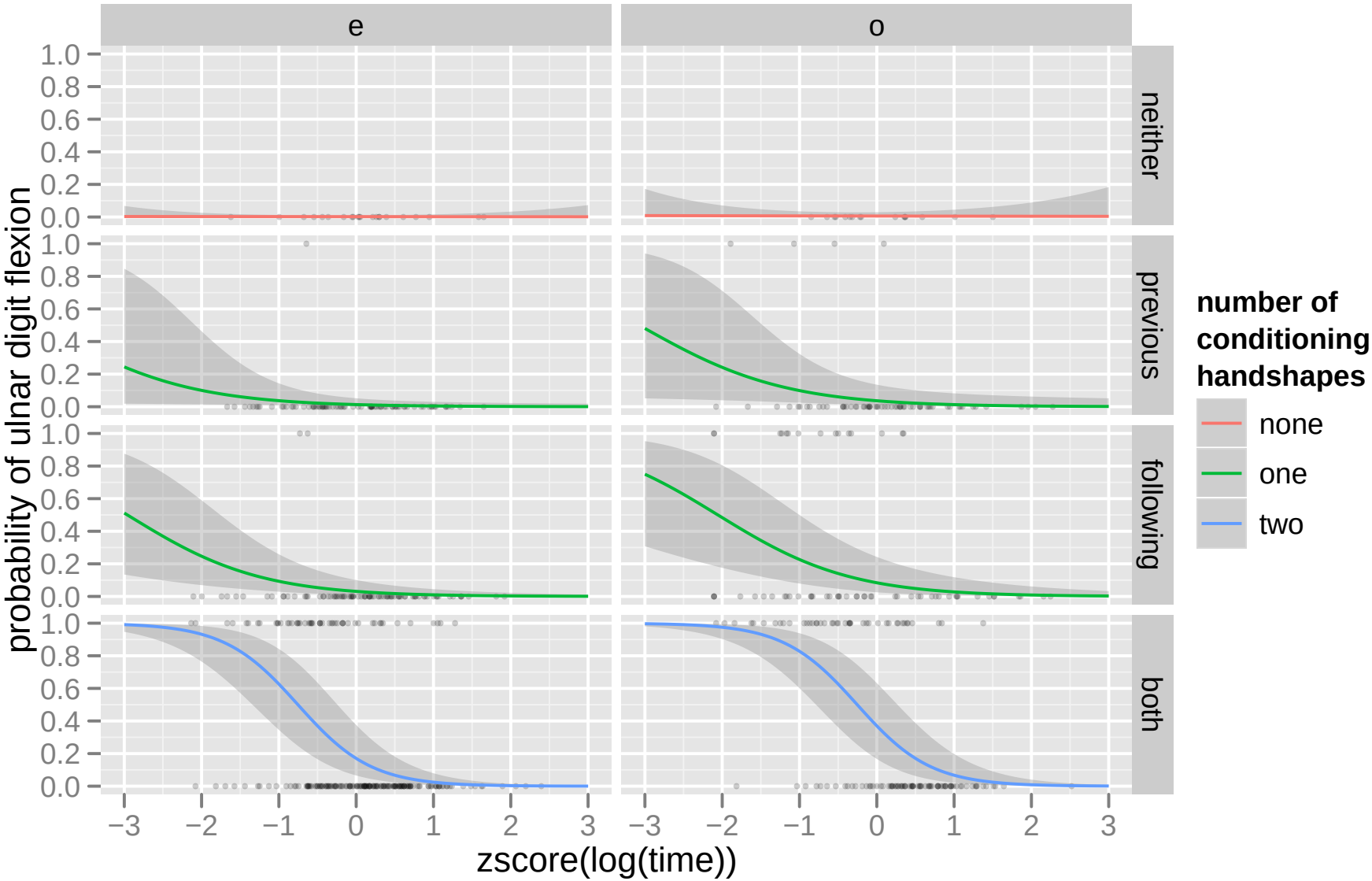


# Distribution of transition times



# Model predictions based on transition time




e
o
neither
previous
following
both
probability of ulnar digit flexion
zscore(log(time))
number of conditioning handshapes
none
one
two