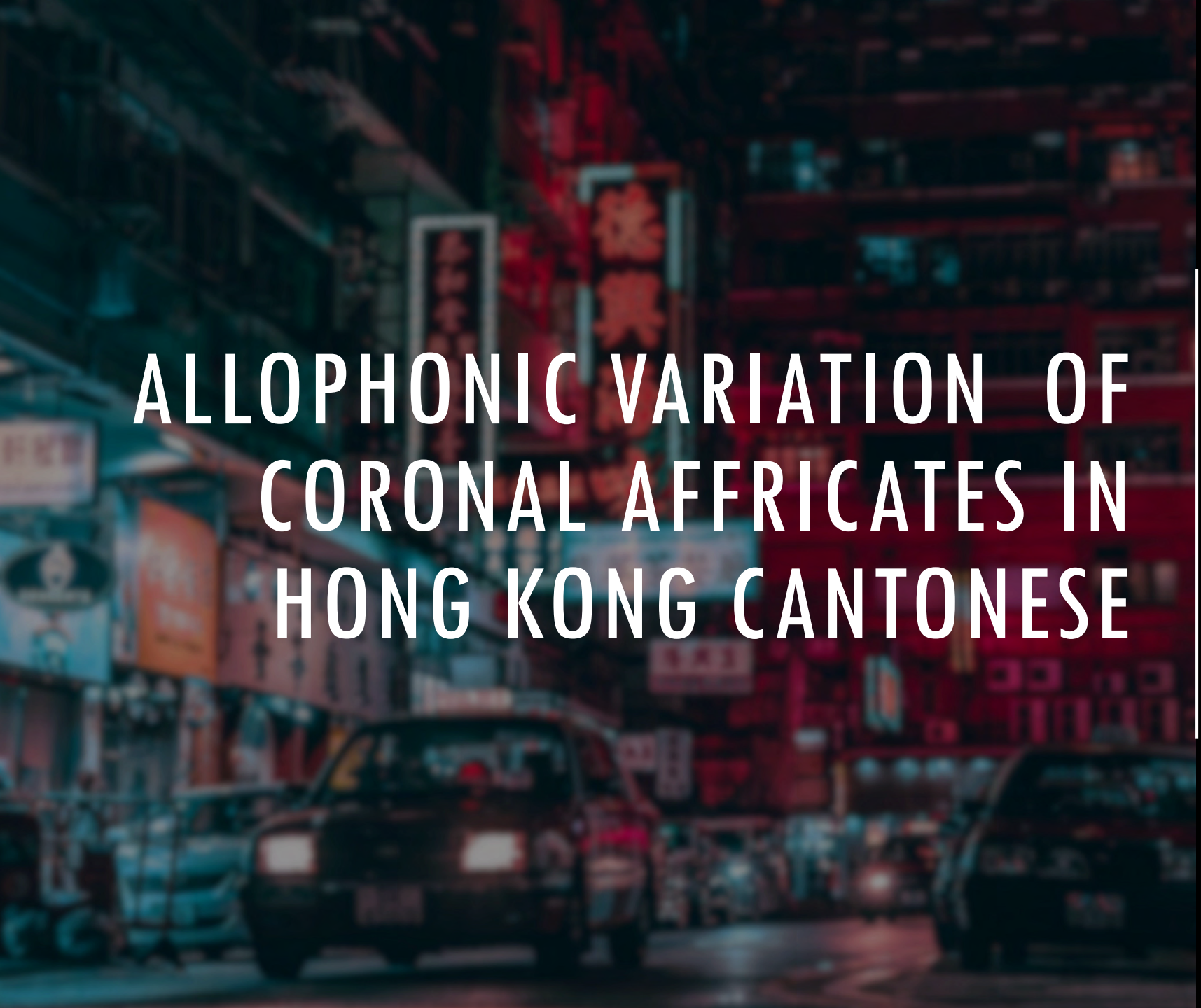

ALLOPHONIC VARIATION OF CORONAL AFFRICATES IN HONG KONG CANTONESE

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NWAV-AP 6
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INTRODUCTION

Phonemically, Hong Kong Cantonese (HKC) has three sibilants: /s, ts, ts^h/

It has been proposed that the HKC affricates /ts/ and /ts^h/ (but not the fricative /s/) are palatalized in certain linguistic environments (Yu 2016, Chan 2007, Liu 2010, Lan 2017)

Hence, /ts/ and /ts^h/ may have two allophones while/s/ has one:

- /ts/: Alveolar [ts] vs. post-alveolar [tʃ]
- /ts^h/: Alveolar [ts^h] vs. post-alveolar [$tʃ^h$]
- /s/: only alveolar [s]

OBJECTIVES

- Investigate socio-phonological variation in the allophonic pattern of sibilants in HKC by combining **acoustic** and **articulatory** analysis

Research questions:

- What is the conditioning environment of the sibilant allophones?
- Does the distribution of sibilant allophones vary among speakers of HKC?
- Is such variation stratified by age and gender?
- How are the allophones realized in terms of their articulation?

LITERATURE REVIEW

Palatalization of fricative /s/ in HKC?

- Yes but not prevalent (Chan 2007, Liu 2010)
- No (Lee & Zee 2010, Yu 2016)

Palatalization of affricates /ts, ts^h/ in HKC?

- Yes (Yeung 1980, Chan 2007, Liu 2010, Lan 2017)
- No (Lee & Zee 2010)

Conditioning environment of sibilant palatalization?

- Before **rounded** vowels (Chan 2007, Liu 2010)
- Before **back** vowels (Lan 2017)

LITERATURE REVIEW

Effect of age and time:

- Palatalization of all sibilants: 2000s > 1970s (Liu 2010)
- Palatalization of /ts, ts^h/:
  - Younger speakers > older speakers (Yeung 1980, Lan 2017)
  - Younger speakers = older speakers (Chan 2007)
- Palatalization of /s/: Older speakers > younger speakers (Chan 2007)

Effect of gender:

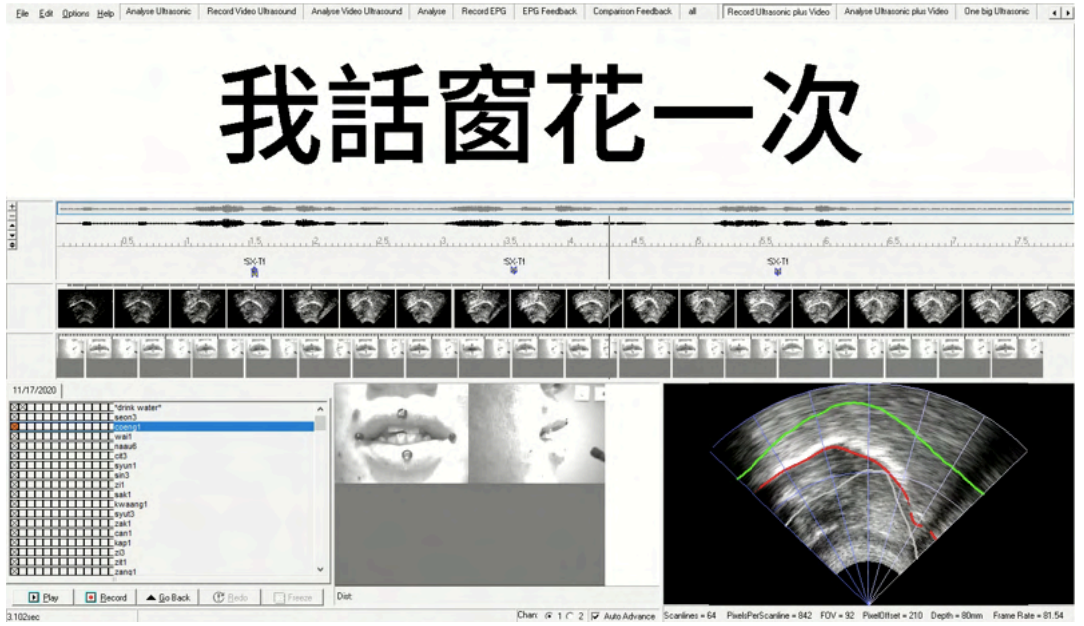
- Palatalization of all sibilants: Male speakers > female speakers (Chan 2007, Liu 2010)

METHODOLOGY

Part 1: **Acoustic** analysis of spontaneous speech from TV programme

Part 2: **Articulatory** experiment with ultrasound tongue imaging





METHODOLOGY: PART 1

Data: 24 speakers of HKC from *City Forum*, a TV program of RTHK

Public figures discuss their opinions on social and political issues in an informal setting

9 episodes, aired from 13 Nov 2016 to 29 Dec 2019





METHODOLOGY: PART 1

Speakers chosen from six groups by age and gender

Age:

8 older speakers (born 1945-1964)

8 middle-aged speakers (born 1965-1984)

8 younger speakers (born 1985-1999)

Gender:

12 female and 12 male

Age group	Female	Male
Older	4	4
Middle	4	4
Younger	4	4

METHODOLOGY: PART 1

Approximately 7 hours of recording extracted

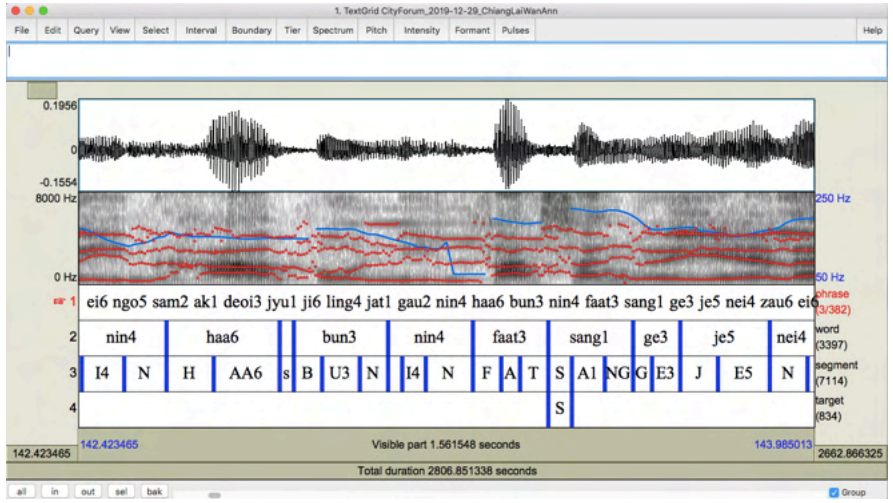
Recordings transcribed and processed with Montreal Force Aligner and ELAN (McAuliffe et al. 2017, ELAN 2020)

Utterances with background noise or overlapping speech excluded

Tokens of sibilants /ts, ts^h, s/ selected: 8,093 in total

No. of tokens per segment: 3,677 /ts/, 1,422 /ts^h/, 2,994 /s/

METHODOLOGY: PART 1



Middle 50% of frication extracted in Praat (Boersma & Weenink 2021), high-pass filtered at 500Hz

Spectral peak frequency measured: indicator of sibilant place of articulation (Stevens 1998, Jongman et al. 2000)

- ↑ Higher value: more fronted alveolar place
- ↓ Lower value: more backed post-alveolar place

METHODOLOGY: PART 1

- Mixed-effect regression model in R with *lmerTest* (Kuznetsova et al. 2020)
- Model stepped down from full model:
  - Fixed effects: preceding segment, following vowel (roundedness, height, backness), type of sibilant, tone, duration, age, gender
  - Random effects: speaker, word
  - *M* ~ type * roundedness * age * gender + precede + height + backness + tone + duration + (1 | age) + (1 | gender)

RESULTS: PART 1

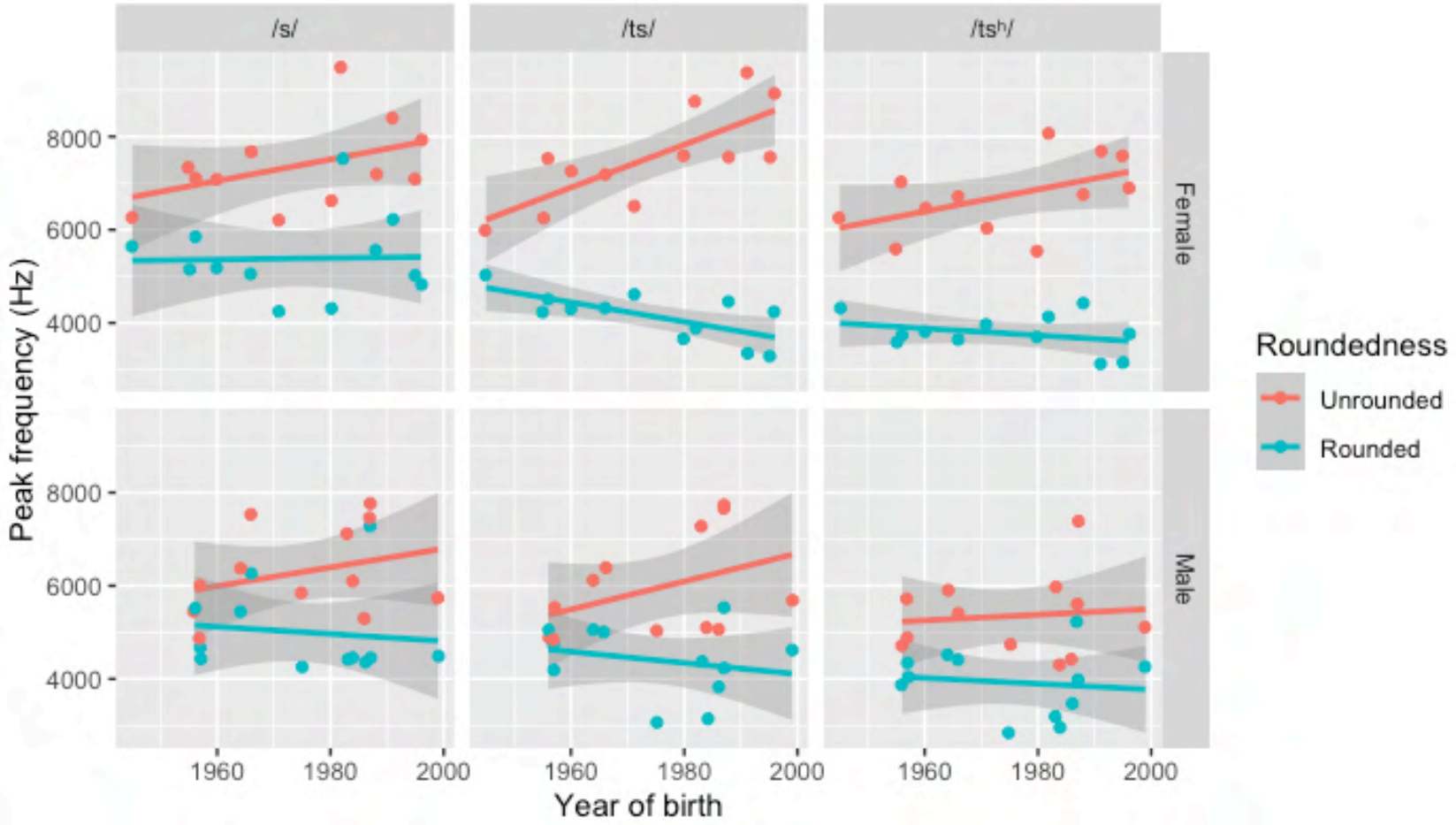


Figure 1. Peak frequency (in Hz) of HKC sibilants by year of birth and gender

RESULTS: PART 1

Fixed effects:	Estimate	Std. Error	df	t value	Pr(>|t|)
roundedness (round)	-3108.4143	246.6127	3521.1834	-12.604	**< 2E-16*** **

Effect of following vowel:

- Significant effect of vowel roundedness, **rounded** vowels **lower** peak frequency
- Backness and height did not improve model fit

No significant effect of vowel height or backness

No significant effect of tone

RESULTS: PART 1

- Significant effect of preceding segment
- Significant effect of type of sibilant
- Significant effect of duration
- Significant interaction between type of sibilant and age/gender

RESULTS: PART 1

Fixed effects:	Estimate	Std. Error	df	t value	Pr(>|t|)
round * age	22.9437	4.7487	8002.2713	4.832	**1.38E-06*** **
* gender (M)	585.5186	387.3168	7721.8976	1.512	0.130643
* age * gender (M)	4.3721	7.8157	7671.8451	0.559	0.575905

Significant interaction between roundedness of following vowel and age

- Peak frequency of sibilants **lower** for **younger** speakers when before **rounded** vowels
- **No** interaction between roundedness and gender

RESULTS: PART 1

Fixed effects:	Estimate	Std. Error	df	t value	Pr(>|t|)	
round * /ts/	-3460.0465	338.2417	3557.7815	-10.23	**< 2E-16**	***
* /ts^{h}/	-1139.0624	432.7383	4812.58	-2.632	**0.00851**	**

- Significant interaction between type of sibilant and roundedness of following vowel
- Peak frequency of /ts, ts^{h}/ **lower** when followed by **rounded** vowels

RESULTS: PART 1

Fixed effects:	Estimate	Std. Error	df	t value	Pr(>|t|)	
round * age * /ts/	44.6936	6.3641	8021.1234	7.023	**2.35E-12**	***
* /ts^h/	4.3441	8.2489	8010.534	0.527	0.598463	
* gender (M) * /ts/	2036.5141	521.7617	7890.421	3.903	**9.57E-05**	***
* /ts^h/	1541.1277	656.9656	7559.56	2.346	**0.019011**	*
* age * gender (M)* /ts/	-22.577	10.4167	7854.5246	-2.167	**0.030235**	*
* age * gender (M)* /ts^h/	-14.5942	13.246	7664.2782	-1.102	0.270591	

Significant interaction between type of sibilant, roundedness and age/gender:

- Peak frequency of /ts/ **lower** before rounded vowels for **younger** speakers
- Peak frequency of /ts, ts^h/ **lower** before rounded vowels for **female** speakers
- Peak frequency of /ts/ **higher** before rounded vowels for **younger female** speakers

DISCUSSION: PART 1

- **Roundedness** (not backness or height) of the following vowel conditions articulation of sibilants
  - Consistent with Chan (2007) and Liu (2010)
- In general, sibilants more palatalized/labialized before **rounded** vowels
  - Palatalization, or co-articulatory effect of vowel rounding?

DISCUSSION: PART 1

- **Affricates** /ts, ts^h/ more palatalized/labialized than fricative /s/ before **rounded** vowels
  - Consistent with Chan (2007) and Liu (2010)
- Sibilants more palatalized/labialized before **rounded** vowels for **younger** speakers
  - Change from co-articulatory effect to phonologization of allophones?

DISCUSSION: PART 1

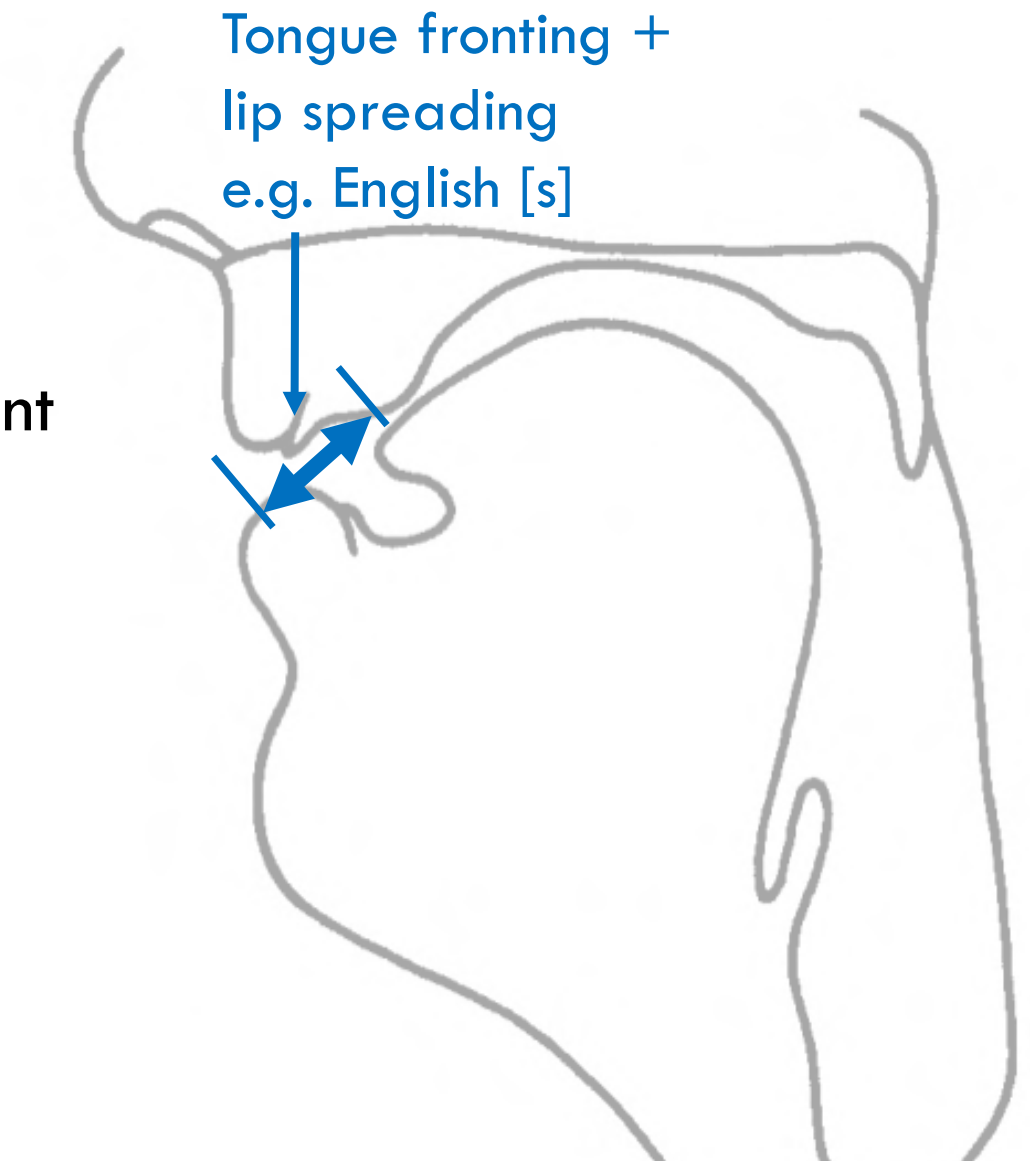
- **Affricates** tend to be more palatalized/labialized than fricative before rounded vowels for **younger** speakers and **female** speakers
- Articulatory difference between affricates and fricative found only for speakers of certain age and gender
- Evidence for **phonologized allophonic split** among HKC affricates?

DISCUSSION: PART 1

Differences in spectral peak can be result of any gestures that changes length of front cavity of vocal tract

Both tongue and lip configuration change length of front cavity:

- **Tongue fronting** or **lip spreading**, front cavity shortens, **higher** peak frequency



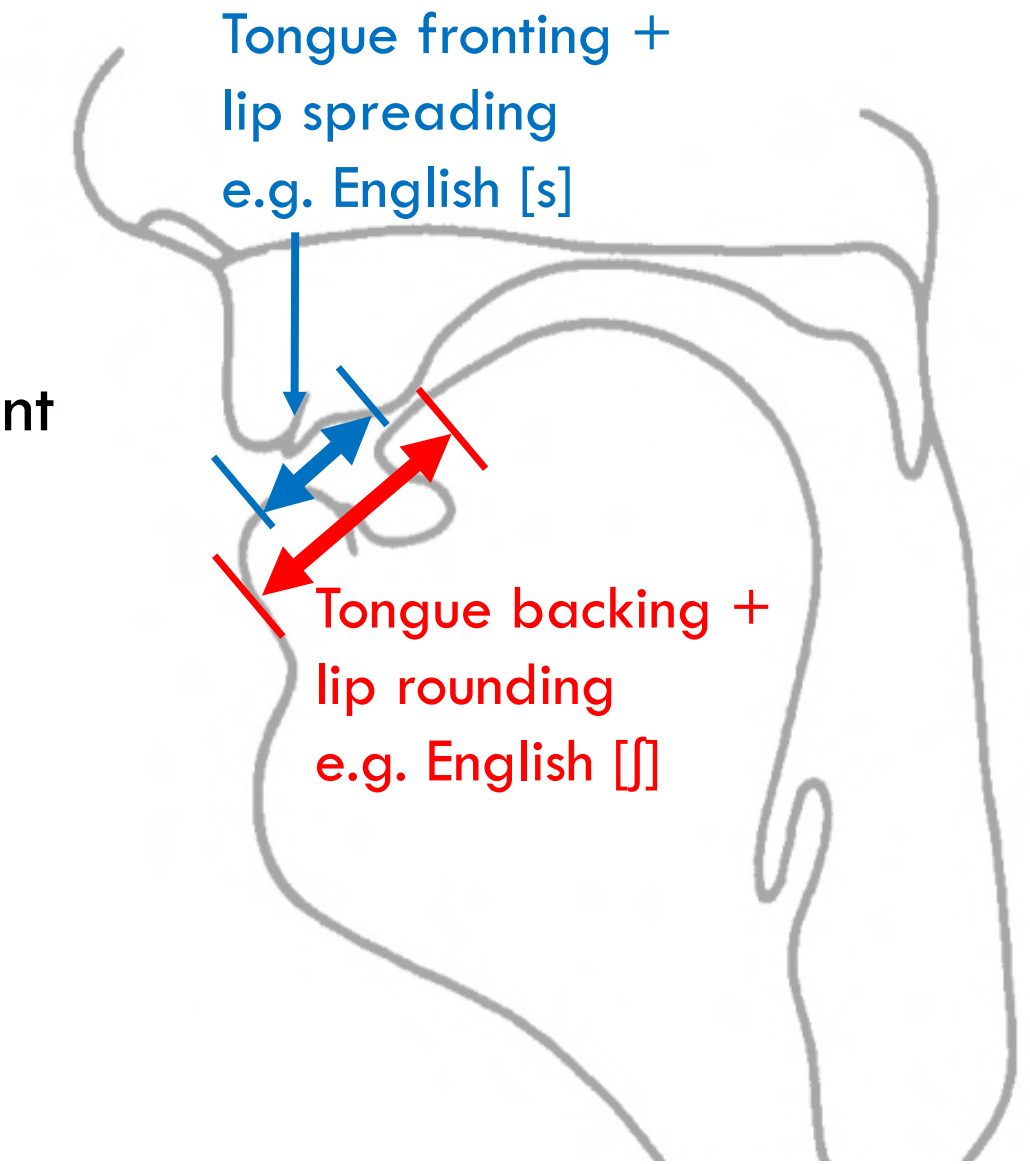
Figures adapted from Ladefoged & Johnson (2010)

DISCUSSION: PART 1

Differences in spectral peak can be result of any gestures that changes length of front cavity of vocal tract

Both tongue and lip configuration change length of front cavity:

- **Tongue fronting** or **lip spreading**, front cavity shortens, **higher** peak frequency
- **Tongue backing** or **lip rounding**, front cavity lengthens, **lower** peak frequency



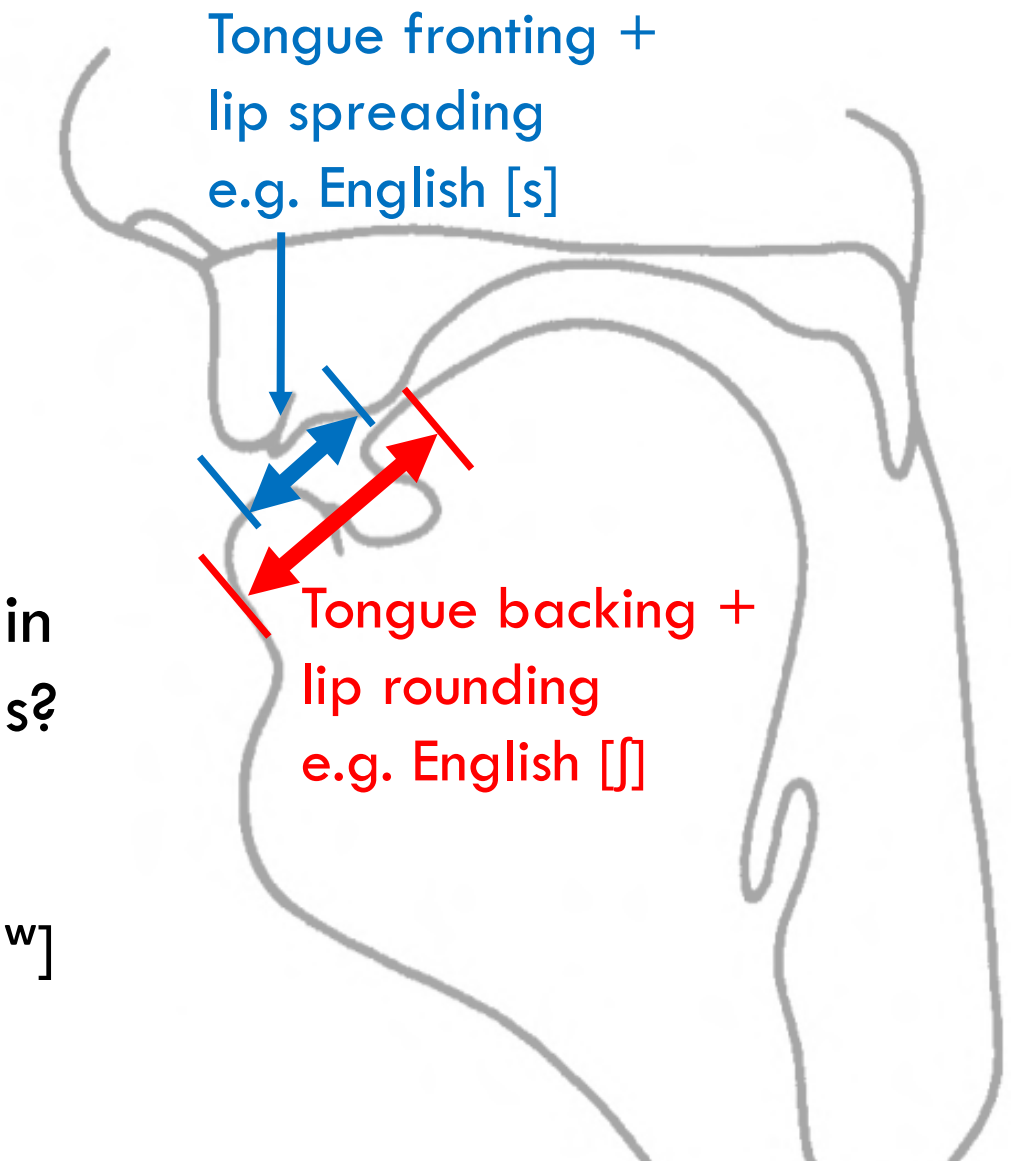
Figures adapted from Ladefoged & Johnson (2010)

DISCUSSION: PART 1

Acoustic analysis alone **cannot** disambiguate effect of tongue and lip in the articulation of sibilants

What causes age and gender differences in sibilants articulation before rounded vowels?

- Lip rounding only?
  - co-articulatory effect or allophones [ts^{w}, ts^{hw}]



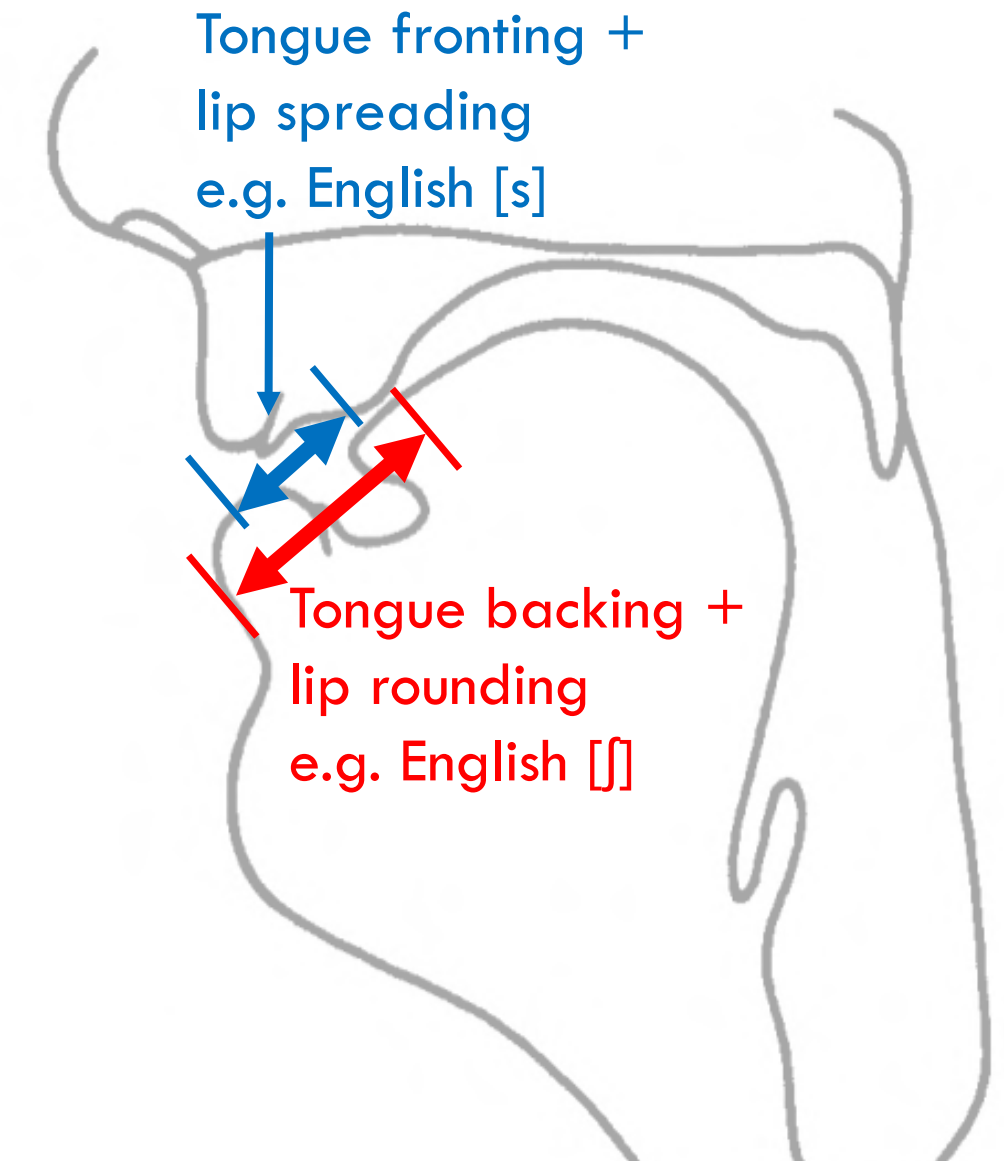
Figures adapted from Ladefoged & Johnson (2010)

DISCUSSION: PART 1

- Tongue backing?
  - Strong evidence for phonologization of allophones [tʃ, tʃʰ]

Articulatory measurement with **ultrasound tongue imaging** and **lip video** necessary

Follow-up study: articulatory experiment of HKC sibilants



Figures adapted from Ladefoged & Johnson (2010)

METHODOLOGY: PART 2

Materials:

- 126 disyllabic words that start with sibilants: 42 /s/, 45 /ts/, 39 /ts^{h}/
- All attested **sibilant** + monophthong CV combinations tested
  - Vowels: [aː, ɐ, ɛː, œː, ɵ, iː, ɪ, yː, ʊ, ɔː]
  - Coda consonants: /#, t, n, k, ŋ/
  - Tone: 1 /˥/ (high level) or 3 (mid level) /˧/
- 44 filler items to obscure aim of study

METHODOLOGY: PART 2

Participants:

- 12 native speakers of HKC, born between 1956-2001
- No previous history of speech or hearing impairments

Four groups by age and gender:

- 6 older speakers (born 1956-1962)
- 6 younger speakers (born 1997-2001)
- 6 female, 6 male

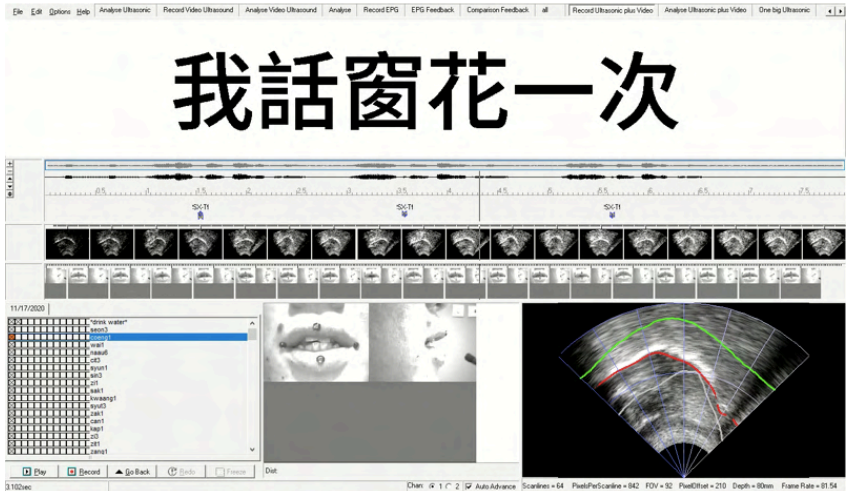
Age group	Female	Male
Older	3	3
Younger	3	3

METHODOLOGY: PART 2

Procedure:

- Data collected at the University of Hong Kong
- Words embedded in carrier phrase [ŋɔ:˩˧ wa:˧] ___ [jɐt̚ tsʰi:˧] "I say ___ once"
- Words presented to each participant in unique randomized order
- Each word presented once, repeated three times
- 378 target tokens per participant, total of 4,536 tokens across all participants prior to exclusion of mispronounced words etc.

METHODOLOGY: PART 2



Recording:

- Simultaneous audio, ultrasound, and video recording
- Ultrasound: High speed (84 fps) SonoSpeech Micro ultrasound system, 20mm radius probe
- Audio: Recorded at 48kHz/16-bit with Sennheiser MKE2-P-C Microphone
- Video: coronal and sagittal view of speaker's lips recorded at 60 fps
- Synchronized in Articulate Assistant Advanced (AAA) (Articulate Instruments Ltd. 2012)

METHODOLOGY: PART 2

Tongue contour extracted at midpoint of frication in AAA

Polar Smoothing Spline ANOVA (SS-ANOVA, Davidson 2006, Mielke 2015) using gss package (Gu 2014) in R

For each speaker, best-fit smoothing splines for each sibilant by following rounded vs. unrounded vowel

95% Bayesian confidence intervals

Audio: Middle 50% of frication extracted in Praat (Boersma & Weenink 2021), high-pass filtered at 500Hz

RESULTS: PART 2

Speaker 9 (**Older male**):

- **Same** tongue position before rounded vs. unrounded vowels for all three sibilants
- **Different** tongue positions for affricates and fricative
- /s/ more **fronted,** /ts, ts^h/ more **backed**

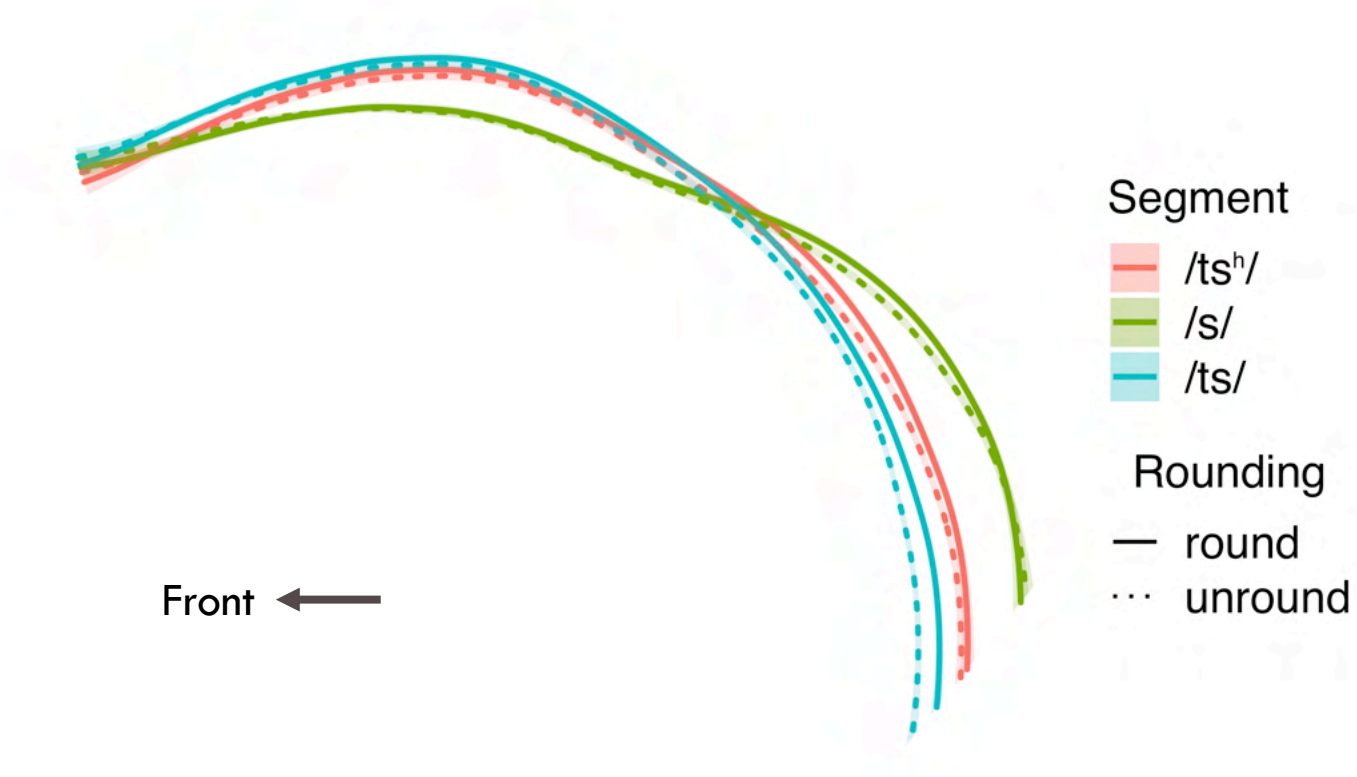


Figure 2. Polar SSANOVA tongue contours of sibilants by rounding for speaker 9 (Older male)

RESULTS: PART 2

Speaker 8 (**Older female**):

- **Same** tongue position before rounded vs. unrounded vowels for all three sibilants
- **Different** tongue positions for affricates and fricative
- /s/ more **front,** /ts, ts^h/ more **back**

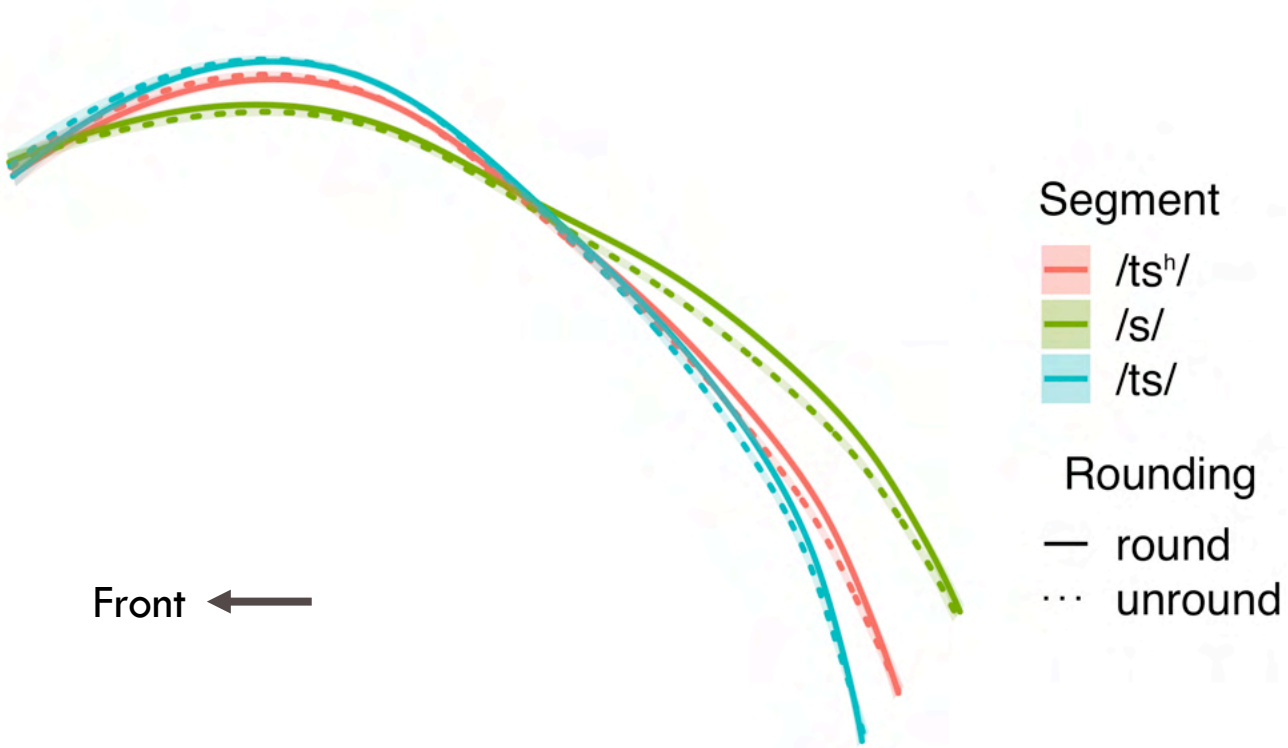


Figure 3. Polar SSANOVA tongue contours of sibilants by rounding for speaker 8 (Older female)

RESULTS: PART 2

Speaker 3 (**Younger male**):

- **Different** tongue positions before rounded vs. unrounded vowels for /ts, ts^h/
- **Fronted** before **unrounded** vowels
- **Backed** before **rounded** vowels

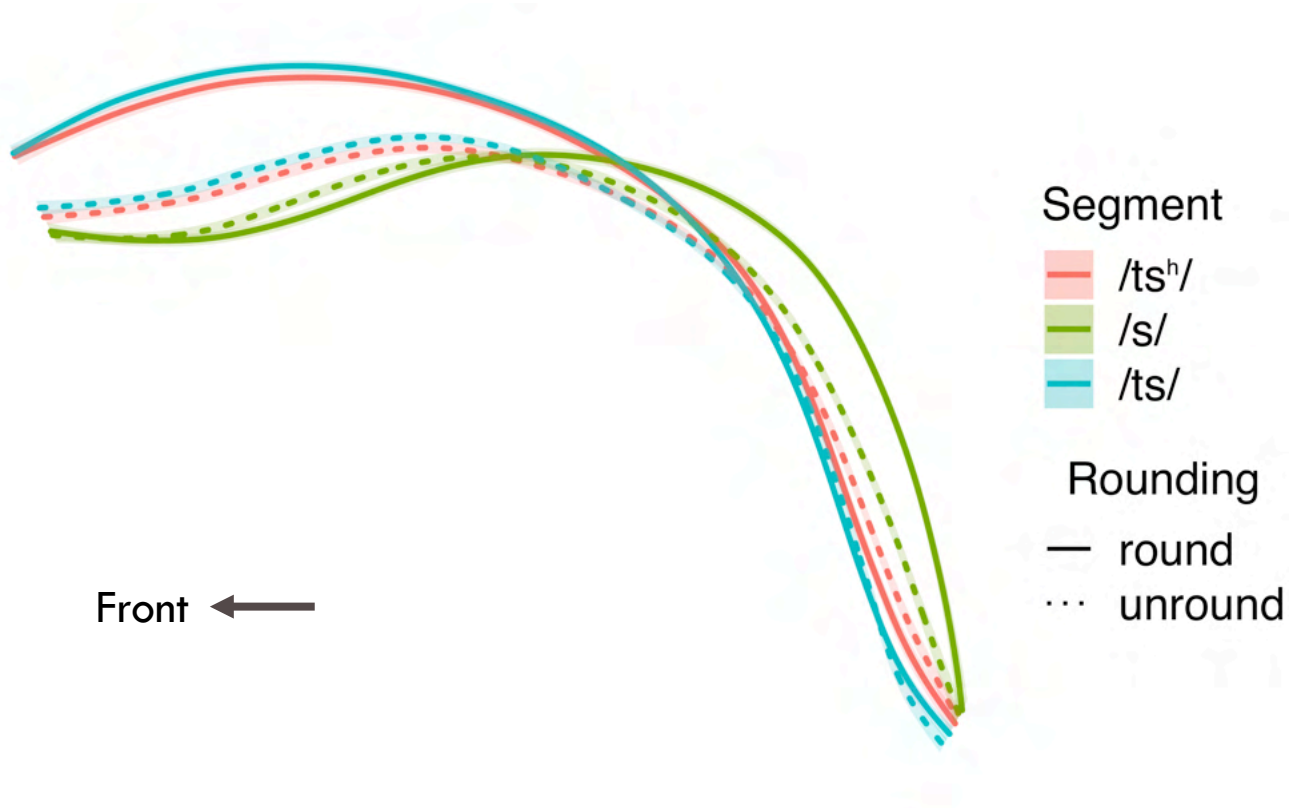


Figure 4. Polar SSANOVA tongue contours of sibilants by rounding for speaker 3 (Younger male)

RESULTS: PART 2

Speaker 3 (**Younger male**):

- **Same** tongue positions before rounded vs. unrounded vowels for /**s**/
- **Different** tongue positions for affricates and fricative
- /s/ more **front,** /ts, ts^{h}/ more **back**

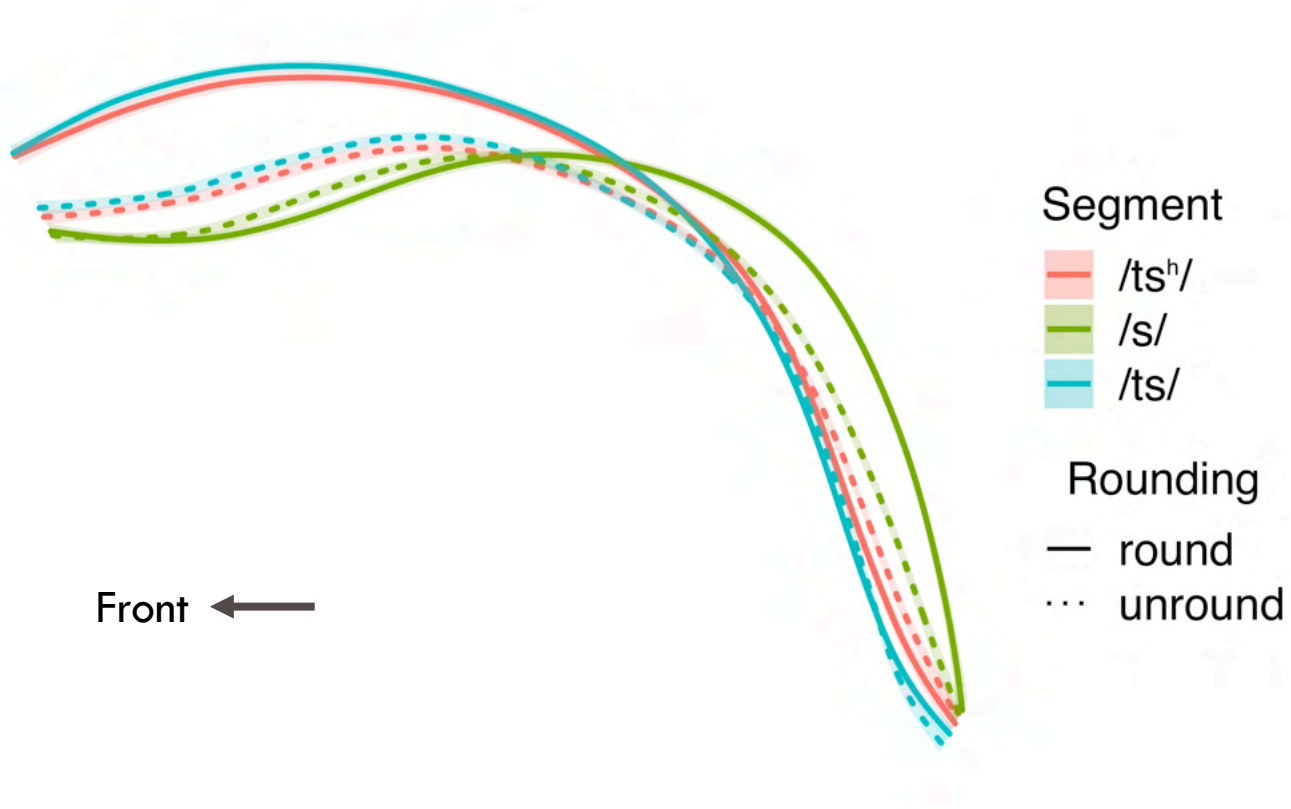


Figure 4. Polar SSANOVA tongue contours of sibilants by rounding for speaker 3 (Younger male)

RESULTS: PART 2

Speaker 5 (**Younger female**):

- **Different** tongue positions before rounded vs. unrounded vowels for /ts, ts^h/
- **Fronted** before **unrounded** vowels
- **Backed** before **rounded** vowels

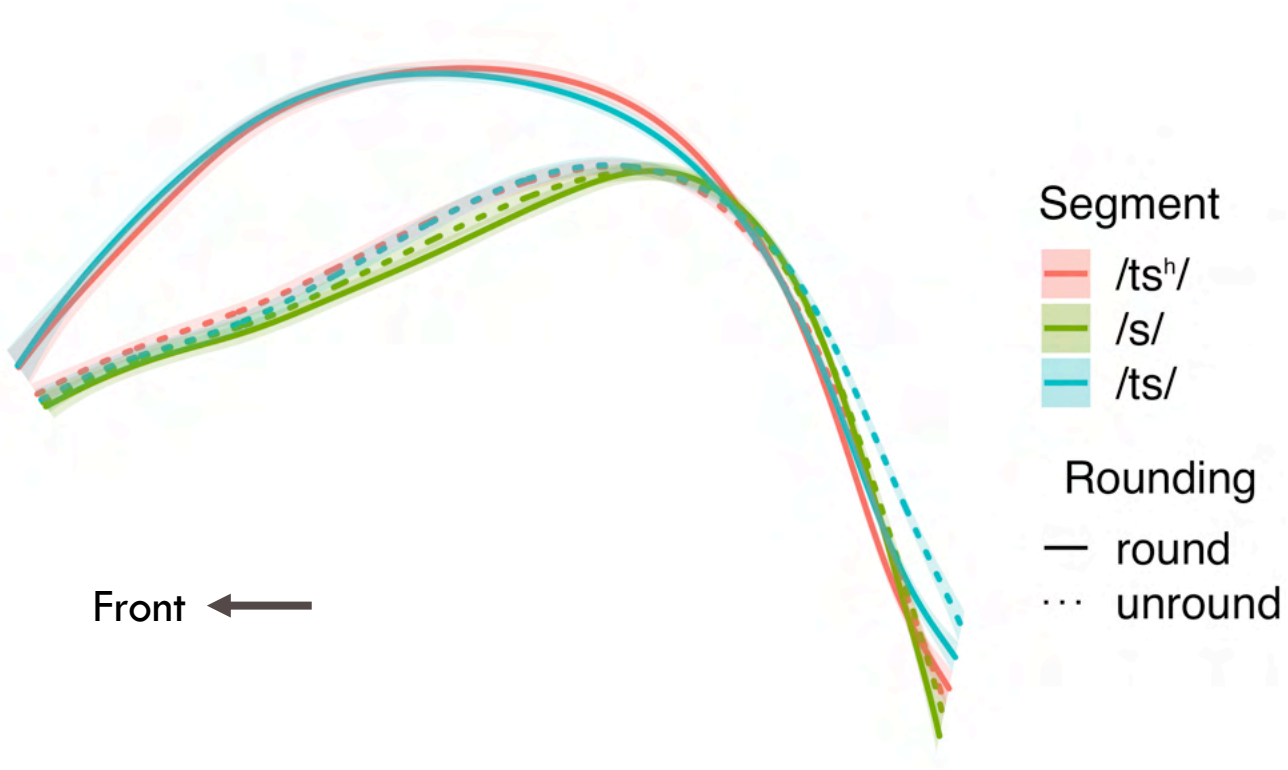


Figure 5. Polar SSANOVA tongue contours of sibilants by rounding for speaker 5 (Younger female)

RESULTS: PART 2

Speaker 5 (**Younger female**):

- **Same** tongue positions before rounded vs. unrounded vowels for /s/
- **Same** tongue position for affricates before unrounded vowel and fricative

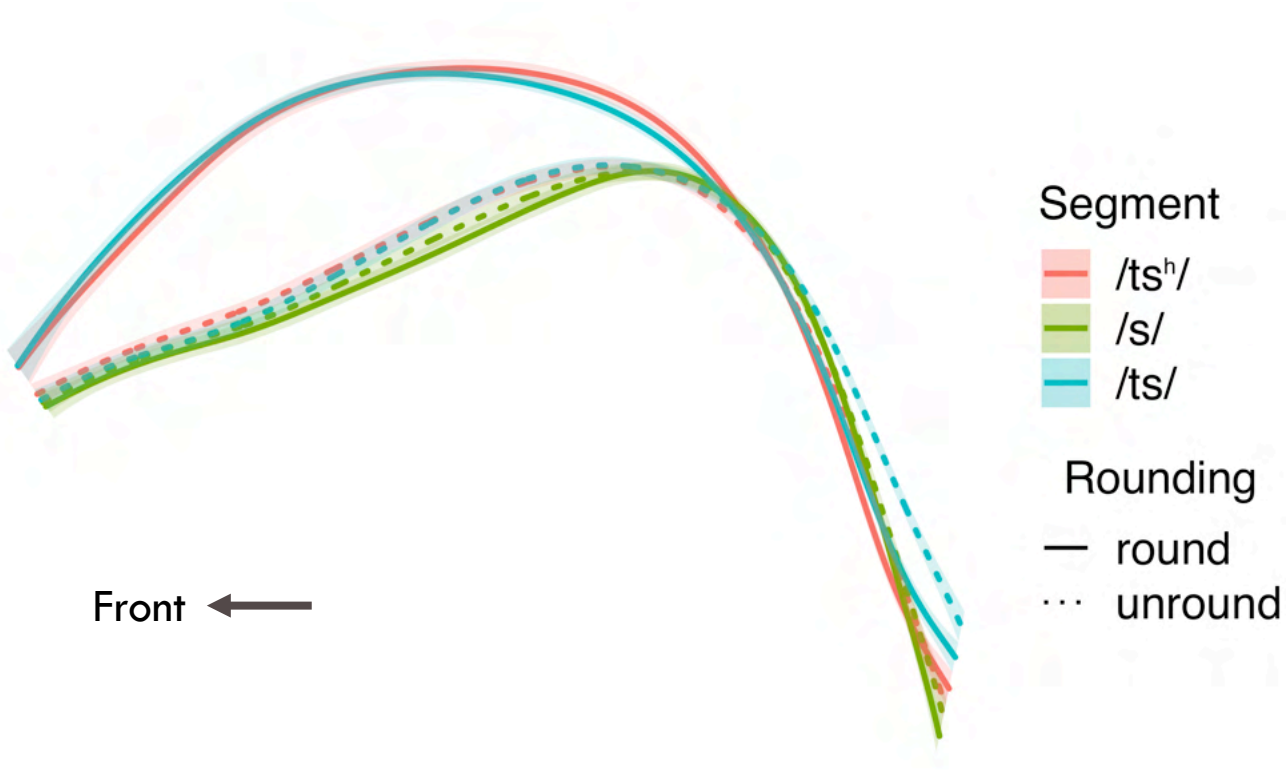


Figure 5. Polar SSANOVA tongue contours of sibilants by rounding for speaker 5 (Younger female)

RESULTS: PART 2

	/s/	/ts/	/tsʰ/
Old male	0/3	0/3	0/3
Old female	0/3	1/3	1/3
Young male	0/3	2/3	2/3
Young female	0/3	3/3	3/3

No. of speakers with differences in **tongue position** by roundedness of following vowel by age and gender

RESULTS: PART 2

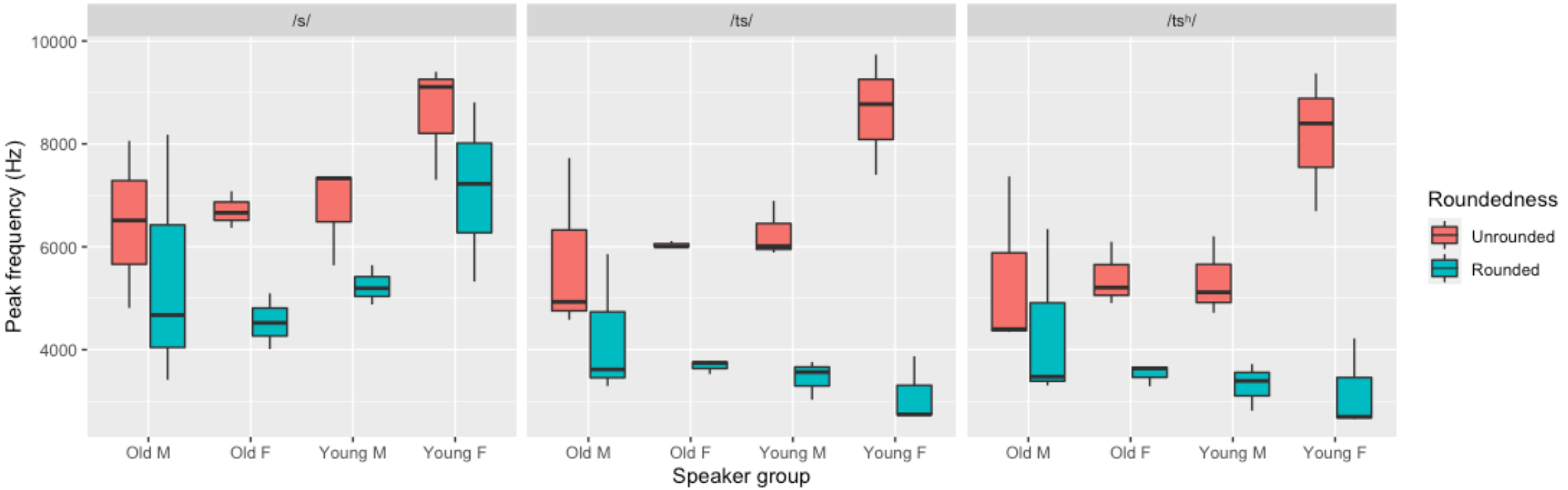


Figure 6. Peak frequency (in Hz) of HKC sibilants for speakers of articulatory experiment

RESULTS: PART 2

Affricates /ts, ts^h/ vary in tongue position by roundedness of following vowel among **younger** speakers, consistent with acoustic measurements

Before unrounded vowels: alveolar [ts, ts^h]

Before rounded vowels: (palatalized) post-alveolar [tʃ, $tʃ^h$]

Older speakers: same tongue position for affricates regardless of roundedness of following vowel

Gender: female speakers > male speakers

RESULTS: PART 2

No palatalization of fricative /s/

- For all speakers, tongue position of /s/ remains the **same** regardless of roundedness of following vowel

Articulation of affricates /ts, ts^h/ vs. fricative /s/:

- Given the same vowel context, /ts, ts^h/ more **backed** than /s/ for most speakers except young females
- For **young females**, same tongue position for /s/ and /ts, ts^h/ before unrounded vowels, /ts, ts^h/ before rounded vowels more backed than the rest

DISCUSSION: PART 2

Results of both **acoustic** and **articulatory** analyses support the hypothesis of affricate allophone phonologization in HKC

Conservative system: /ts, ts^h/ as [ts, ts^h] in all contexts

Innovative system: /ts, ts^h/ > [tʃ, $tʃ^h$] / _ [+round]

DISCUSSION: PART 2

Incidence of affricate allophone phonologization is stratified by age and gender:

young female > young male > old female > old male

Young females often lead sound changes, first in the community to adopt innovative linguistic features (Labov 1990)

Diachronic sound change in progress?

DISCUSSION: PART 2

Is affricate allophonic restructuring induced by **language contact**?

Liu (2010) and Lan (2017): Influence of English

- Onset of change coincide with the period when Cantonese-English bilingualism became widespread in HK (late 20th century)
- The only phonemic affricates in English are post-alveolar /tʃ, dʒ/

DISCUSSION: PART 2

Yet, does not explain why palatalization only occurs **before rounded vowels** but not in other environments

- English /tʃ, dʒ/ post-alveolar in all linguistic environments
- e.g. cheese vs. choose, check vs. chalk
- Phonetic motivation for restructuring of affricate allophonic system?

DISCUSSION: PART 2

Lip rounding and tongue backing share similar acoustic effect

- Both lower spectral peak and mean frequency

- Younger speakers reinterpret lowering of spectral peak from anticipatory lip rounding as tongue backing (palatalization)

- Hypo-correction: accentuate articulatory difference between affricates before rounded vs. unrounded vowels

- Palatalization became feature of affricates, two allophones formed

DISCUSSION: PART 2

Why palatalization targets **affricates only** but not fricative?

- Under **articulatory phonology**-style approach (Browman & Goldstein 1989), affricates and fricatives might be affected by vowel co-articulation to a different extent

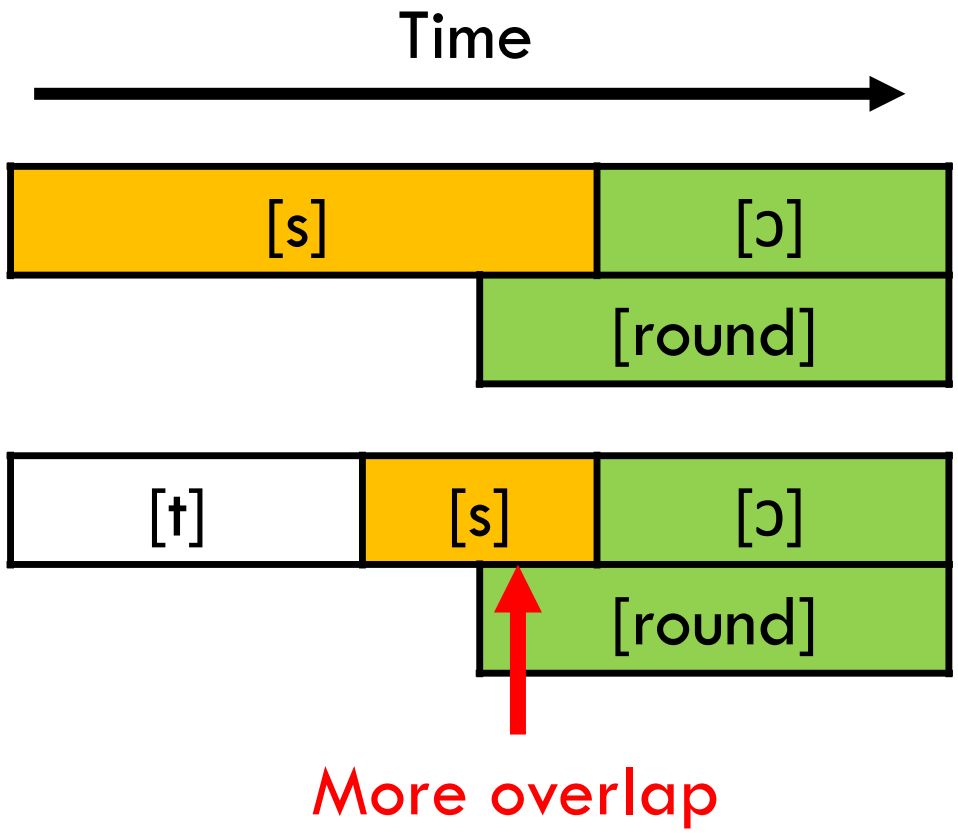
DISCUSSION: PART 2

Affricates shorter than fricatives, more gestural overlap with following vowel

Anticipatory lip rounding affects a larger portion of affricates

Thus, precondition for sound change more pronounced for affricates

Further analysis of temporal dynamics of sibilants with lip measurement needed





THANK YOU!

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