

# *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: across environment, signer, handshape?
- What is the best type of explanation to capture this variation across environments?
  - phonetic – i.e., gradient
  - phonological – i.e., categorical
  - systematic use of both

# Objectives of the research

- Analyze a large corpus of fingerspelling data using automatic recognition and statistical methods (techniques from corpus linguistics)
- Formulate explanations grounded in phonetics and phonology to explain the variation
- Develop an articulatory model of handshape

# Why fingerspelling?

- It is quick and sequential, unlike handshape in signing
- The types coarticulation (especially partial assimilation) are numerous and varied.
  - Unlike *compounding*, which also involves assimilation/co-articulation, the handshapes involved in compounding are far fewer.
- It is relatively easy to obtain a high number of tokens for each type of coarticulation.

# Background of ASL fingerspelling

- 12-35% of signing
- Fingerspelling is not used equally across all word categories. (predominantly names, nouns, and to a smaller extent adjectives)
- for emphasis (Y-E-S)
- to create a distinction in meaning for the same word (PROBLEM vs. P-R-O-B-L-E-M)

The data look like this. . .



# Pinky Extension (PE) and Ulnar Flexion (UF)

- ***Handshape***: canonical configuration of the articulators for each FS-letter (“phonemic”)



- ***Hand Configuration***: the phonetic implementation of the handshape (“phone”)



# Why PE and UF?

## ■ *Phonetically similar*

- *Pinky extension (PE) Ulnar flexion (UF) both involve the pinky. UF also involves the ring finger.*
- The pinky (and ring) extensors and flexors are weaker/slower than those used of the index and middle fingers, so we can predict that there will be similarities between them and different from index and thumb behavior.

## ■ *Phonologically different*

- In PE the “triggers” are selected fingers and the “targets” are unselected,
- In UF both the “triggers” and “targets” are selected fingers



# Participants and Data Collection

- 4 adult signers have been collected
  - 3 native; 1 early learner
- 2 word lists, repeated multiple times some at “normal” and some at “careful” speed:
  - one intended to cover all possible di-phones in collected shorter and longer words (short, medium, long words)
  - CELEX list (300 of the most common English nouns)
- specific data analyzed for these studies:
  - 2 signers
  - approximately 2,400 words of “normal” speed
  - 8,115 total hand configurations
  - 7,317 medial hand configurations

# Coding: apogee detection and identification

Apogees are:

- the point where the hand reaches a target hand configuration and orientation
- the point of minimum instantaneous velocity of all of the articulators
- crucially not the canonical handshape

Human coding, algorithmic averaging, forced alignment and verification were used to create the set of apogees on which we did further analysis.

# manual coding of apogees

Still images of the apogees were extracted and then coded by humans

- Definition of pinky extension (Coded for all handshapes):
  - the proximal interphalangeal (PIP) and metacarpal phalangeal joint (MCP) extended greater than  $90^\circ$
  - fingertip perceived to be above the the plane perpendicular to the palm
- Definition of Ulnar flexion (for -C-, -D-, -E-, and -O-)
  - apogees where either the proximal interphalangeal or the metacarpophalangeal joint was more flexed in ulnar digits than radial digits.

# Pinky Extension



(a) -R- [-ext]

(b) -R- [+ext]

(c) -C- [-ext]

(d) -C- [+ext]

(e) -E- [-ext]

(f) -E- [+ext]

Figure 10: Apogees from (a) D-I-N-O-S-A-U-R, (b) C-H-R-I-S, (c) Z-A-C-K, (d) E-X-P-E-C-T-A-T-I-O-N, (e) E-V-E-R-G-L-A-D-E-S, and (f) Z-D-R-O-Q-U-E

# Pinky Extension



(a) -R- [-ext]

(b) -R- [+ext]

(c) -C- [-ext]

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# Pinky Extension

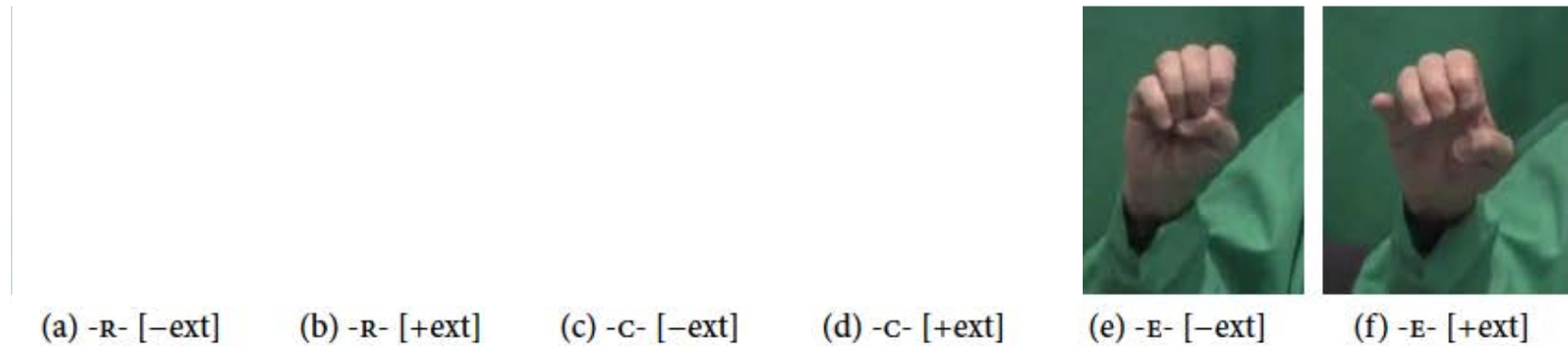


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O-I-L

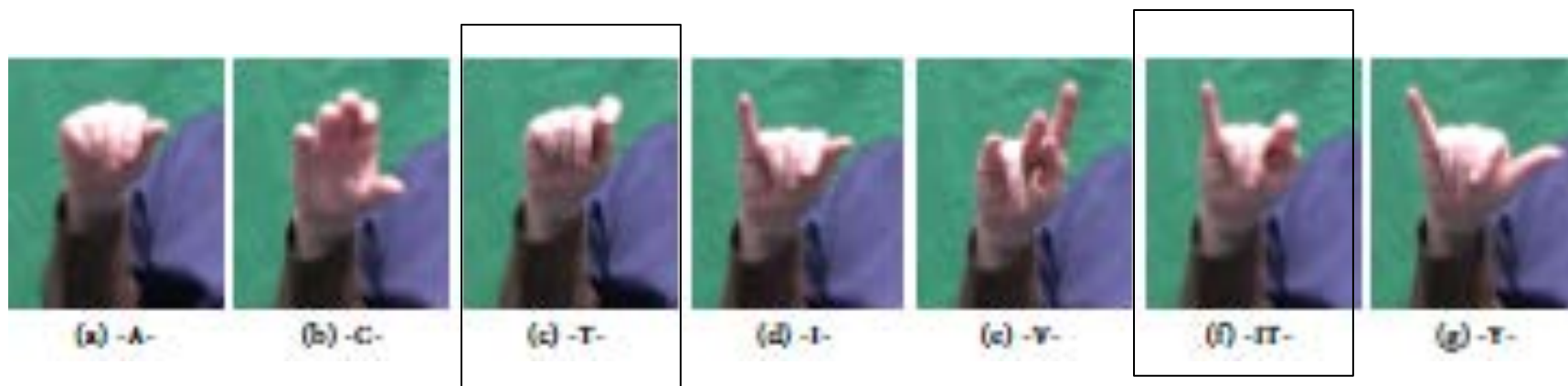


A-C-T-I-V-I-T-Y





# What effects these 2 realizations?



no PE

PE

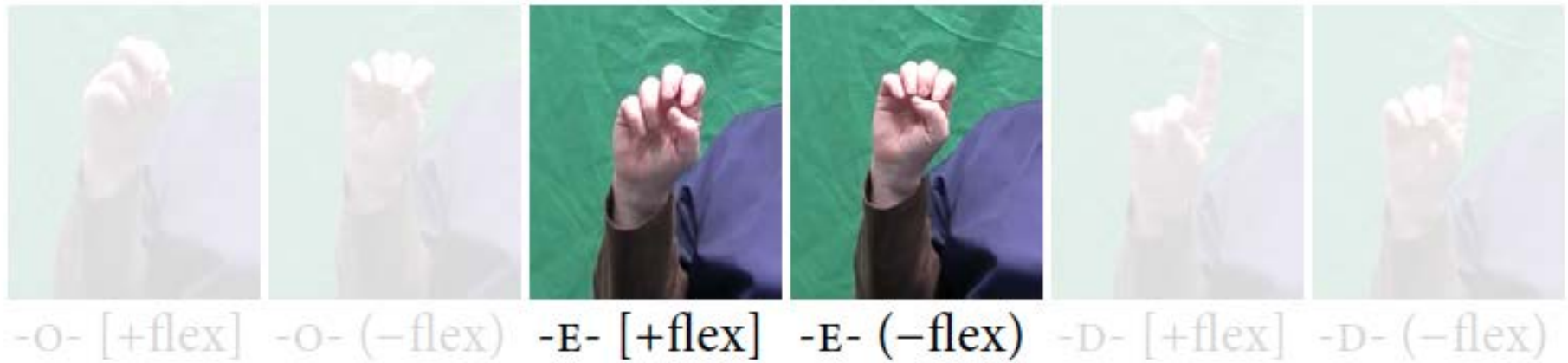
## Increased ulnar digit flexion



-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,

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G-R-O-U-N-D, and D-A-Y-S,

I-N-T-E-R-E-S-T (has increased UF)

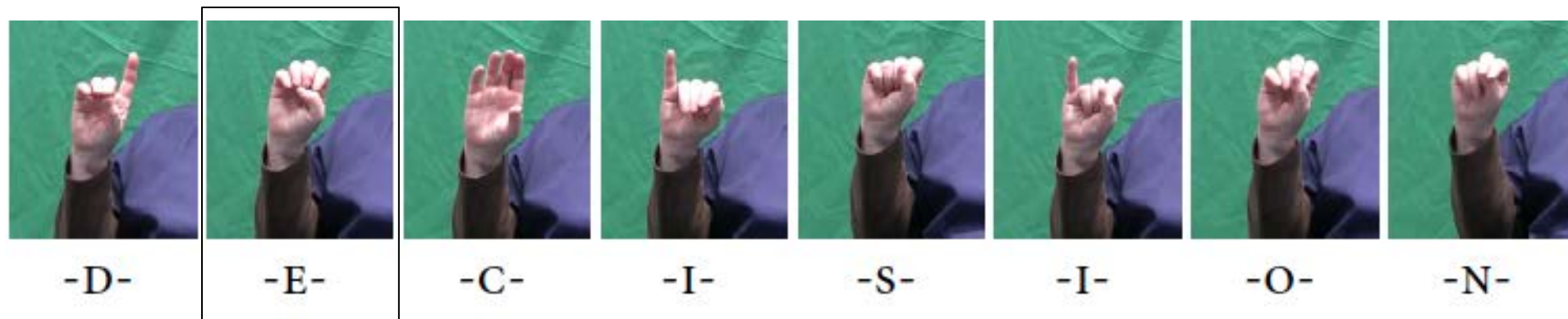
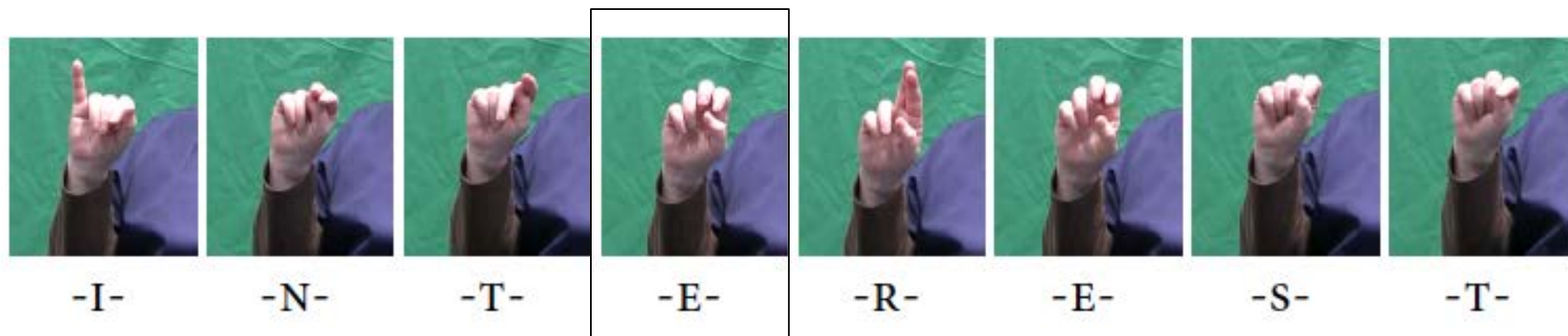


D-E-C-I-S-I-O-N (no increased UF)



# What effects these 2 realizations?

UF



no UF

# Analysis

- multilevel models
- They allow data to be pooled based on subject and item
- They allow the intercept to vary among groups



# Factors that could potentially influence pinky extension & ulnar flexion

- signer
- word type
- previous transition time
- following transition time
- previous handshape
- following handshape

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- **signer**
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- following transition time
- previous handshape
- following handshape

# phonetic effects on PE and UF

## ■ pinky extension (PE)

- previous and following hand configuration
- following transition time
- interaction of following HS with following transition time

## ■ ulnar flexion (UF)

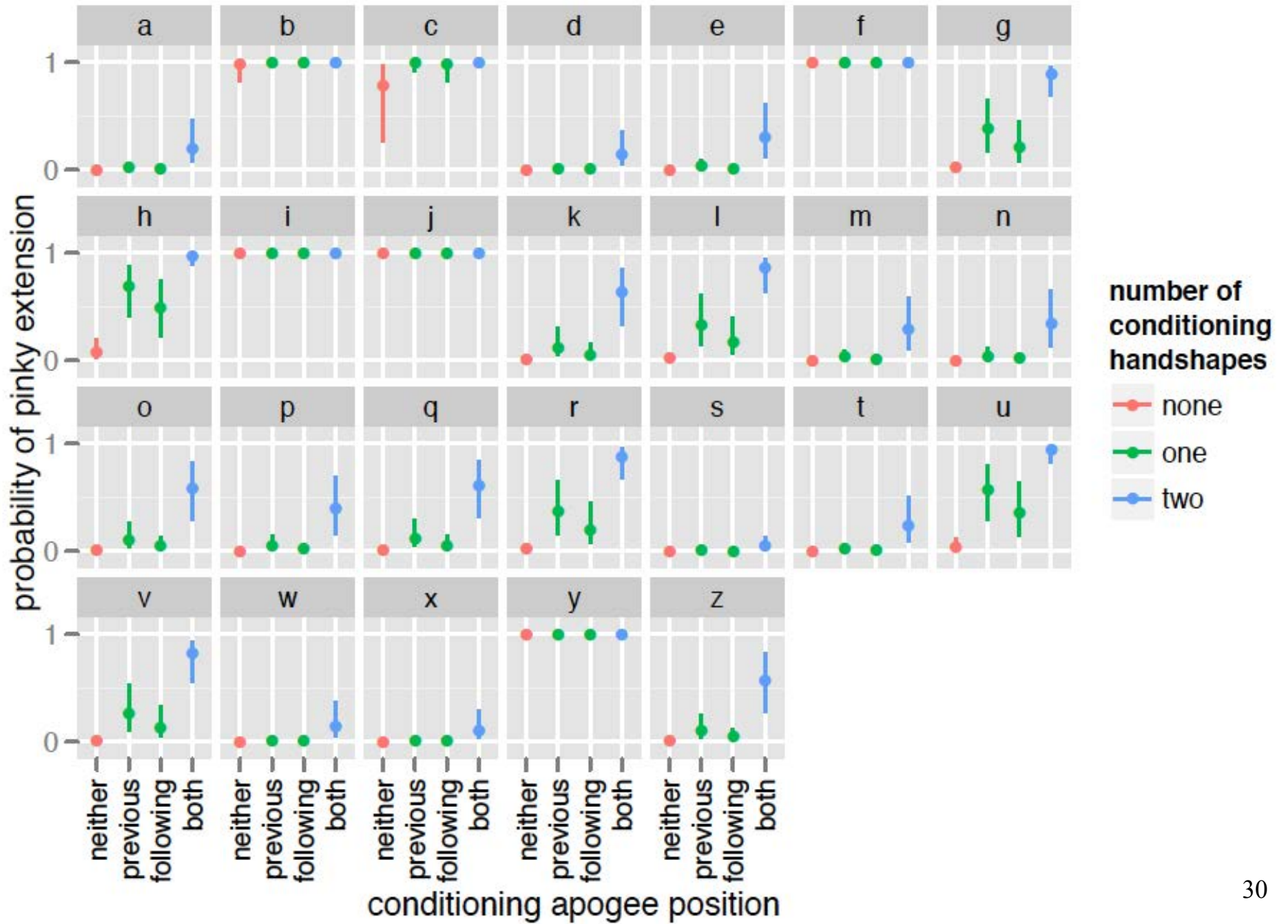
- previous and following hand configuration
- interaction of previous HS with previous transition item and following HS with transition time

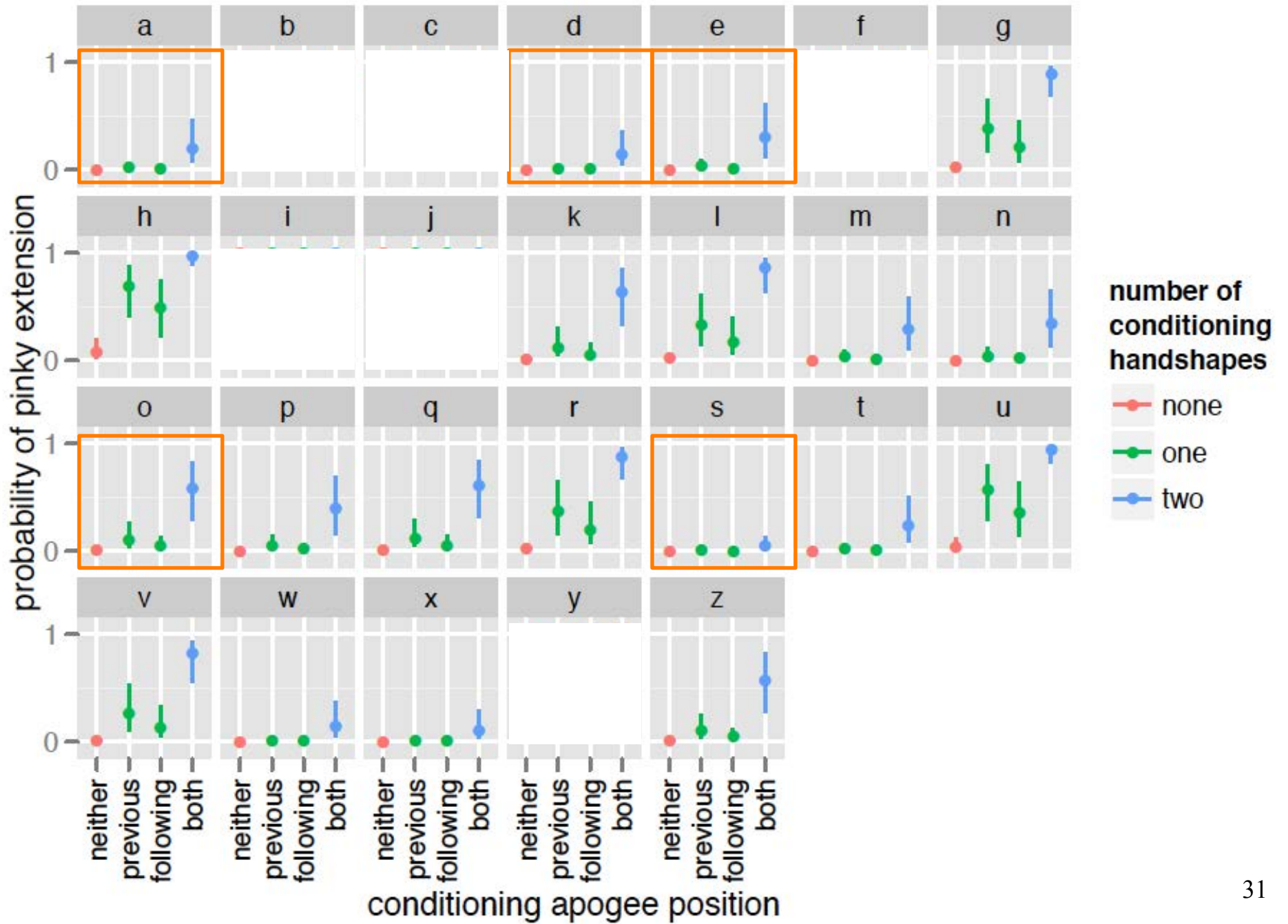
# pinky extension

	expected	unexpected
+pinky extention	1438	295
-pinky extention	49	5870

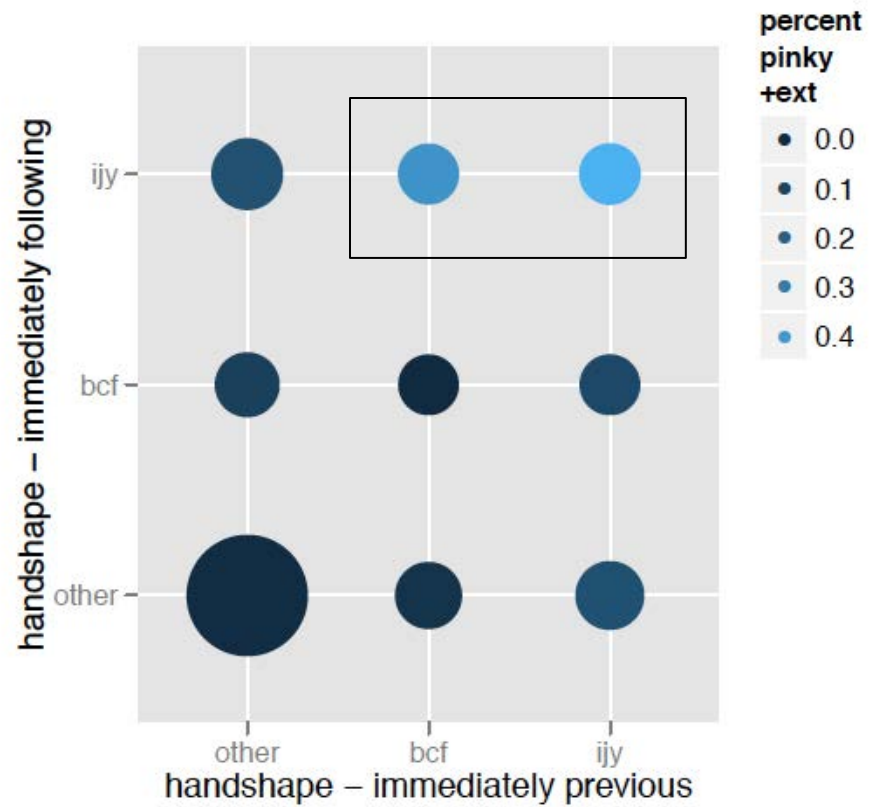
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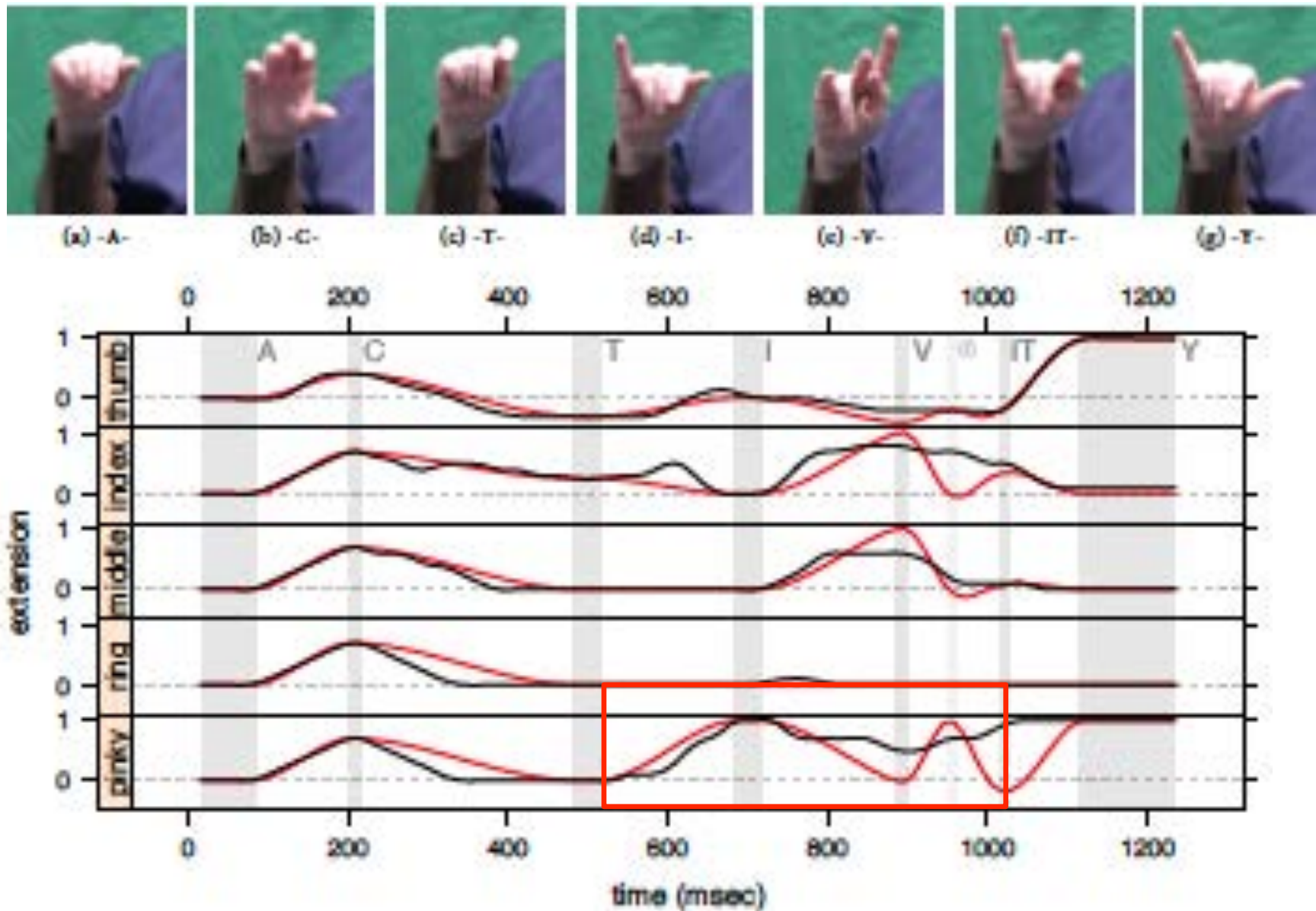


# Pinky extension





# A-C-T-I-V-I-T-Y//PE: gradient



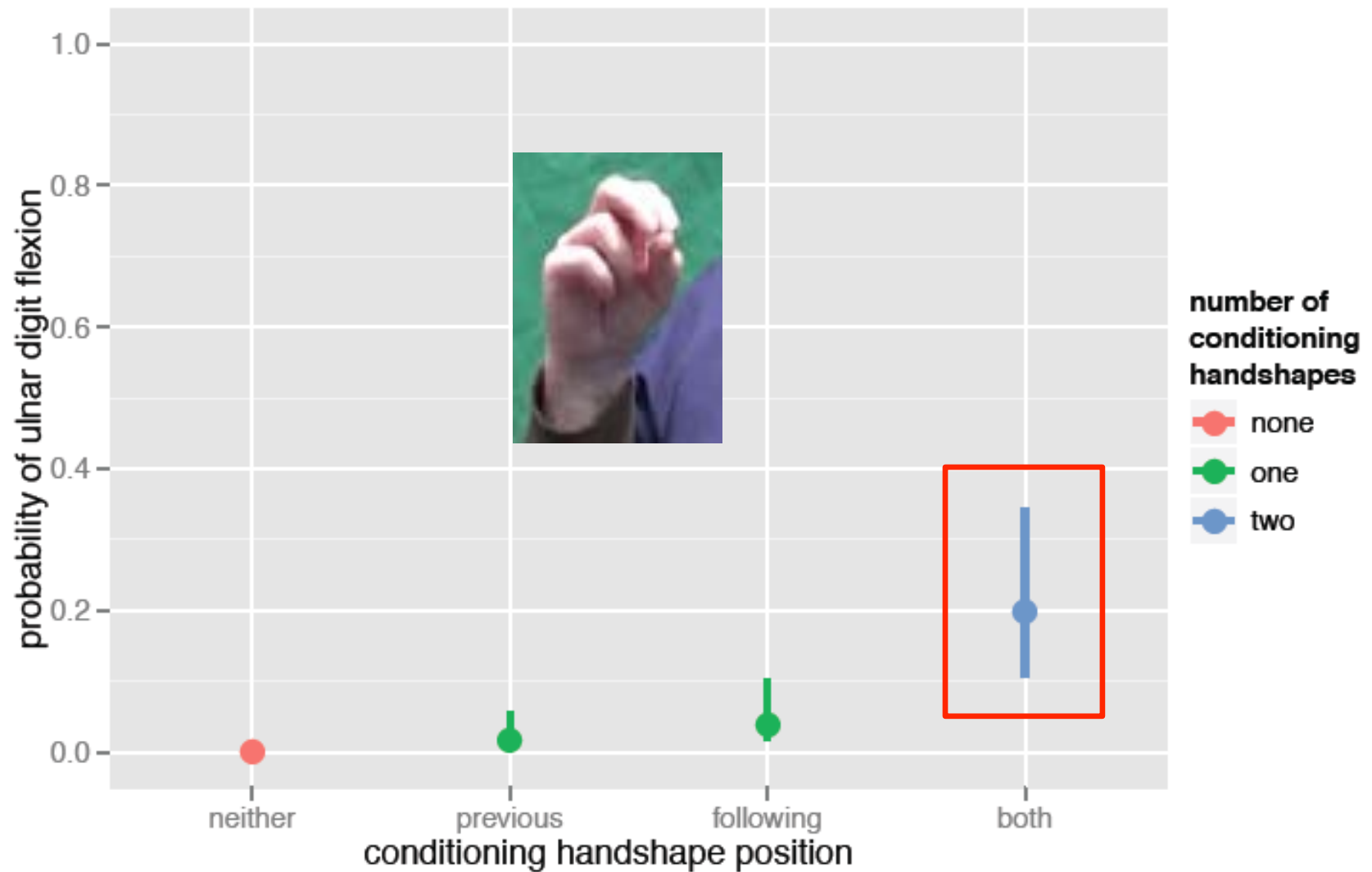
# Conclusions – pinky extension

## ■ PHONETIC

- Gradient in execution
  - affects unselected fingers more than selected fingers, but doesn't exclude any groups of fingers
  - does seem sensitive to confusions between letters and blocks PE from applying
- ..... Now we move on to **Ulnar Flexion**

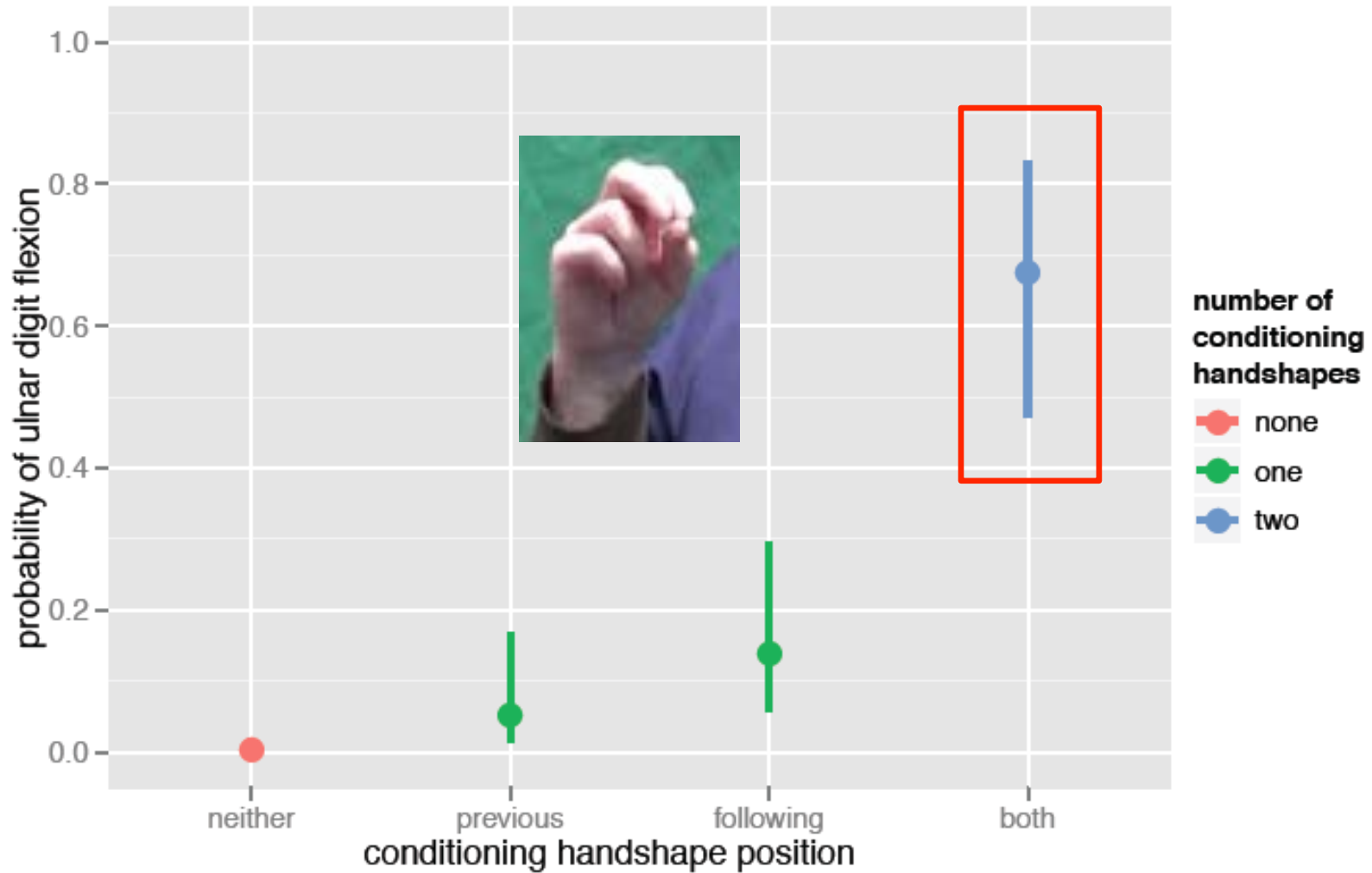
# Phonetic Effects on Ulnar Flexion

## Near conditioning handshapes, mean trans.



# Phonetic Effects on Ulnar Flexion

## Near conditioning handshapes, fast (-1 sd)

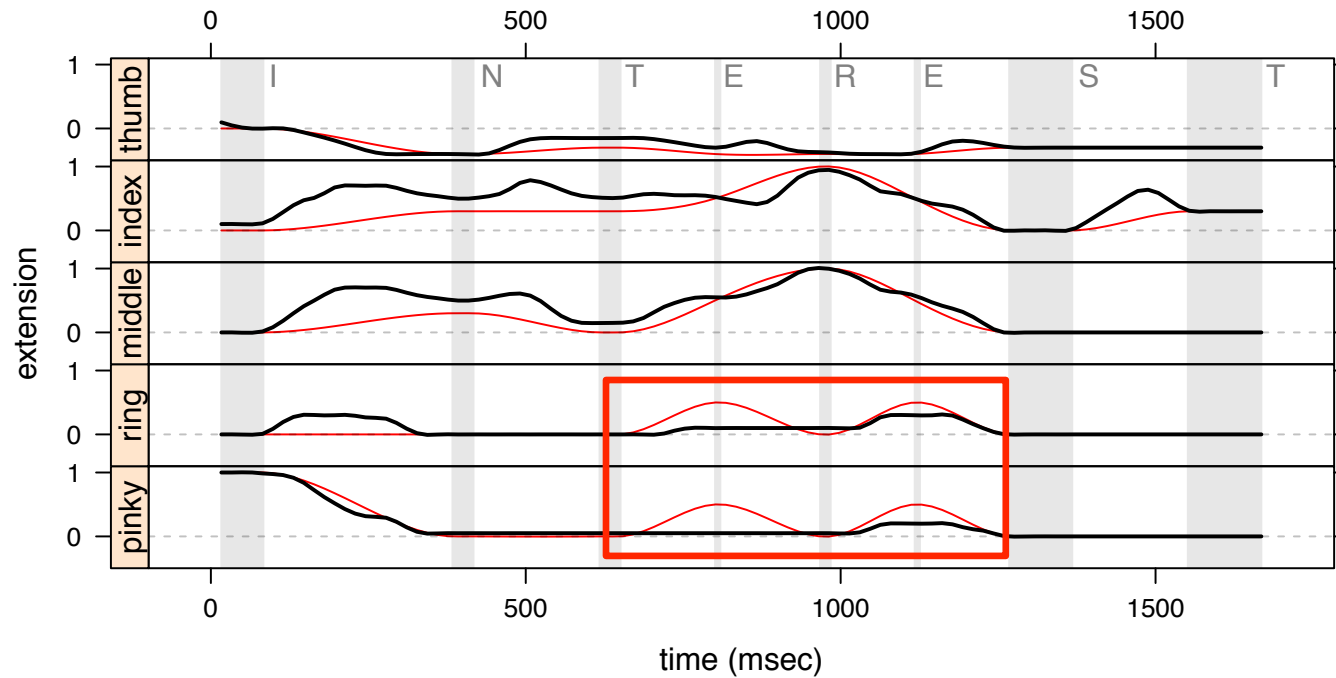


# Phonological explanations

## I-N-T-E-R-E-S-T //UF: categorical



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



## Phonological explanations

### What features encourage ulnar digit flexion?

#### SELECTED FINGERS

- with 1, 2, or 3 fingers selected
- not [all] of the fingers selected, and
- ulnar fingers not extended

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

## Phonological explanations

What features are affected by ulnar digit flexion?

### SELECTED FINGERS

--handshapes with [all] of the fingers selected

--specifically those with curved or bent joints

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-, <del>-C-</del> , -E-, -O-, and -S- targets	-F-, -I-, -J-, and -Y-		} non-conditioning

# Explanation for targets is phonetic and phonological

Of the possible handshapes that could exhibit UF because they have all fingers selected (-E-, -O-, -B-, -A-, -S- and -C-), **only -E- and -O- show effects:**

## *phonetic explanation*

- 1) -E- and -O- are partially closed already. -D- also shows UF in the variant
- 2) -B-, -A-, and -S- with fully open or closed joints are blocked; we don't see it at all. A and S are already fully closed, and fully extended fingers may be too different

## *phonological explanation*

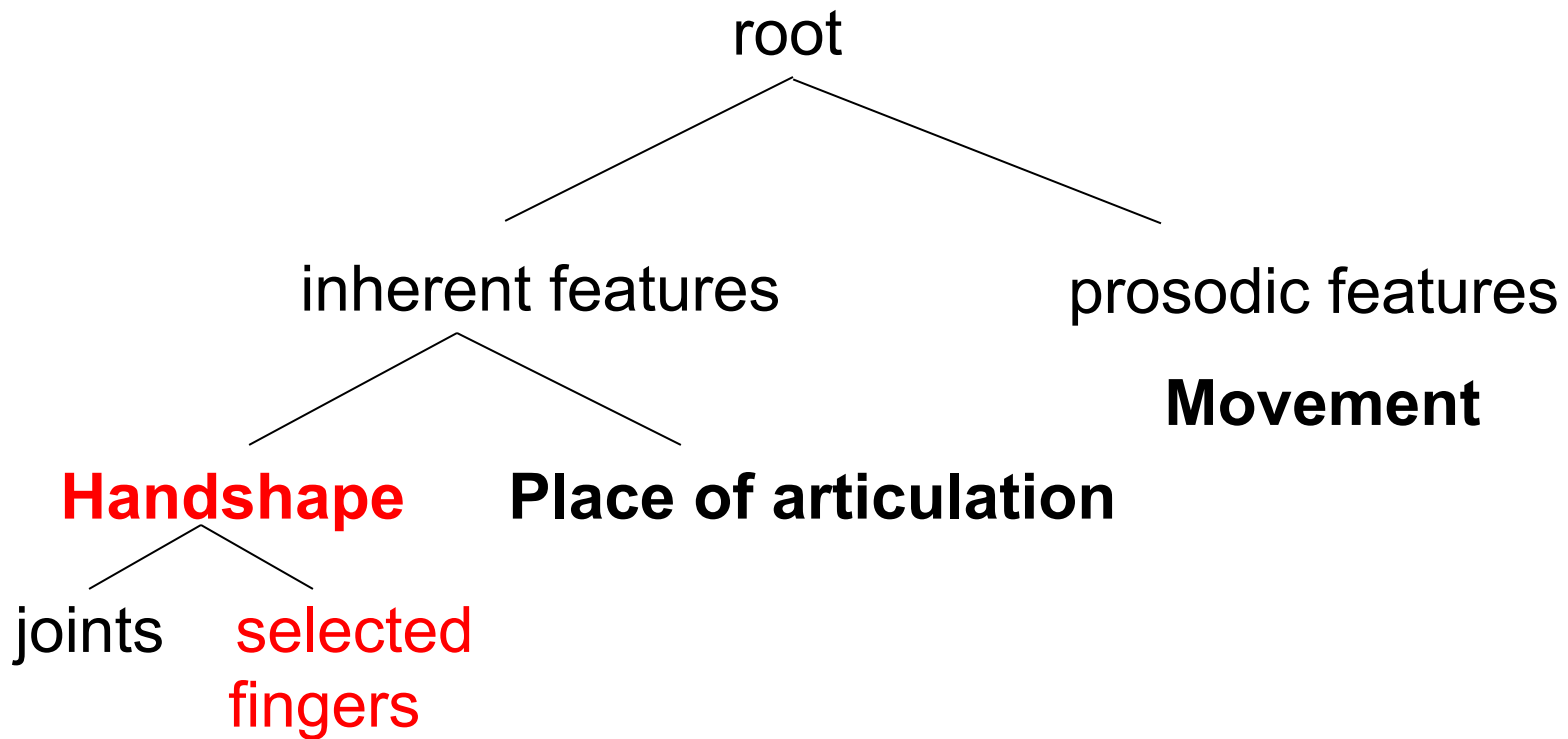
- 1) Underspecification



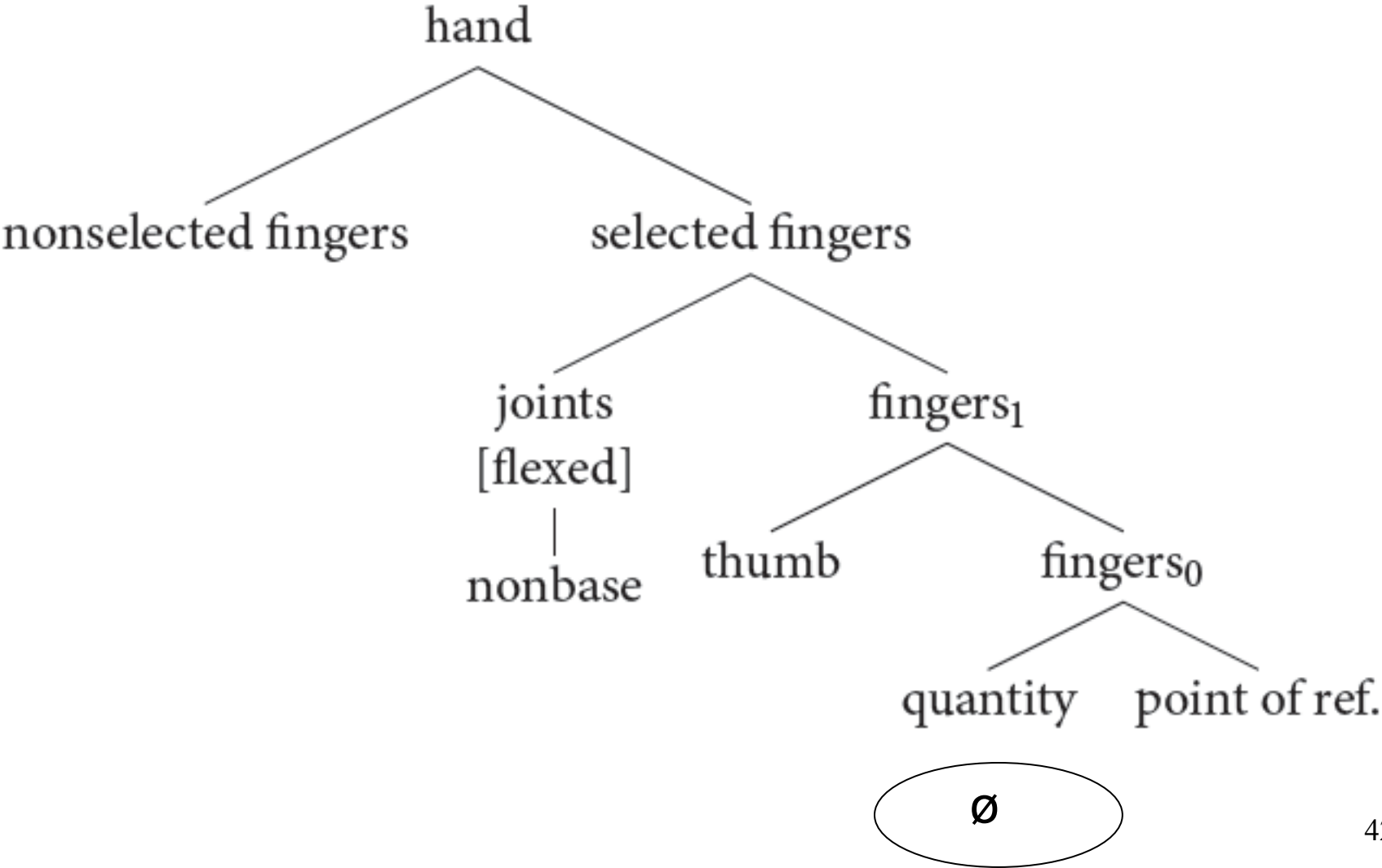
# Phonological structure

(Brentari 1998)

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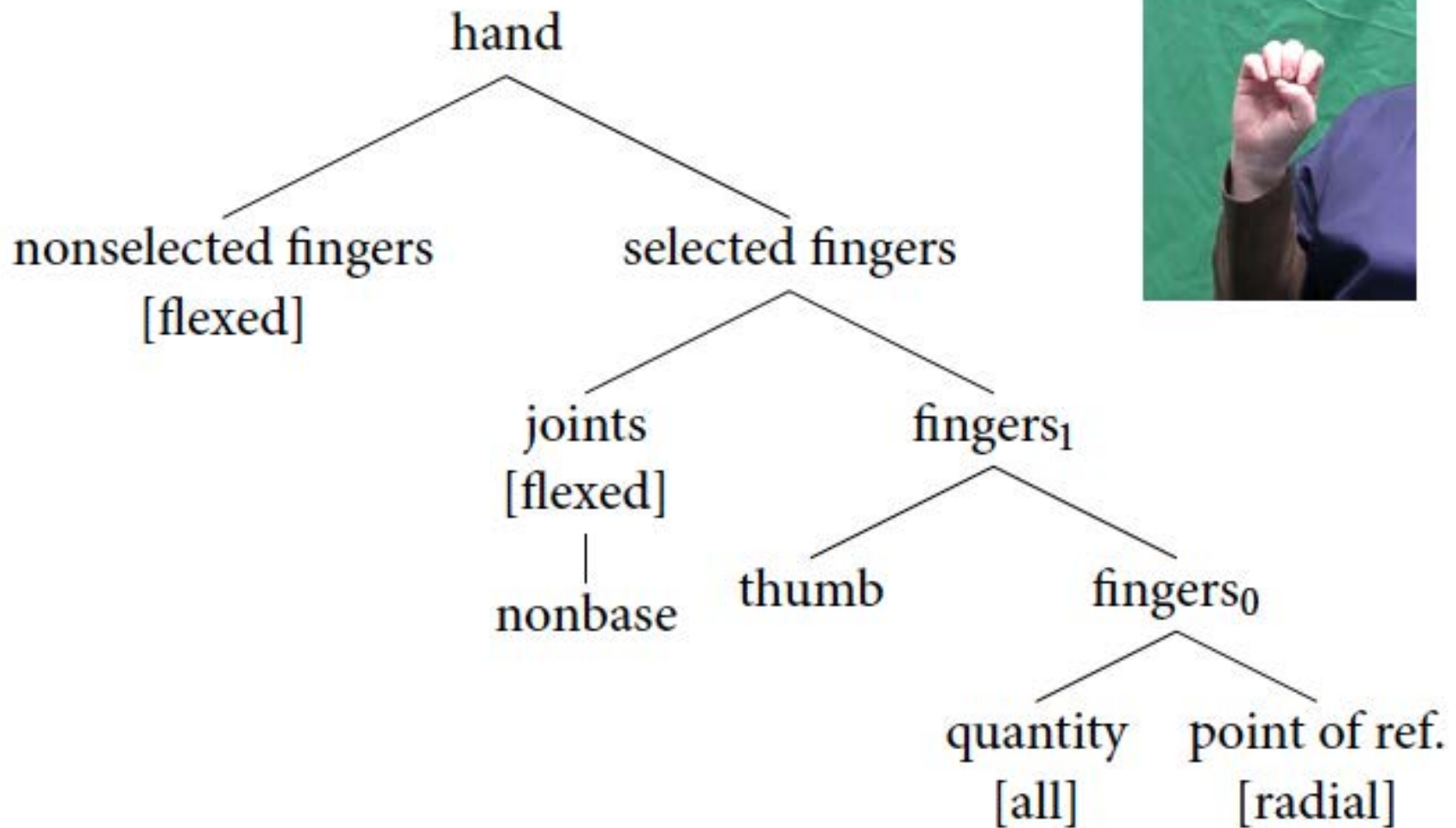


# Phonological representation of -E-



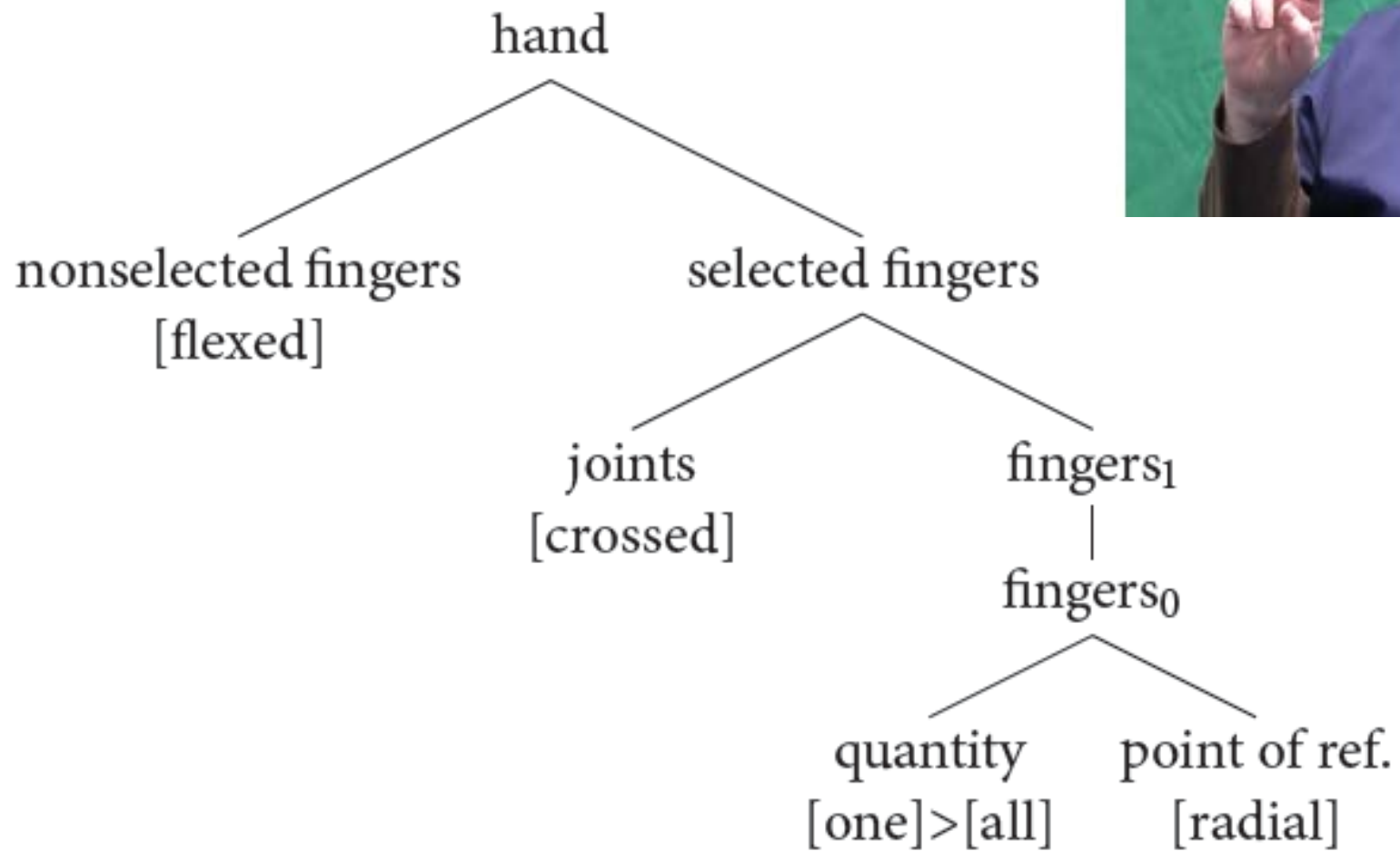
# Canonical -E- (no increased ulnar digit flexion)

## Phonetic representation



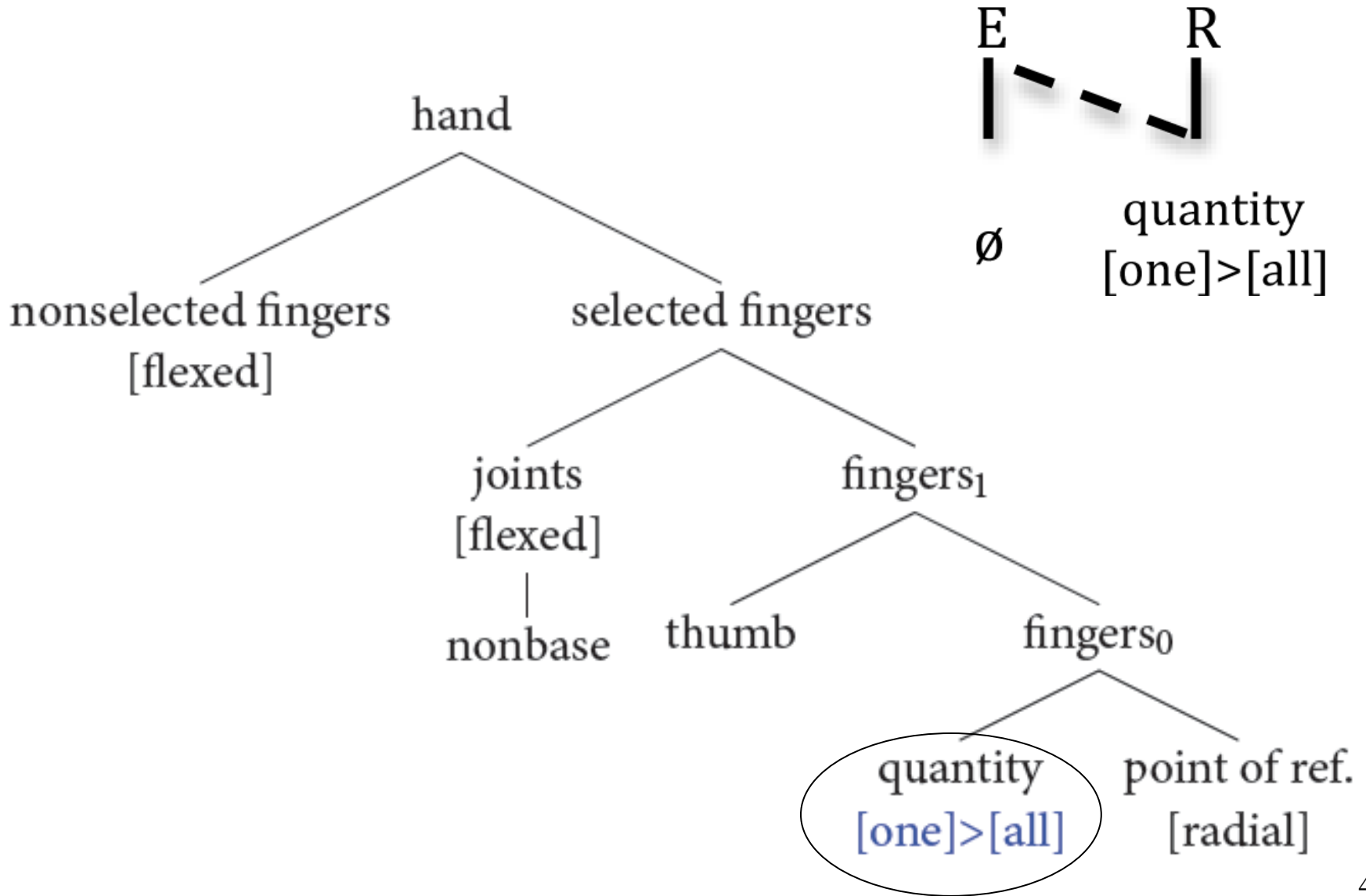
**-R-**

## Phonological representation



# -E- with increased ulnar digit flexion

## Phonetic representation



# Conclusions: Phonology vs. Phonetics

## ■ PE more phonetic

- Moves from selected fingers to unselected fingers.
- Gradient changes across the signal, but
- Possible phonological blocking if PE would create letter confusion

## ■ UF is more phonological

- Moves from selected fingers to selected fingers.
- Categorical timing effects
- Underspecification

# Conclusions: Phonetics

- There are certainly phonetic effects that can only be understood better by doing analyses that have a close connection to the data:
  - A better sense of which sub-parts of the hand work best together
  - Develop a model of the kinematics of the hand as it is fingerspelling: e.g., slower vs. faster

# Future work

- Understanding the gradient and categorical nature of selected and unselected fingers
- Understanding how long fingerspelled words are broken up
  - By number/type of movements
    - ASL structure – i.e., SL syllables
  - By English phonological principles
    - by English syllable structure
    - by English morphological structure





# Acknowledgments

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  - Drucilla Ronchen, Andy Gabel, Rita Mowl, Robin Shay
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