Exploring voice onset time, place of articulation, and vowel context in children

MONTCLAIR STATE UNIVERSITY

Elaine R. Hitchcock[a], Laura L. Koenig[b,c], Laura Ochs[a]

[a] Montclair State University, [b] Adelphi University, [c] Haskins Laboratories

Haskins Laboratories — THE SCIENCE OF THE SPOKEN AND WRITTEN WORD

Introduction

- Voicing acquisition in English-learning children has been widely studied using VOT [1]: the interval between oral release and the onset of glottal vibration.
- VOT has been found to vary according to place of articulation [POA] (velar > alveolar > bilabial) and vowel context.
- However, magnitudes of the effect vary across studies and the nature of the vowel effect is not clear [2–7].
- Little data on children (but cf. [8-9])
- No past work has evaluated the degree to which such effects are consistent over time for a single speaker.

- **Purpose**
  - To explore how VOT varies in children...
    - with consonant POA
    - with vowel
    - over time

Participants

- 13 typically-developing, monolingual, English speaking children.
- Ages 3;4-7;6 at study onset.
- Inclusion criteria:
  - Within normal limits on standardized speech and language assessments, oral mechanism exam, and hearing screening.

Design

- Participants were recorded every 2-4 weeks for 10 months, for a total of 18 sessions.
- VOT was measured in CV/CVC monosyllabic minimal pairs:

  beach-peach   *boo-pooh*
  dock-tock   *doe-toe*
  gay-kay   *goat-coat*

- 18+ tokens each of /b, p, d, t, g, k/ was attempted in each session.

- A total of ***29,504*** tokens were included for analysis.

Stimuli and Recording

- Stimuli were randomized and presented in PowerPoint.
- Verbal prompts were used to elicit responses.
- Recordings were made in a quiet room using a Marantz (PMD660) digital recorder.
- Data subsequently transferred to the Kay Pentax Computer Speech Laboratory (Model 4500) for analysis using both an acoustic waveform and spectrogram.

Participants' Age Distribution

Age in Years: 3;4-3;11

Participants	Gender	40	41	42	43	44	45	46	47
PE	M	√	√	√	√	√	√	√	√
PF	F					√	√	√	√
SL	F								
AC	M								
PC	F								
AN	F								
SJ	F								
SC	F								
GM	M								
SN	M								
SG	F								
AB	F								
HL	F								

Age in Years: 4;0-4;11

Participants	48	49	50	51	52	53	54	55	56	57	58	59
PE	√	√										
PF	√	√	√	√	√	√						
SL		√	√	√	√	√	√	√	√	√	√	
AC							√	√	√	√	√	√
PC												
AN												
SJ												
SC												
GM												
SN												
SG												
AB												
HL												

Age in Years: 5;0-5;11

Participants	60	61	62	63	64	65	66	67	68	69	70	71
PE												
PF												
SL												
AC	√	√	√	√								
PC				√	√	√	√	√	√	√	√	√
AN				√	√	√	√	√	√	√	√	√
SJ							√	√	√	√	√	√
SC							√	√	√	√	√	√
GM										√	√	√
SN												
SG												
AB												
HL												

Age in Years: 6;0-6;11

Participants	72	73	74	75	76	77	78	79	80	81	82	83
PE												
PF												
SL												
AC												
PC	√											
AN	√											
SJ	√	√	√	√								
SC	√	√	√	√								
GM	√	√	√	√	√	√	√					
SN		√	√	√	√	√	√	√	√	√	√	
SG												√
AB												
HL												

Age in Years: 7;0-7;11

Participants	84	85	86	87	88	89	90	91	92	93	94	95
PE												
PF												
SL												
AC												
PC												
AN												
SJ												
SC												
GM												
SN												
SG	√	√	√	√	√	√	√	√	√			
AB				√	√	√	√	√	√	√	√	√
HL						√	√	√	√	√	√	√

Age in Years: 8;0-8;2

Participants	96	97	98
PE			
PF			
SL			
AC			
PC			
AN			
SJ			
SC			
GM			
SN			
SG			
AB	√		
HL	√	√	√

Group Patterns

Vowel Effects on VOT

	Vowel	Mean (ms)	SD	t	df	Sig. (2-tailed)	%
/b/	/u–i/	-3.68	21.99	-2.558	233	0.011	46%
/d/	/o–a/	-5.94	20.72	-4.385	233	0.000	48%
/g/	/o–e/	-3.23	20.70	-2.389	233	0.018	53%
/p/	/u–i/	6.05	14.33	6.456	233	0.000	70%
/t/	/o–a/	15.61	17.24	13.851	233	0.000	87%
/k/	/o–e/	-5.32	12.58	-6.469	233	0.000	65%

- Paired-samples t-tests were significant for all vowel comparisons.
- Vowel height (mid vs. low) shows the clearest effect on VOT.
- Direction as predicted for /t/ but not /d/.
- /to-ta/ difference observed quite consistently (87% of cases).
- Front/back differences are less consistent.

POA Effects on VOT

POA	Mean (ms)	SD	t	df	Sig. (2-tailed)	%
/d–b/	6.25	15.02	6.363	233	0.000	71%
/g-d/	2.94	12.75	3.532	233	0.000	72%
/t-p/	5.90	9.78	9.230	233	0.000	75%
/g-t/	6.19	9.91	9.547	233	0.000	76%

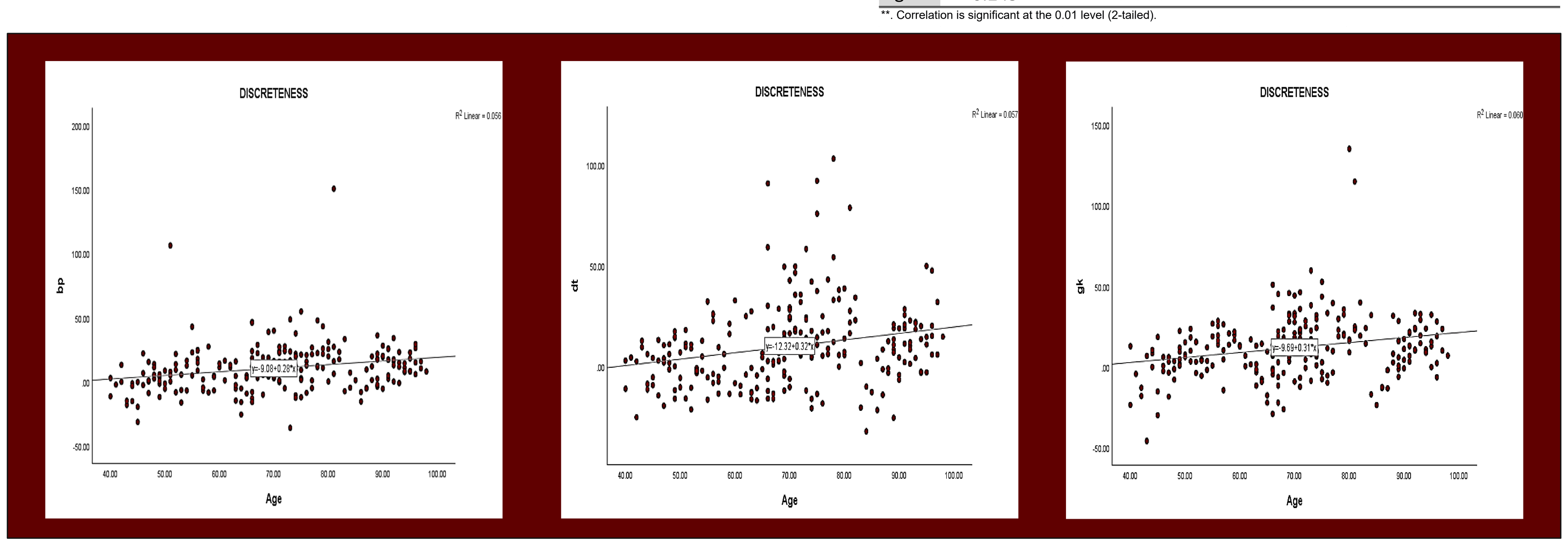
- Paired-samples t-tests were significant for all POA comparisons.
- Average POA effects are robust: velar > alveolar > bilabial.
- Differences are quite consistent: >70% of all comparisons show expected effect.

Discreteness by Age and POA

- Age and discreteness of VOT distributions were positively correlated per POA using token by token analyses.

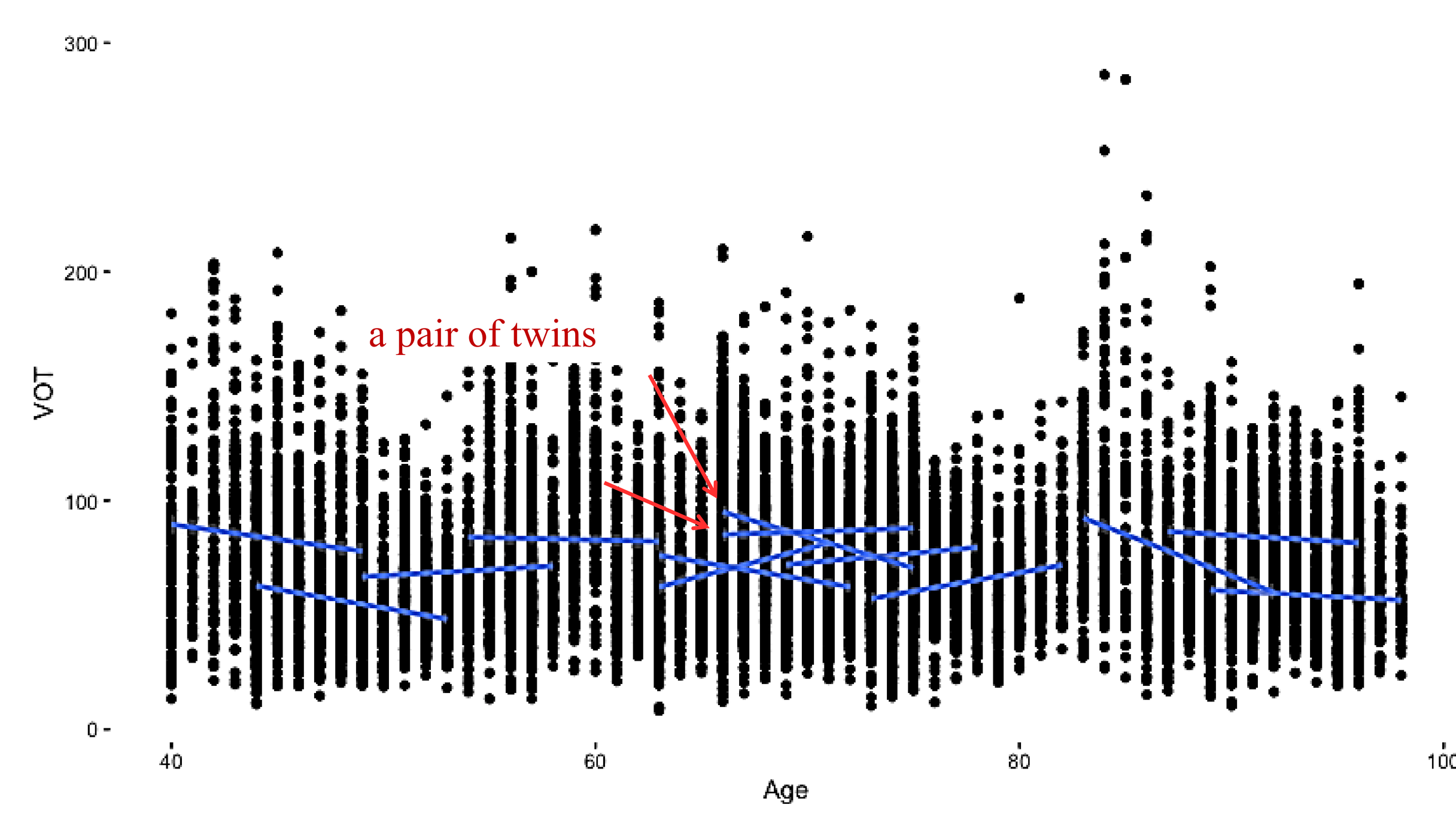
	Token by Token Data		Mean Data		
POA	Pearson Corr.	Sig. (2-tailed)	Pearson Corr.	Sig. (2-tailed)	N
b - p	0.237**	0.000	0.038	0.558	234
d - t	0.239**	0.000	0.053	0.422	234
g - k	0.245**	0.000	0.059	0.367	234

**. Correlation is significant at the 0.01 level (2-tailed).

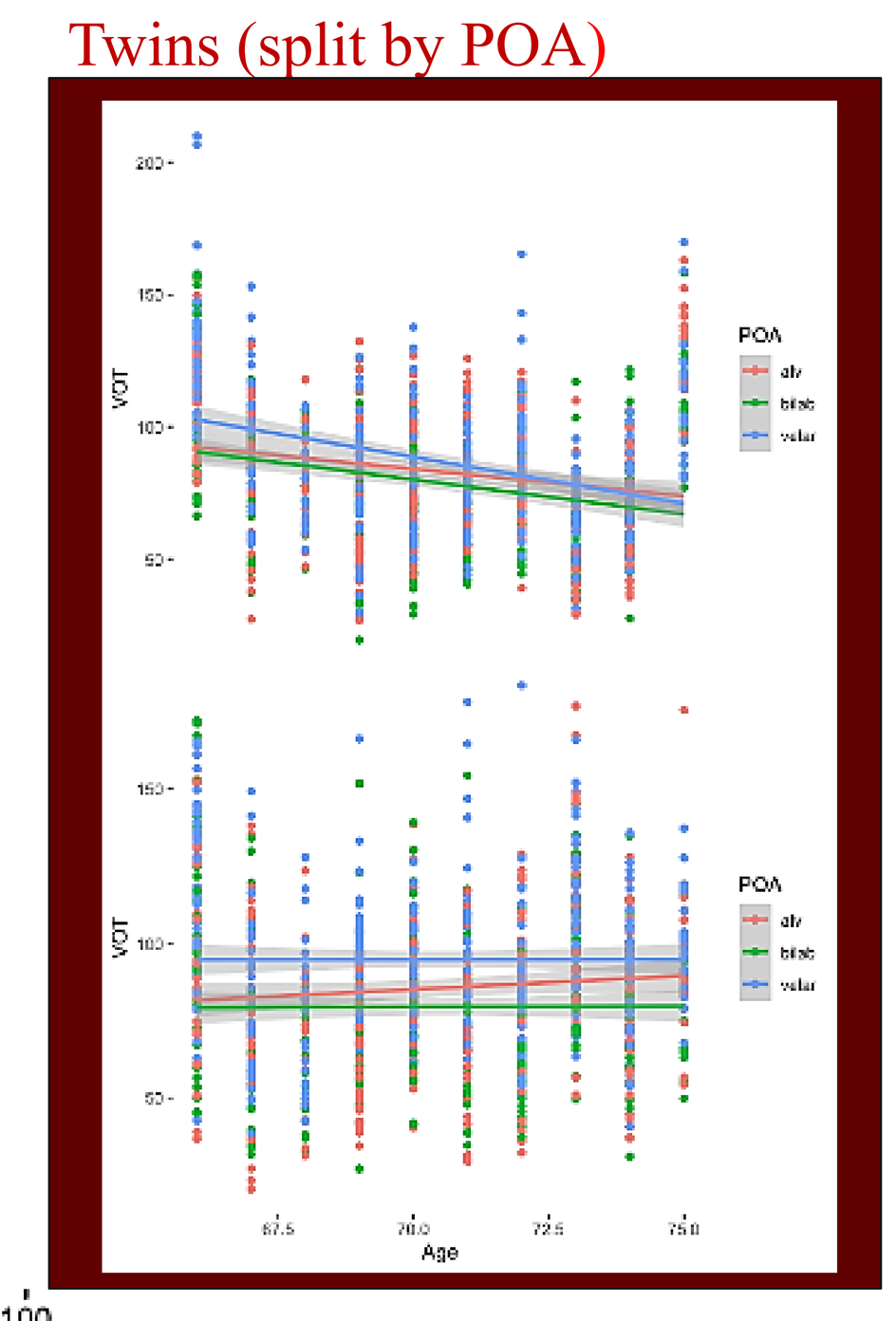


Individual Patterns

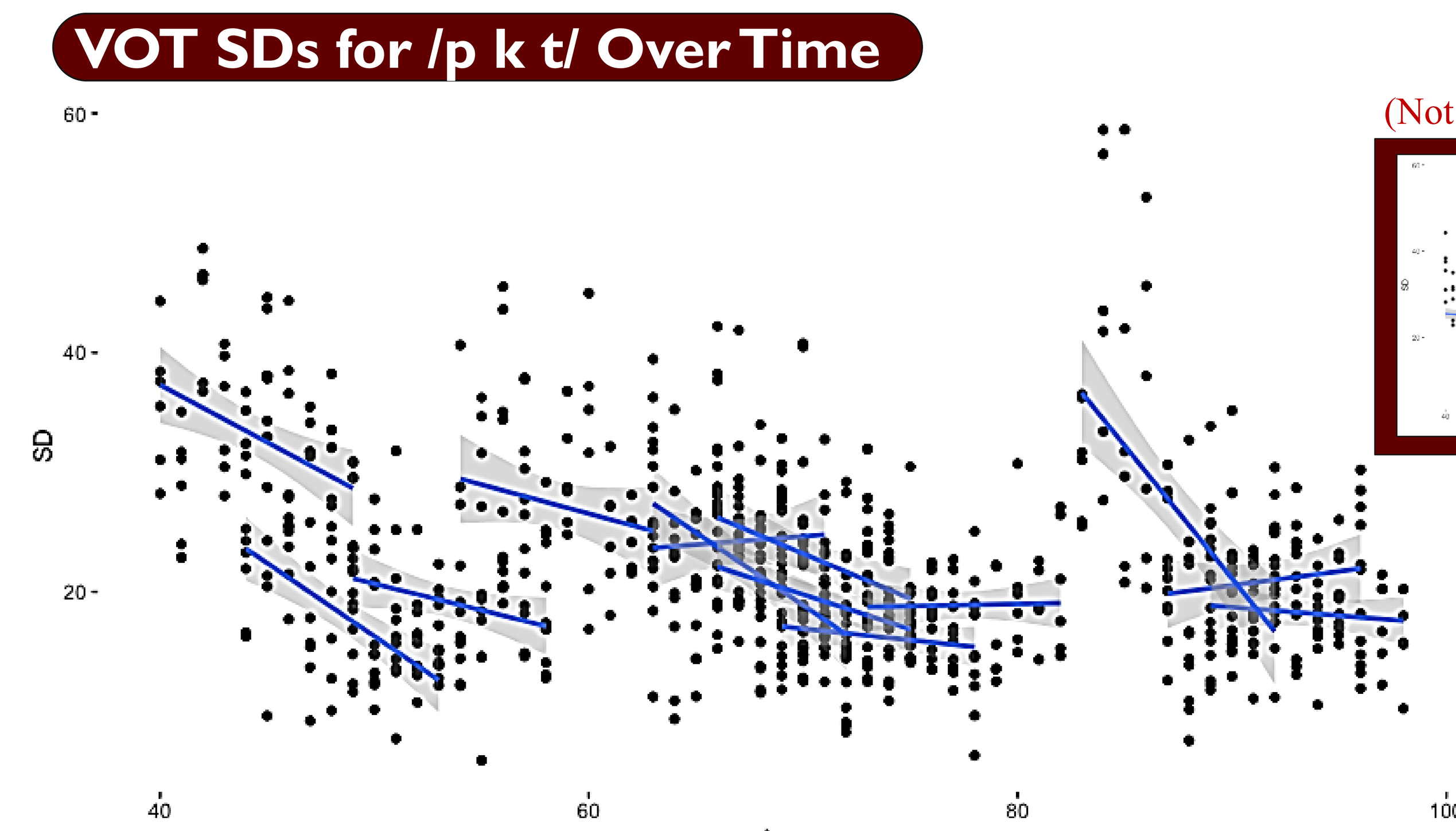
VOTs for /p k t/ Over Time



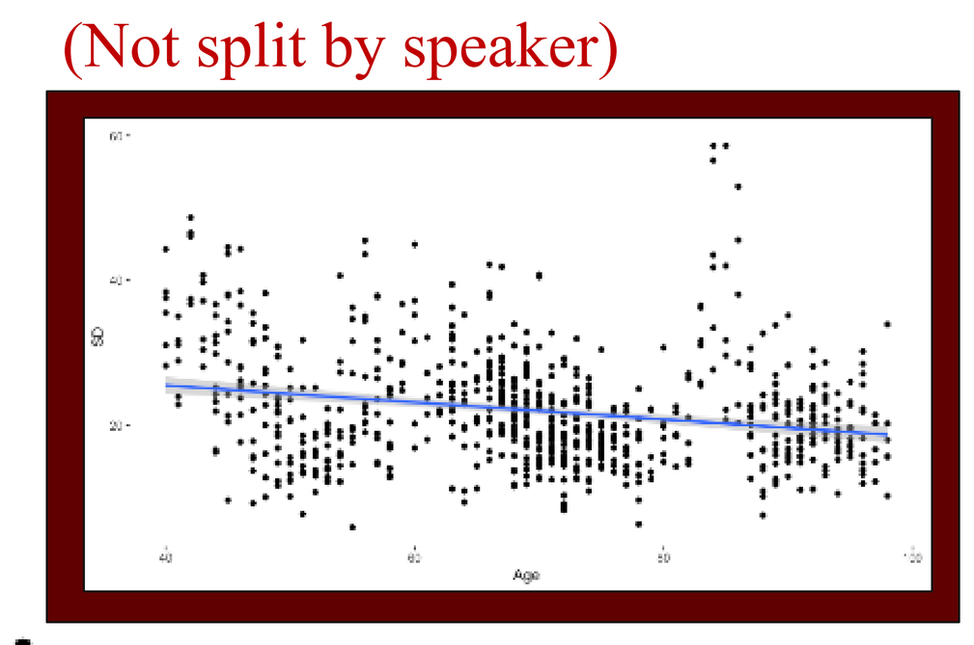
Twins (split by POA)



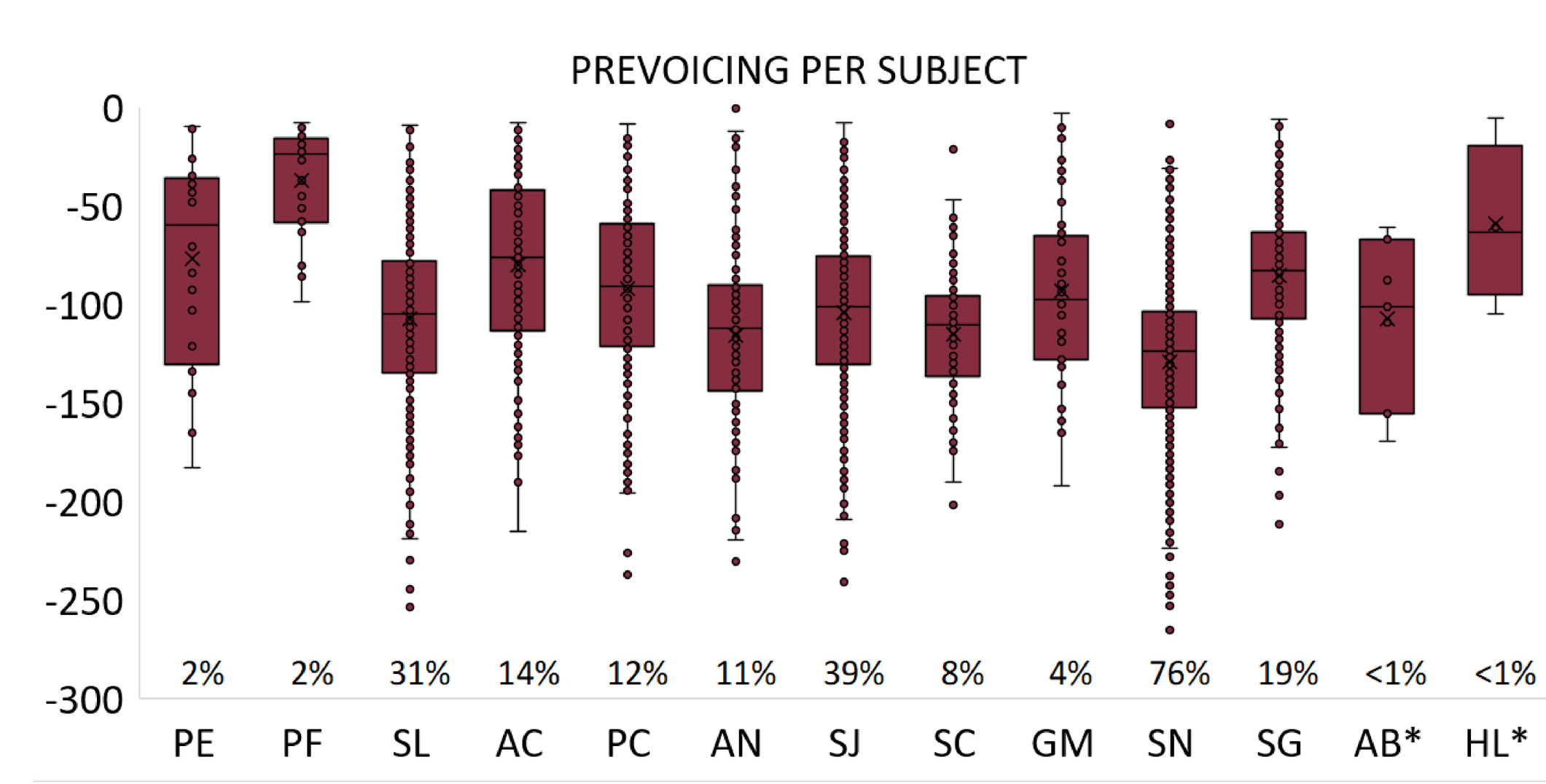
VOT SDs for /p k t/ Over Time



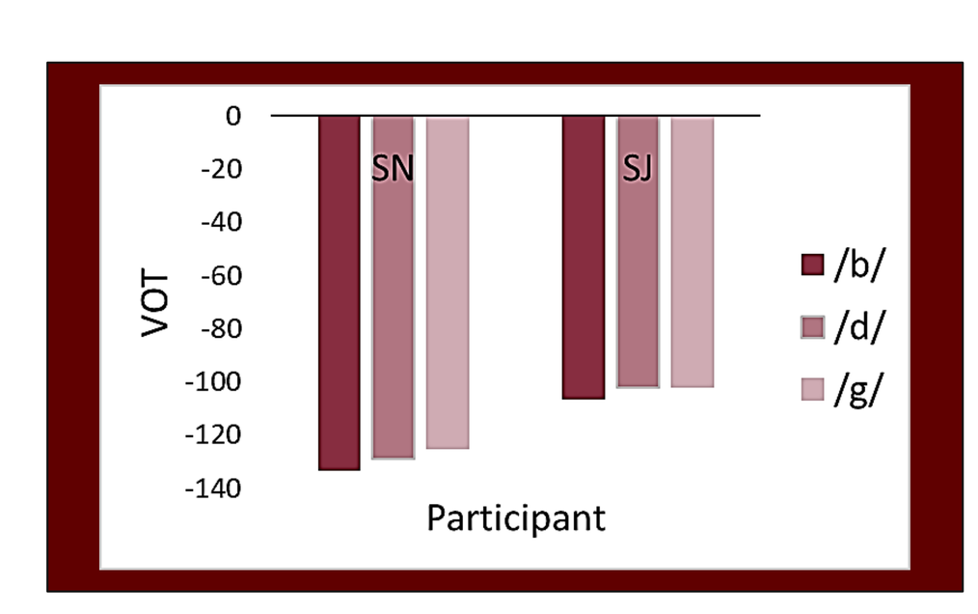
(Not split by speaker)



Prevoicing



*Prevoicing not observed for all POA.



Conclusions

On the whole, contextual variations based on POA and vowel context do not show clear correlations with overall VOT variation; however, the following trends were observed:

- GROUP PATTERNS:
- On average, VOT increases as POA moves posteriorly.
  - All *average differences* are positive.
  - Differences are towards the *high* end of what has been reported for adults [3].
- Vowel effects are less clear than POA effects.
  - Greatest effect observed for tongue height differences, specifically for voiceless alveolar targets.
  - Height differences are clearest for /t/; direction differs for /d/.
  - Front-back differences are less consistent and warrant additional investigation.
- Category discreteness improves as a function of age using token by token analyses.; no differences observed over time using mean data.

- INDIVIDUAL PATTERNS:
- Average aspiration duration varies over time in speaker-specific ways
  - Participants reduced the variability in aspiration duration over recording sessions, but the magnitude varied widely.
  - Prevoicing observed for all speakers; percentage of occurrence appears to be speaker-specific and unrelated to age.

Further research is needed to explore the relationship between the VOT and vowel effects.

- A systematic comparison of the relationships between high-mid, mid-low and high-low vowel differences for vowels measured over time would provide greater insight into the effects of lingual posture and voicing contrasts.

Disclosure:
Financial — No relevant financial relationships exist.
Nonfinancial — No relevant nonfinancial relationships exist.

References:
[1] Lisker, L., & Abramson, H. (1964). A cross language study of voicing in initial stops: Acoustical measurements. Word, 20, 384-442
[2] Esposito, A. (2002). On vowel height and consonantal voicing effects: Data from Italian. *Phonetica, 59*, 197–231.
[3] Klatt, D. H. (1975). Voice onset time, frication, and aspiration in word-initial consonant clusters. *Journal of Speech and Hearing Research, 18*, 686–706.
[4] Ohala, J. J. (1981). Articulatory constraints on the cognitive representation of speech. In T. Myers, J. Laver & J. Anderson (Eds.), *The cognitive representation of speech* (pp. 111–122). California: North Holland.
[5] Port, R. F., & Rotunno, R. (1979). Relation between voice-onset time and vowel duration. *Journal of the Acoustical Society of America, 66*(3), 654–661.
[6] Weismer, G. (1979). Sensitivity of voice-onset time (VOT) measures to certain segmental features in speech production. *Journal of Phonetics, 7*, 197–204.
[7] Yeni-Komshian, G. H., Caramazza, A., & Preston, M. S. (1977). A study of voicing in Lebanese Arabic. *Journal of Phonetics, 5*, 35–48.
[8]Whalen, D. H., Levitt, A. G., & Goldstein, L. M. (2007). VOT in the babbling of French- and English-learning infants. *Journal of Phonetics, 35*, 341–352.
[9] Zlatin, M. A. (1972). *Development of the voicing contrast: A psychoacoustic study of voice onset time.* Unpublished doctoral dissertation, Northwestern University.