Mining speech corpora for gestural timing differences as a precursor to metathesis

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What is metathesis?

- The reordering of phonological segments in a word (Grammont, 1933; Hock, 1985)

$$wasp \rightarrow waps \text{ (Steriade, 2001)}$$

- While factors in both perception and production have been advanced for metathesis, recent literature and experimental approaches have primarily focused on testing the role of perception

Questions

- Theoretical: What is the role of gestural timing in metathesis?
- Methodological: How can we use speech corpora to study precursors of metathesis?

Perceptual Explanations

Two main perceptual theories for metathesis

1. Ambiguity-Attestation Hypothesis (Hume, 2004)
   - There must be ambiguity in the phonetic signal
     (also Blevins and Garrett, 1998, 2004)
   - Metathesized sequence must be licit in language–metathesis is structure-preserving
     (but cf. Blevins and Garrett (1998) for counterargument)
   - Built off Ohala's listener-based model of sound change
     Ohala (1981, 1993)
2. Perceptual Optimization (Hume, 1998; Steriade, 2001)
   - Metathesis occurs to improve perceptibility
   - Can involve enhancement of a cue when accompanying cue is hard to hear or has disappeared

Masking and Cues: Sibilants and Stops

- Fricatives have strong internal cues in general
- Stops have weak place cues

	Manner	Place
Stops	silence (internal)	bursts, transitions (contextual)
Fricatives	noise (internal)	spectrum, amplitude (internal)

Cues for stops and fricatives

- The noisiness of sibilants also masks acoustics of a neighboring stop (Mielke, 2001)
- Auditory decoupling: high frequencies decoupled from speech stream in perception, so sibilants can cause confusion in sequential order (Bregman and Campbell, 1971; Bregman, 1990; Blevins and Garrett, 2004)

Masking and Cues

- Stops need a vowel transition
- Bias for CV over VC transitions (Fujimura et al., 1978)
- Diachronic patterns
  1. #TSV → #STV: Greek *p^hsyk^{h}e:* > *sp^{h}yk^{h}e:*
  2. VST# → VTS#: Southern American English *wasp* → *waps*
  3. VSTC → VTSC: Lithuanian *dresk-ti:* → *dreks-ti*
  4. VTSV → VSTV: Rural Latin *ipse* → *ispe*

Perception

- Perceived order in nonce aSTa/aTSa (Graff and Scontras, 2012)
  - More likely to hear [aksa] as [aska] than vice versa
  - Removal of burst makes this percept even *more* likely
  - Bias for stops in prevocalic position
- Perceived order of ST/TS in Hebrew by English speakers (Jones, 2016)
  - Fricatives and sibilants in cluster lead to significantly higher reaction times in determining order
  - Tendency to misinterpret [dz] as [zd], despite higher phonotactic frequency of [dz] in English
- Sibilant noise is key factor in ST/TS metathesis

Production & Gestural Timing

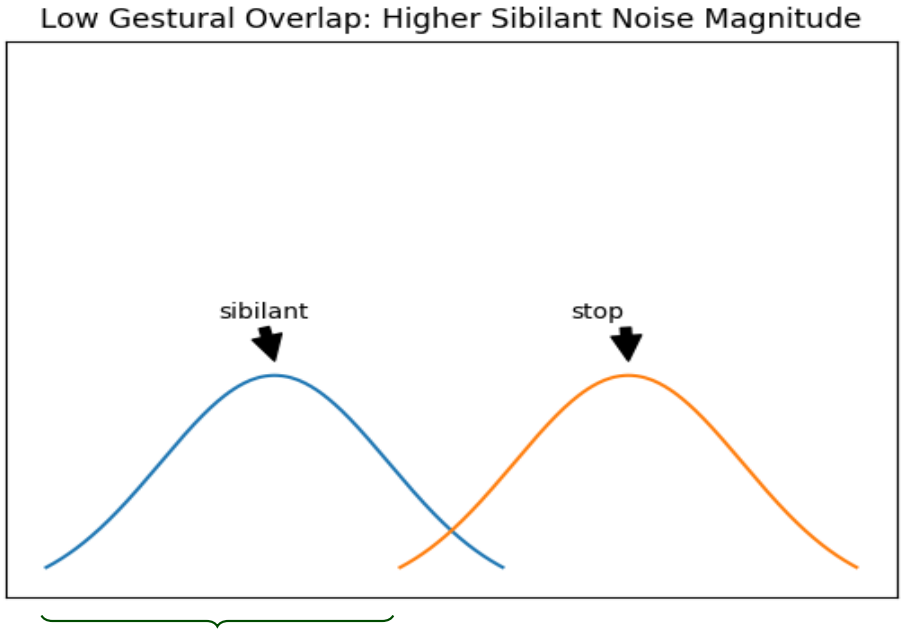
- Position in the word
  - More gestural overlap & variability in medial vs. onset position: Georgian (Chitoran et al., 2002); Hebrew (Yanagawa, 2003)
  - More gestural overlap and variability in coda vs. onset position in English (Byrd, 1996)
- Existence of morpheme boundary
  - More gestural variability hetero- vs. tautomorphemically: Korean (Cho, 2001); Hebrew (Yanagawa, 2003)
  - Non-morphemic *-s* significantly longer than morphemic *-s* if voiceless (Plag et al., 2017)
  - Non-morphemic *-s* significantly shorter than morphemic *-s* (Walsh and Parker, 1983; Losiewicz, 1995; Seyfarth et al., 2018)
- Yanagawa claims that metathesis in Hebrew occurs in *hi**t-p**a'el* binyan with TS sequences because they are *word-medial, heteromorphemic*

Questions

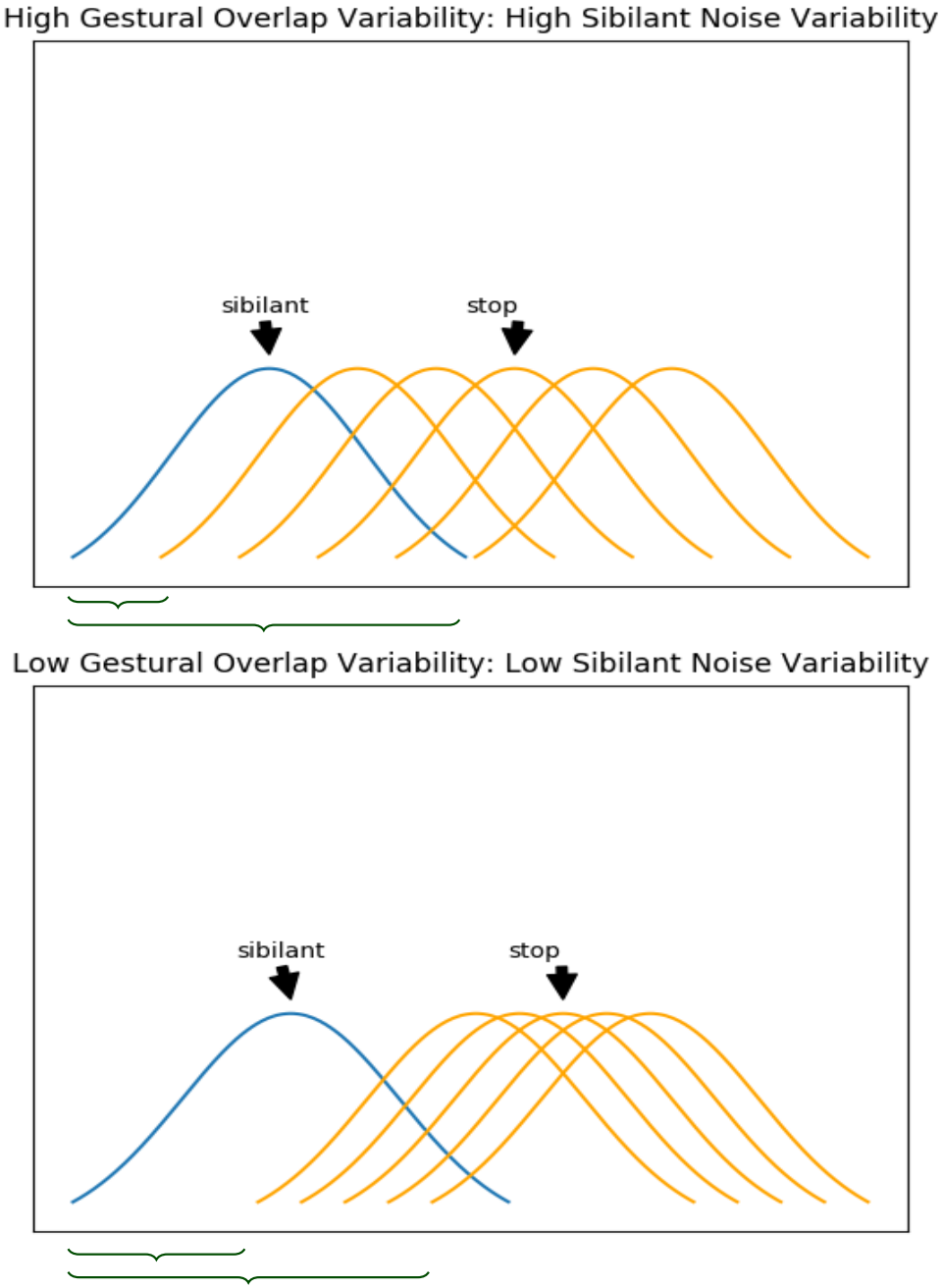
- Are articulatory findings reproduceable in acoustic data?
- Articulatory studies have few speakers:

  5 (Byrd, 1996), 3 (Cho, 2001), 2 (Chitoran et al., 2002), 1 (Yanagawa, 2003)
- Are experimental findings reproduceable in corpus data?
- Do magnitude and variability of gestural overlap provide an ambiguous signal that can lead to metathesis?
  - Do we see longer sibilant noise where we expect to see metathesis?
  - Do we see greater variability in sibilant noise where we expect to see metathesis?

Gestural Magnitude



Gestural Variability



The Buckeye Corpus

- Pulled data from Buckeye Corpus of Conversational Speech: recordings of interviews with 40 speakers from Columbus, OH (Pitt et al., 2007)
- Extract tokens with phonetic ST/TS clusters
- n = 13,975

Factors

- Independent variables
  - Position in word: Onset, Medial, Final
  - Morpheme existence (coded one of two different ways)
    - Binary: Yes, No
    - Ternary: None, -s, -ed
  - Cluster type: Stop is Prevocalic (STV), Postvocalic (VTS)
- Dependent variable: log ratio of sibilant to stop duration
- Other factors available (not significant)
  - Speaker gender
  - Speaker age
  - Interviewer gender

Hypotheses

- Word position effects
  - Gestural overlap greater and more variable in non-initial than initial position
  - Magnitude of sibilant duration: non-initial < initial
  - Variance of sibilant duration: non-initial > initial
- Morpheme boundary effects
  - Gestural overlap more variable in heteromorphemic than tautomorphemic clusters
  - Magnitude: conflicting
  - Variance: heteromorphemic > tautomorphemic
- Cluster type effects
  - Gestural overlap: ?
  - Magnitude: VTS > STV
  - Variability: VTS > STV

Model Comparison

- Ran LMERs with *lme4* (Bates et al., 2015) in R (R Core Team, 2017)
- Position in word, morpheme, cluster type as fixed effects
  - Morpheme coded either as binary (yes/no) or ternary morpheme type (none, -s, ed)
  - Interaction between position in word and cluster type considered
- Random intercepts for subjects and by-subject random slopes for fixed effects
- Best model
  - Binary morpheme coding
  - Interaction of Word Position x Cluster Type

Results

- Results reported without outliers (= 268 tokens, 1.92%)
- Before removal, Type (VTS) was *not significant*

Fixed Effect	Est.	SE	t		
Intercept	0.8814	0.014	63.07	***	
WP (Medial)	-0.0642	0.0097	-6.63	***	n.s.
WP (End)	-0.0513	0.0136	-3.78	***	
Morph (Yes)	0.0334	0.0155	2.16	*	
Type (VTS)	-0.0978	0.0405	-2.42	*	
WP (Medial) : Type (VTS)	0.2457	0.043	5.69	***	***
WP (End) : Type (VTS)	0.1653	0.048	3.44	**	

$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

- Medial and final sibilants significantly shorter than onset
- Heteromorphemic sibilants significantly longer
- VTS sibilants significantly shorter than STV in *onset*
- Non-initial VTS sibilants significantly *longer* than STV


Model Estimates for Log Ratio by Position & Cluster Type
Fitted Log Ratio
1.00
0.95
0.90
0.85
0.80
onset
medial
end
Word Position
type
STV
VTS

Discussion

- Non-initial cluster sibilants longer than initial
  - Corroborates Byrd (1996); Chitoran et al. (2002); Yanagawa (2003)
  - Effect is weaker for final position
  - Final STV not significantly different from medial, but final VTS is
- Heteromorphemic cluster sibilants longer
  - Corroborates Seyfarth et al. (2018), counters Plag et al. (2017)
  - Latter used Buckeye as well, but
    - Coding differences
    - Did not check effect of voicing
- (Non-initial) VTS sibilants longer than STV ones
  - Greater sibilant noise can cause confusion in order (Bregman and Campbell, 1971; Bregman, 1990; Graff and Scontras, 2012; Jones, 2016)
  - Supports auditory metathesis (Blevins and Garrett, 2004)

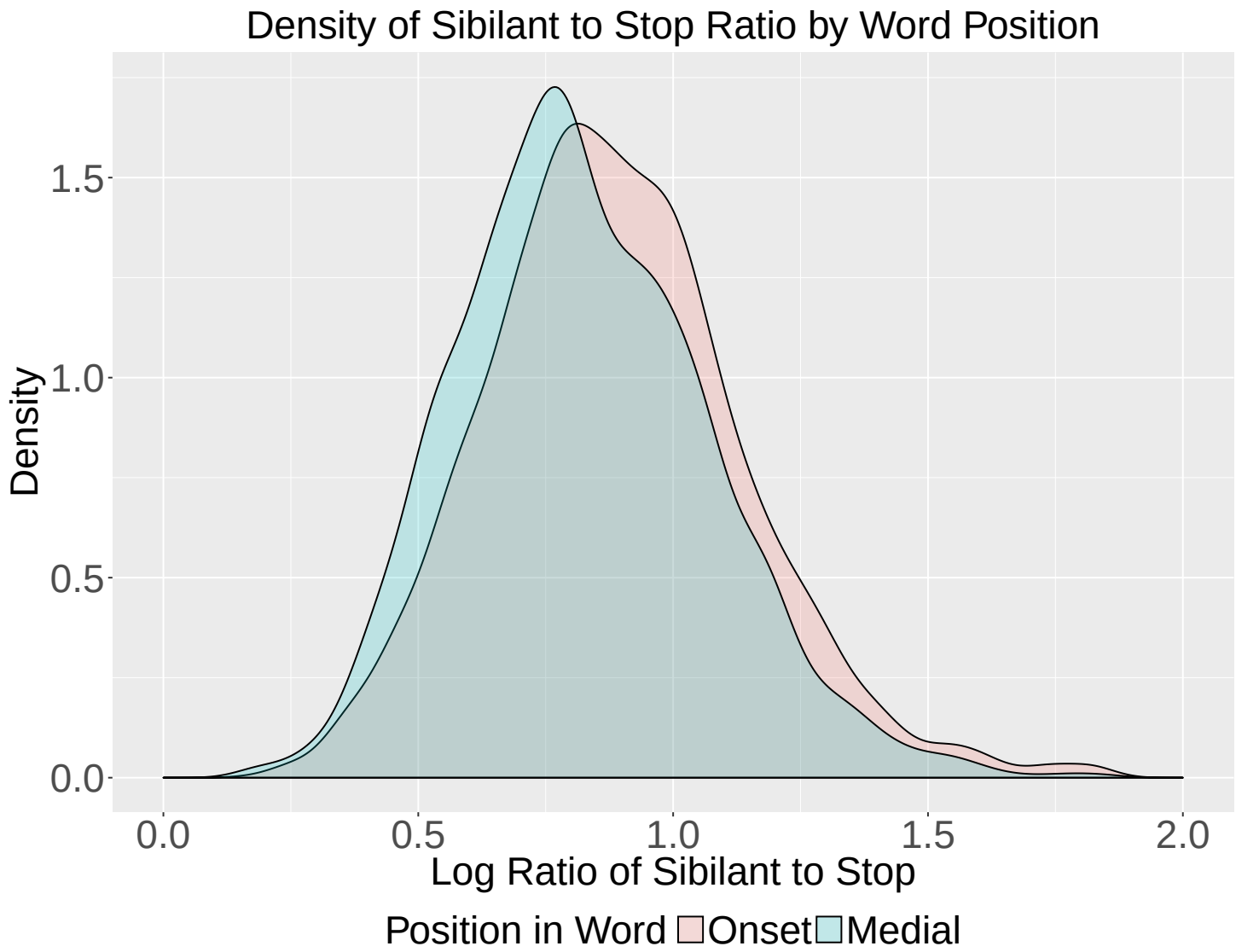
Measuring Variance Differences: Methodology

- Variance is heavily influenced by sample size

Speaker	Onset x STV	Medial x STV
1	144	132
2	172	75
...	...	...

- Limited to speaker x condition cells in which n >= 30
  - Leaves 26 speakers
  - Word position hypothesis: Onset x STV vs. Medial x STV
  - Cluster type hypothesis: STV x Medial vs. VTS x Medial
  - Could not test morpheme hypothesis
- n between cells also uneven (30 < n < 206)
- Ran 2 different analyses using LMER
  - Raw variance for each speaker x condition
  - Sampled 30 from each cell, ran LMER 5000 times, calculated % of cases in which LRT reveals p < .05

Position in Word (STV) and Variance



Onset: 3814 (σ^2 = 0.0676), Medial: 2511 (σ^2 = 0.0612)

Levene's Test: F(1,6323) = 2.324, p = 0.13

Position in Word (STV) & Variance

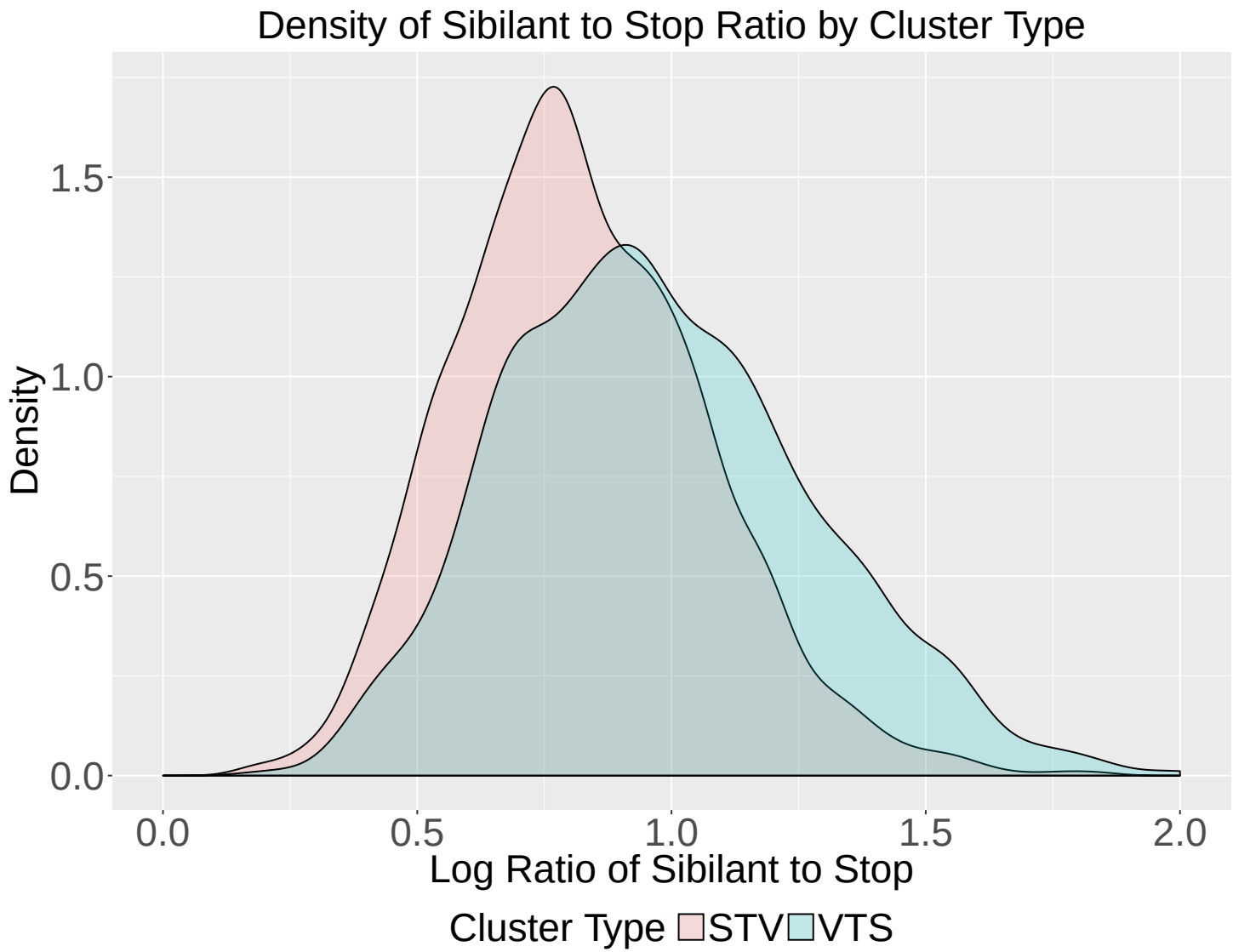
- Position in word as fixed effect, speaker as random effect
- Raw variance: one outlier speaker, removal reduces p-value from .036 to .002

Fixed Effect	Est.	SE	t	
Intercept	0.0598	0.0031	19.375	***
WP (Medial)	-0.0124	0.0036	-3.449	**

$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

- Simulation without replacement: in 30.4% of simulations, model with word position significantly more predictive
- Simulation with replacement: in 31.5% of simulations, model with word position significantly more predictive

Cluster Type (Medial Position) & Variance



STV: 2511 (σ^2 = 0.0612), VTS: 1934 (σ^2 = 0.0948)

Levene's Test: F(1,4443) = 90.861, p < .001

Cluster Type (Medial Position) & Variance

- Cluster type as fixed effect, speaker as random effect
- Raw variance: same outlier speaker, removal makes no significant difference

Fixed Effect	Est.	SE	t	
Intercept	0.0474	0.0041	11.703	***
Type (VTS)	0.0263	0.0057	4.586	***

$^{*}p < .05 \quad ^{**}p < .01 \quad ^{***}p < .001$

- Simulation without replacement: in 96.98% of simulations, model with cluster type significantly more predictive
- Simulation with replacement: in 89.47% of simulations, model with cluster type significantly more predictive

Discussion

- Medial cluster sibilants less variable than initial
  - But this effect is weak
  - Counter to Chitoran et al. (2002); Yanagawa (2003)
  - However, Chitoran et al. only look at stop+stop sequences and Yanagawa looks at stop+stop/fricative
- VTS sibilants much more variable than STV
  - Gestural variability is a possible factor in the preferred directionality of VTSV to VSTV
  - Supports Yanagawa's hypothesis of gestural variability
- Morpheme numbers too few and imbalanced to make any claims about variance across morpheme boundaries

Hypothesis Review

Word position effects

- Gestural overlap greater and more variable in non-initial than initial position ~✓
- Magnitude of sibilant duration non-initial < initial ✓
- Variance of sibilant duration non-initial > initial ✗

Morpheme boundary effects

- Gestural overlap more variable in heteromorphemic than tautomorphemic clusters ?
- Magnitude heteromorph. > tautomorph. ← conflicting
- Variance heteromorph. > tautomorph. ?

Cluster type effects

- Gestural overlap less & more variable in VTS? ← ?
- Magnitude VTS > STV ✓
- Variability VTS > STV ✓

Summary

- Magnitude of sibilant noise
  - Supports previous findings except Plag et al. who found shorter -s
  - Higher magnitude in VTS possibly leads to segmental confusion
- Variance of sibilant noise
  - Lower in non-initial position than onset
  - Greater in VTS than STV
- Greater magnitude and variance of sibilant noise may conspire to pressure VTSV > VSTV metathesis
- Type effect attenuated in final position—perceptual optimization? Stop more salient in VTS# than VST#
- Acoustic corpus findings may corroborate articulatory experimental findings

Directions

- Articulatory corpus
  - Running analysis with articulatory X-ray microbeam database (Westbury, 1994)
  - Validate whether acoustic findings indeed match gestural overlap
- Experiments
  - Production experiment controlling for current factors
  - Perception experiment
    - Is perceptual metathesis more likely with longer sibilant?
    - Interaction with word position and/or morpheme status?
- Explore corpora of other languages

Thansk!

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