AN AERODYNAMIC STUDY OF THE NASALS AND NASALIZATION IN TAIWANESE MANDARIN

Yueh-chin Chang, Kai-yun Ou and Feng-fan Hsieh
National Tsing Hua University

INTRODUCTION

- Nasalization refers to sounds produced while the velum is lowered to allow the air to escape through the nose.
- The phonetic implementation of vowel nasalization may depend on:
  - the phonemic system of the language (whether nasality is phonemic)
  - Direction of nasalization

    Carryover (NV) vs. Anticipatory (VN)

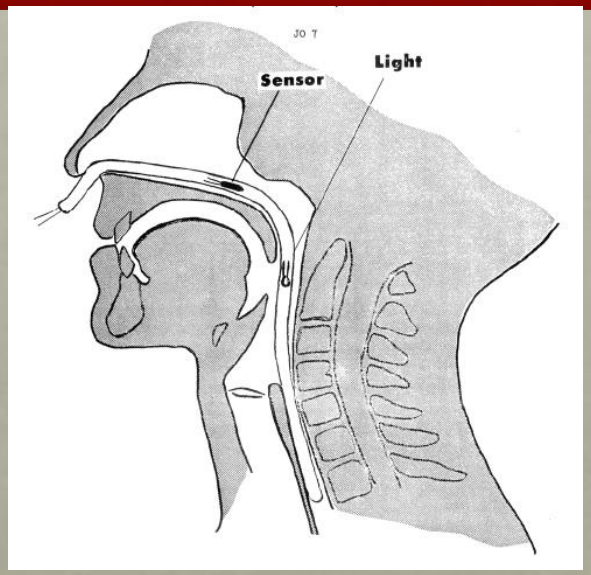
INTRODUCTION (CONT.)

- Vowel height
  - High vowels are produced with higher velum and less velopharyngeal opening than low vowels.(cf. Moll, 1960; Ohala, 1971; Bell-Berti, 1973; ….)

  → low vowels tend to be more nasalized than high vowels

  - Low vowels need a lower velum to be perceived as nasal (Beddor, 1993, ….)

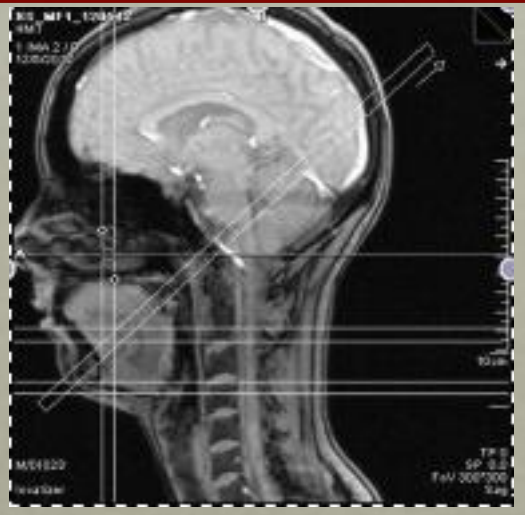
INSTRUMENTS & TECHNIQUES
(KRAKOW AND HUFFMAN, 1993)

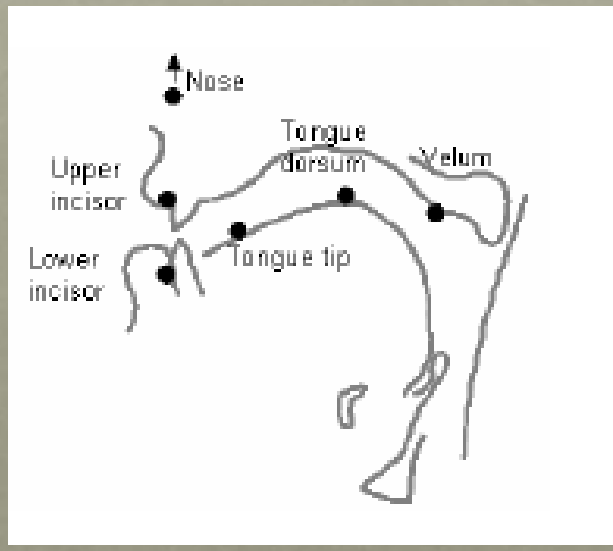


- Velum movement
  - X-ray
  - Ultrasound
  - Fiberoptics
  - Nasograph (Ohala, 1971; Clumeck, 1976)
  - Velotrace (Horiguchi and Bell-Berti, 1987)

INSTRUMENTS & TECHNIQUES (CONT.)

- Velum movement
  - MRI
  - Electromagnetic articulatory (Ushijima and Hirose, 1974; Amelot et al., 2006; Shosted et al., 2012; Carignan et al., 2011,2012, 2015)





INSTRUMENTS & TECHNIQUES (CONT.)

- Acoustic measurements (Berger, 2007)

- Decrease in F1 amplitude
- the emergence of a spectral prominence above **F**1 at around 1000 Hz (House and Stevens, 1956)
- Another nasal resonance below **F**1 between 250 and 450 Hz (Hattori et al., 1958)

INSTRUMENTS & TECHNIQUES (CONT.)

- Acoustic measurements
  - A1-H1 (Huffman 1990)
  - B1 (bandwidth of the first formant),

✓✓ COG(1000): Center of Gravity in the low frequency spectrum (below 1000 Hz) (Glass 1984; Glass and Zue, 1985)

INSTRUMENTS & TECHNIQUES (CONT.)

- Acoustic measurements

✔✔**A1−P0** (**P0**: amplitude of the nasal formant below **F1**, 0 to 450 Hz) (Chen, 1996)

- **A1−P1** (**P1**: amplitude of the nasal formant above **F1**, 800 to 1100 Hz) (Chen, 1996)
- As nasality increases, both **A1−P0** and **A1−P1** should decrease.

INSTRUMENTS & TECHNIQUES (CONT.)

- Airflow equipment

- Nasometer
- Pcquirer

Nasalance: the ratio of nasal to nasal+oral acoustic energy output (Fletcher and Frost, 1974)

PERCEPTION

- Perception of nasality

- **A**1 needed to be reduced by 8 dB (House and Stevens,1956)
- Both the average **A**1 − **H**1 and change in A1-H1 over time contributed to the nasality judgment (Huffman1990)

PERCEPTION (CONT.)

- The introduction of the nasal peak above **F**1 (around 1000 Hz) (Maeda, 1982; Hawkins and Stevens, 1985)
- The other nasal peak below **F**1 (around 250-450 Hz) (Hattori et al., 1958; Maeda, 1982)
- Gating methodology (Bengali and English: Lahiri and Marlsen- Wilson,1992; Hindi and English: Ohala and Ohala,1995)

TAIWANESE MANDARIN

- Taiwanese Mandarin has 5 vowels and 2 nasal coda /n/ and /ŋ/. The possible VN rimes are: {/in/, /iŋ/, /ən/, /əŋ/, /yn/, /oŋ/, /an/, and /aŋ/}
- Taiwanese Mandarin speakers tend to realize
- /in/ → [iŋ] and /ən/ → [əŋ] (Hung 2006, Kubler 1985, Tse 1992, J. H.-T. Yang 2007, Yueh 1992)
- /iŋ/ → [in] and /əŋ/ → [ən] (C.-y. Chen 1991b, Hsu 2006, Hsu & Tse 2007, C. C. Lin 2002)

AIMS

- This work is an aerodynamic study of nasal sounds and nasalization in Taiwanese Mandarin (TM).
  - -- Progressive over anticipatory?
  - -- Is nasality correlated with vowel height?
  - -- Manner of articulation induces vowel nasalization?
  - -- Merger: /in/ → /iŋ/? /iŋ/ → /in/?
- Also, we wanted to investigate whether nasalization is realized differently in Taiwanese Mandarin and Standard Chinese (SC).

PARTICIPANTS

- Ten (10) native speakers of TM (5 male and 5 female in their 20s) from the Greater Taipei Area.
- To minimize potential “L1” interference.
  - They do *not* speak any other Sinitic languages spoken in Taiwan, e.g., Taiwanese Southern Min and/or Hakka.

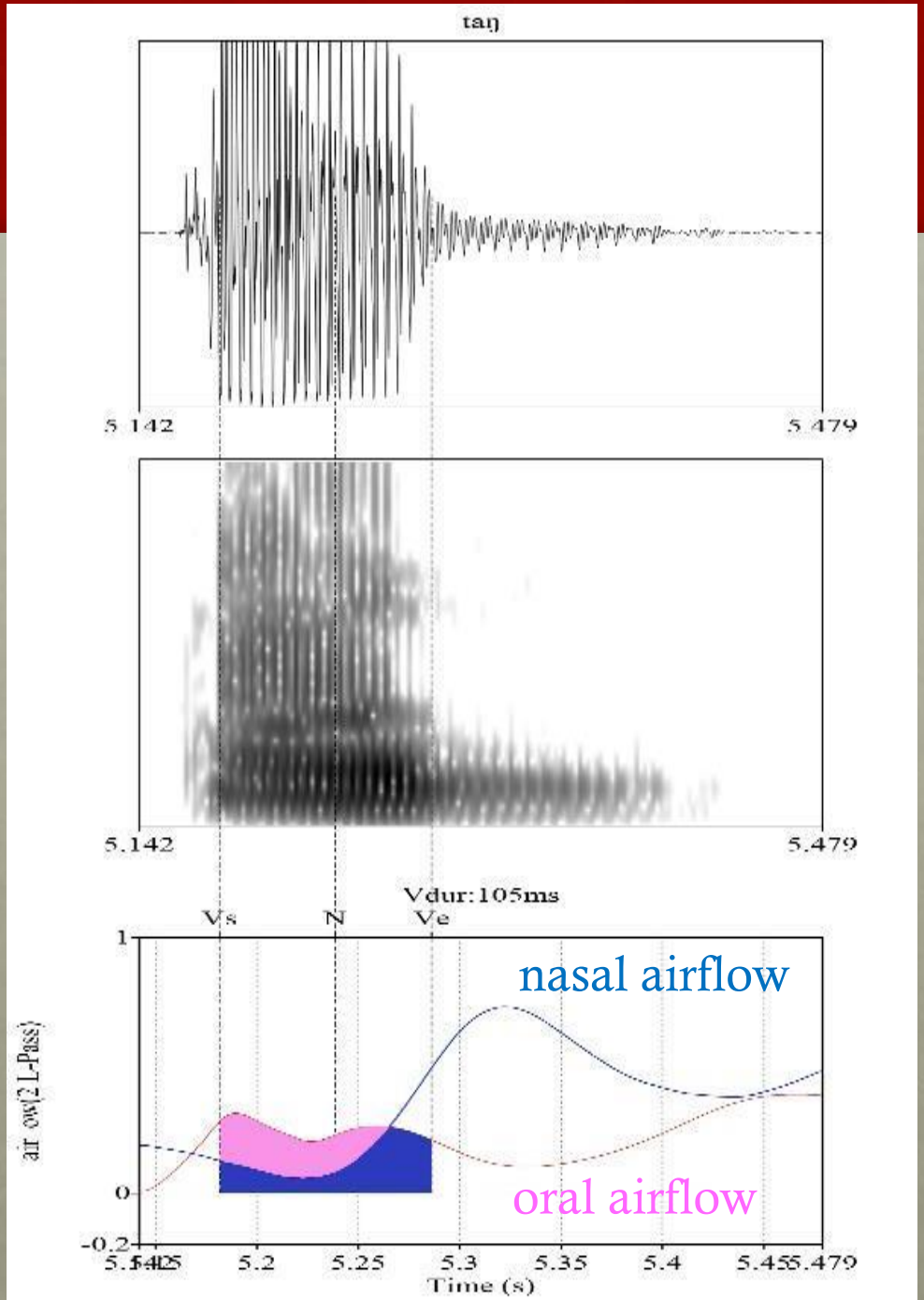
CORPUS

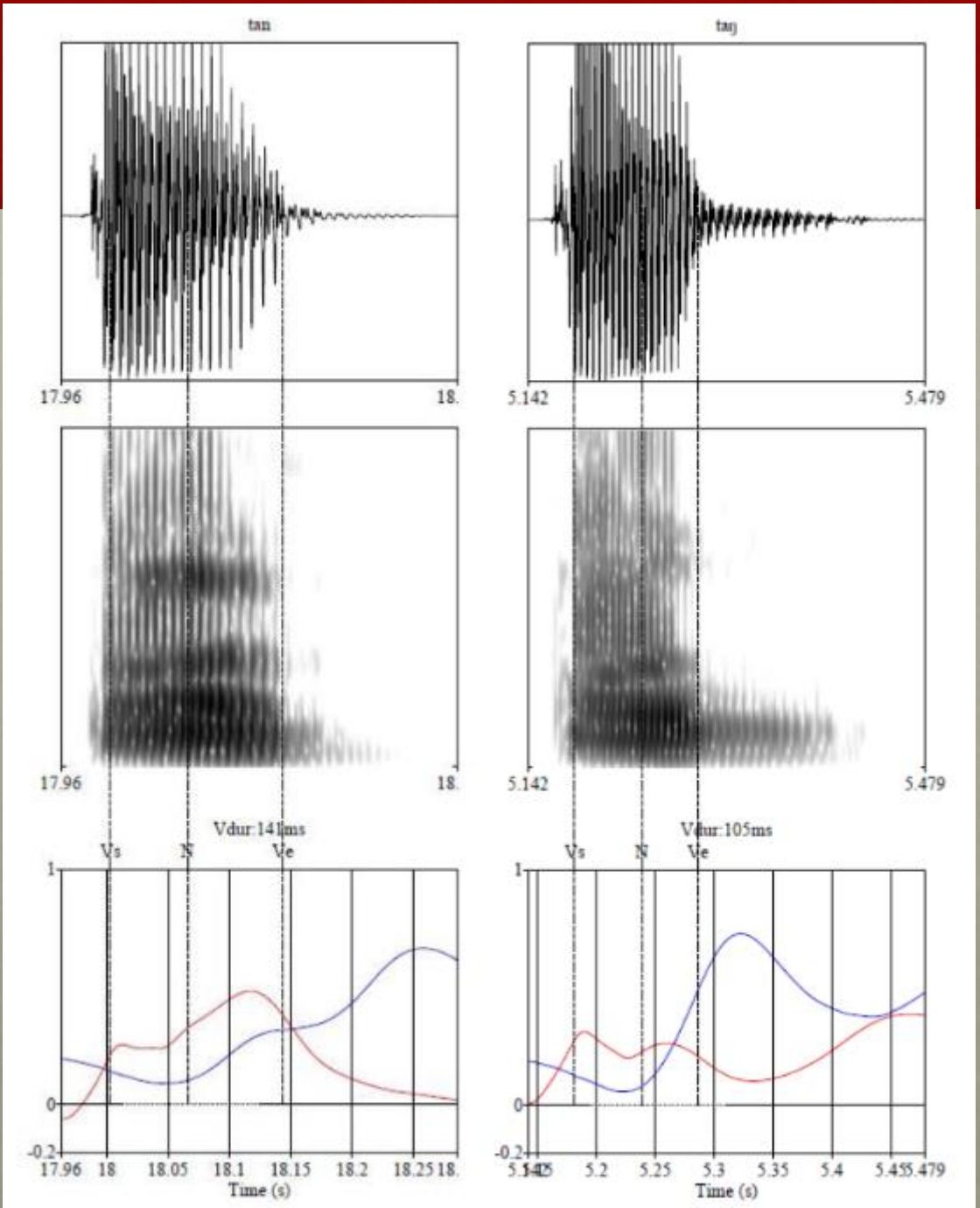
- All possible NV, NVN, CV and CVN syllables in Taiwanese Mandarin.
- Only real words are used (164 words)
- Tone 4 (high falling) is used; otherwise, Tone 1 (high level) is chosen if there is a tonetic gap.
  - Intended for cross-linguistic comparison in the future…

METHOD

- The airflow data were collected with the help of Pcquirer 516 (Scicon R&D Inc.) in a soundproof room at phonetics lab, National Tsing Hua University.
- Data were analyzed by Praat scripts developed at phonetics lab, National Tsing Hua University (Y.-L. Hsieh 2011, Y.-L. Hsieh et al. 2011).

- The onset of nasalization was determined as the time point at which nasal airflow crossed the zero level plus 10% of the maximum level of nasal airflow in vowel (Delvaux et al. (2008).




tan
17.96
18.
17.96
18.
Vdur:141ms
Vs
N
Ve
1
0
-0.2
17.96
18
18.05
18.1
18.15
18.2
18.25
18.
Time (s)
taŋ
5.142
5.479
5.142
5.479
Vdur:105ms
Vs
N
Ve
1
0
-0.2
5.2
5.25
5.3
5.35
5.4
5.455.479
Time (s)

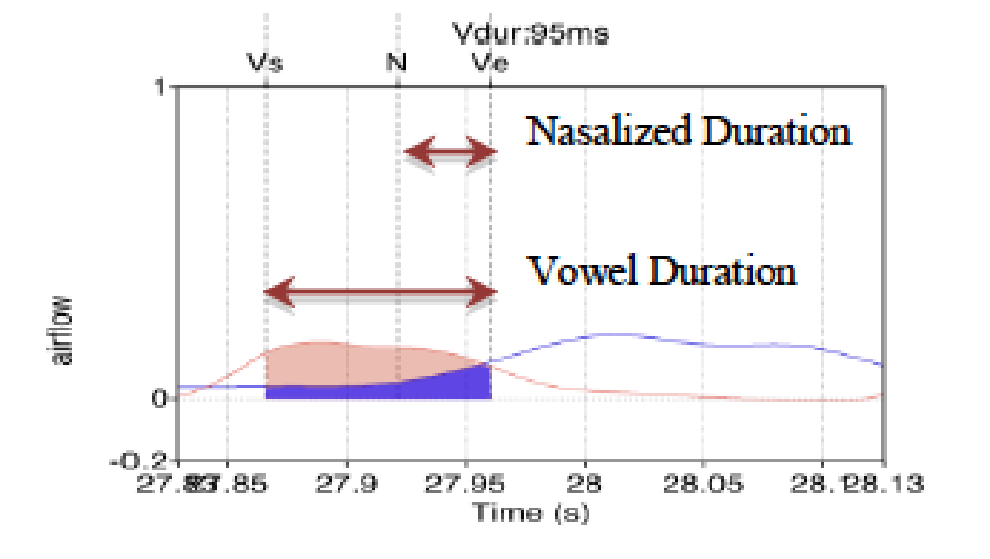
TWO TYPES OF MEASUREMENTS ON THE AIRFLOW DATA (DELVAUX ET AL. 2008)

(1) Percentage of nasalized time (NasalTime%)

$$= \frac{NasalizedDuration}{TotalVowelDuration} * 100\%$$

(2) Percentage of nasal flow volume (NasalFlow%)

$$= \frac{NasalFlow(bleu)}{NasalFlow(blue) + OralFlow(\mathrm{Re}\,d)} * 100\%$$



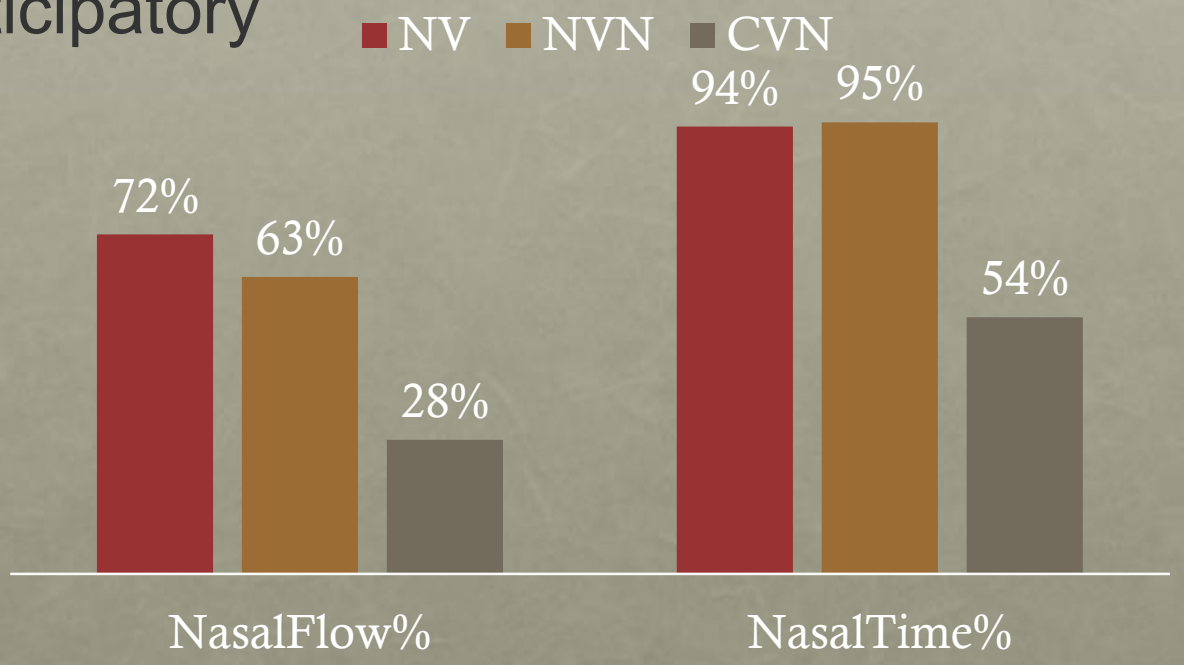
EXPERIMENTAL RESULTS

RESULT (1): VOWELS

- NV vs. VN

The magnitude of progressive nasalization (NV) is significantly larger than that of regressive nasalization (VN) for both NasalFlow% and NasalTime%.

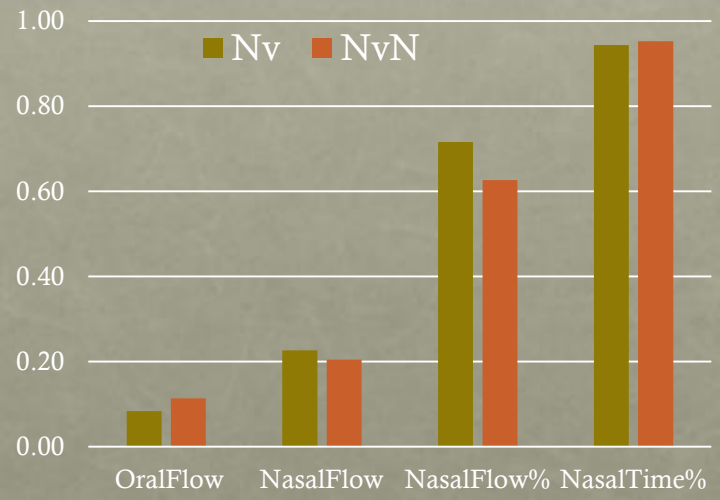
→ progressive > anticipatory

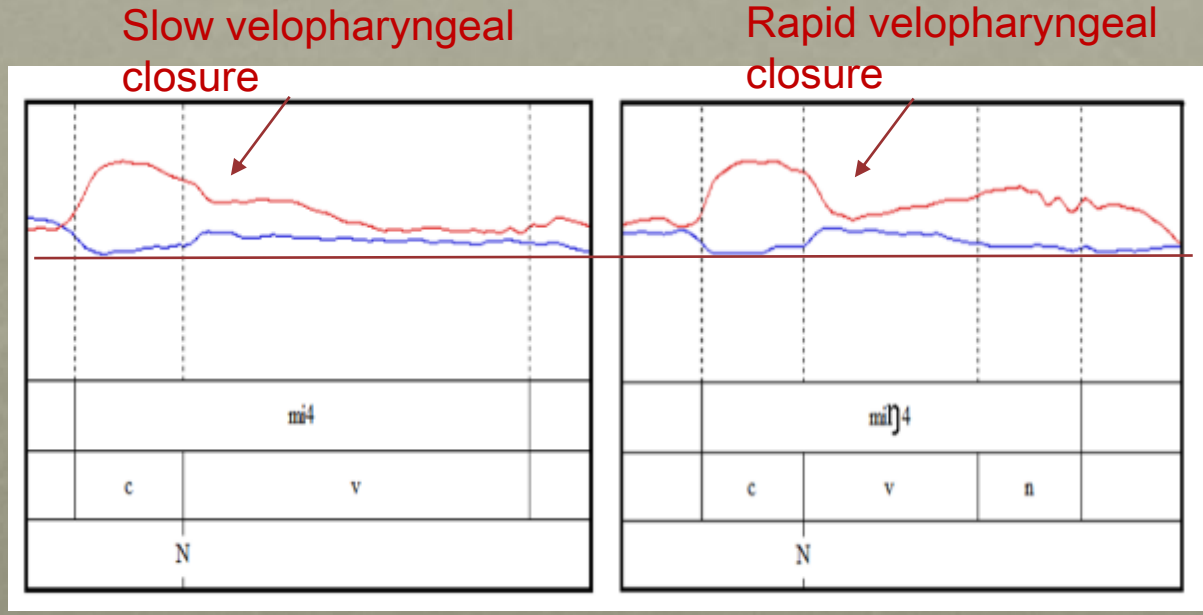


RESULT (1): VOWELS (CONT.)

- NV vs. NVN

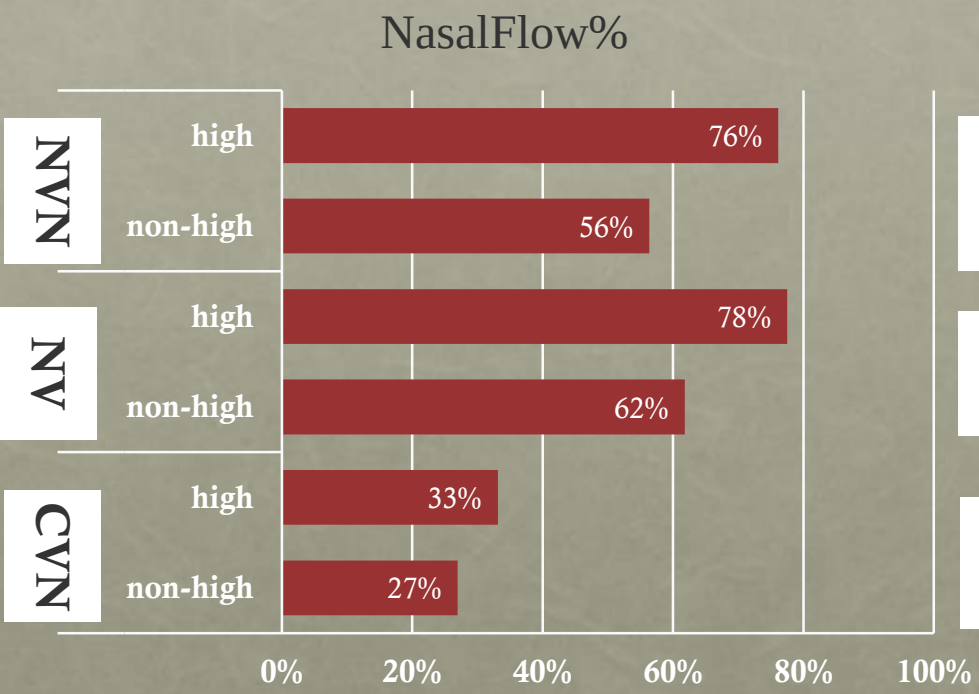
Interestingly, NV has more NasalFlow% than NVN does ($p<0.001$), due to the rapid velopharyngeal closure at the beginning of the vowel for NVN.

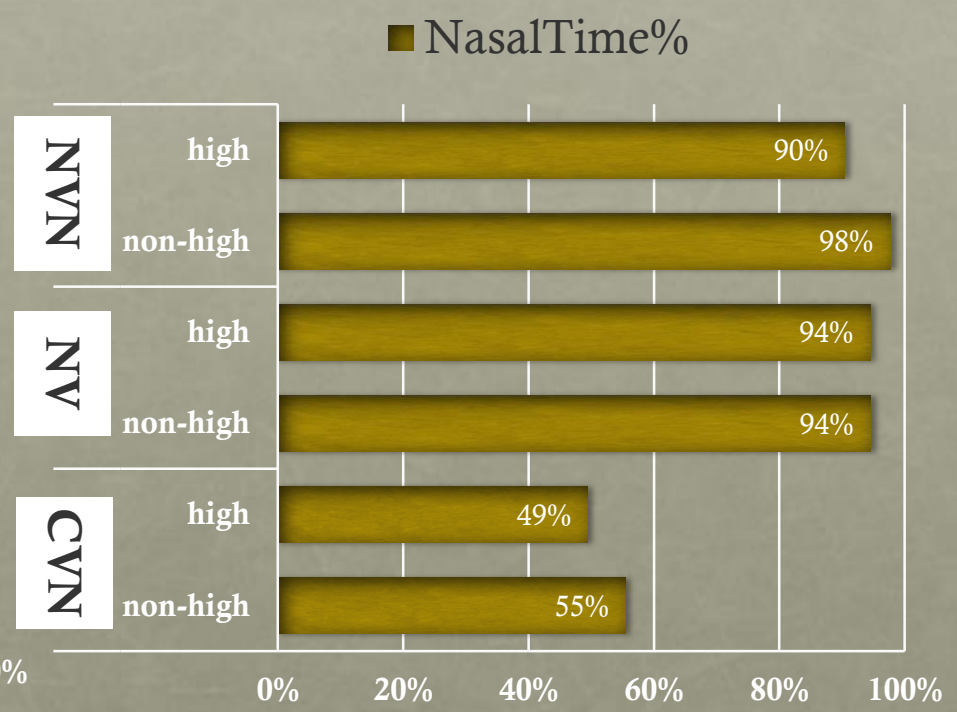




RESULTS (2): NASALITY VS. VOWEL HEIGHT

High vowels have more NasalFlow% in various contexts ($p<0.05$), but have shorter NasalTime% ($p<0.05$).





Result (3): The role of onset on contextual nasalization

- Voiced fricative and liquid induce more NFL% and nasal onset than voiceless counterparts.
- Aspirated consonants have oral and nasal flow volume than unaspirated ones ($p<0.05$) and induce a marginally significant earlier nasal onset ($p=0.06$).

	Unasp. Stop	Unasp. Affricate	Asp. Stop	Asp. Affricate	Voiceless Fricative	Voiced Fricative	Liquid
Oral Flow	0.206	0.194	***0.306***	***0.292***	0.208	0.149	0.157
Nasal Flow	0.082	0.080	***0.102***	***0.094***	0.083	0.066	0.083
NFL%	29.1%	29.3%	24.6%	24.2%	29.4%	**32.3%**	**34.0%**
NDur%	51.0%	51.3%	**58.7%**	**56.5%**	52.1%	**56.6%**	**57.0%**

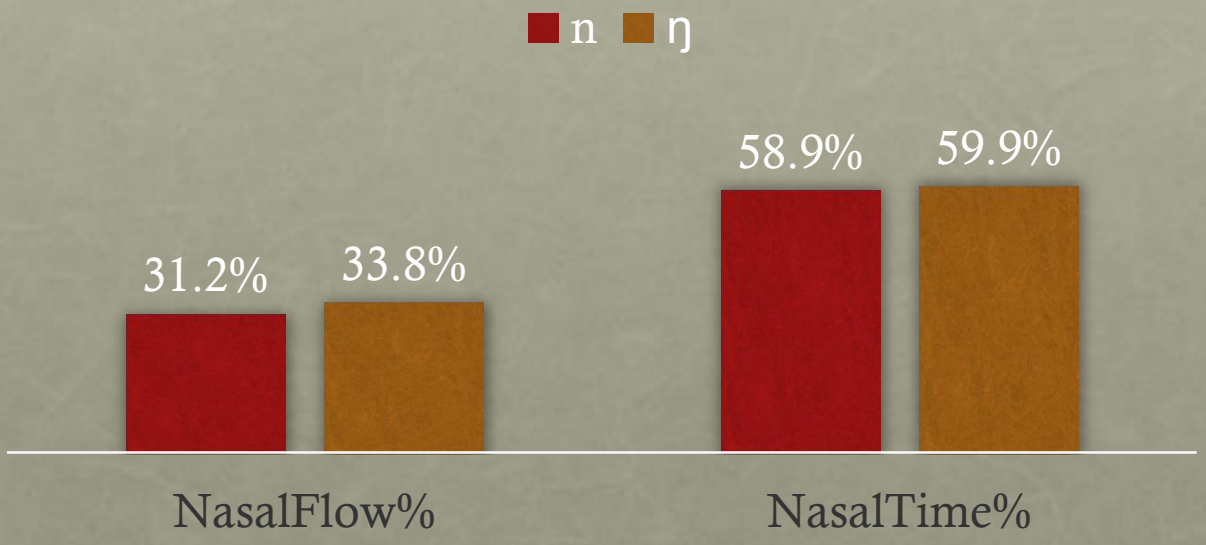
VOICING AND ASPIRATION

- Why voicing induces more nasal airflow:
  - In CVN syllables, velum lowing starts from the closure phase or release phase for liquid, but after release phase for stops and fricatives (Moll and Danioff, 1971).
  - Our results lend support to this view.
- What about aspiration?
  - It has been noted in Matisoff (1973) that /h/ tends to trigger spontaneous nasalization in sound change (rhinoglottophilia).
  - More or less, aspiration = [h]

Result (4): The role of coda on contextual nasalization

- Codas /n/ vs. /ŋ/

Coda /ŋ/ induces “more nasalization” in the preceding vowels than /n/ does for both nasal airflow volume and nasal flow duration, but the difference is insignificant.



SUMMARY (1)

- Progressive nasalization (NV) > Anticipatory nasalization (VN).
- Nasality is positively correlated with vowel height.
- Similar results found in our previous study for Taiwanese Southern Min and French (Hsieh et al. 2011).
- But that is not consistent with some other languages, e.g. Hindi, whereby nasality is negatively correlated with vowel height.

SUMMARY (2)

- Voiced fricatives and liquid induce a larger nasal flow percent than their counterparts do.
- Aspiration is produced with more oral and nasal airflow and triggers an earlier nasal onset.

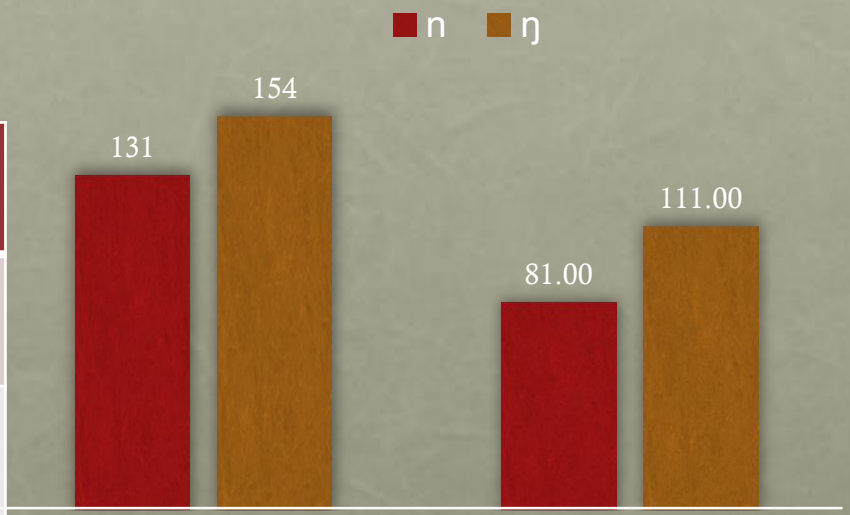
  → Rhinoglottophilia (Matisoff, 1975)
- Coda /ŋ/ induces more nasality in the preceding vowels than coda /n/ does. Similar results are also found in Taiwanese Southern Min (TSM) but not in Standard Chinese (SC).

TAIWAN MANDARIN (TM) VS. STANDARD CHINESE (SC)

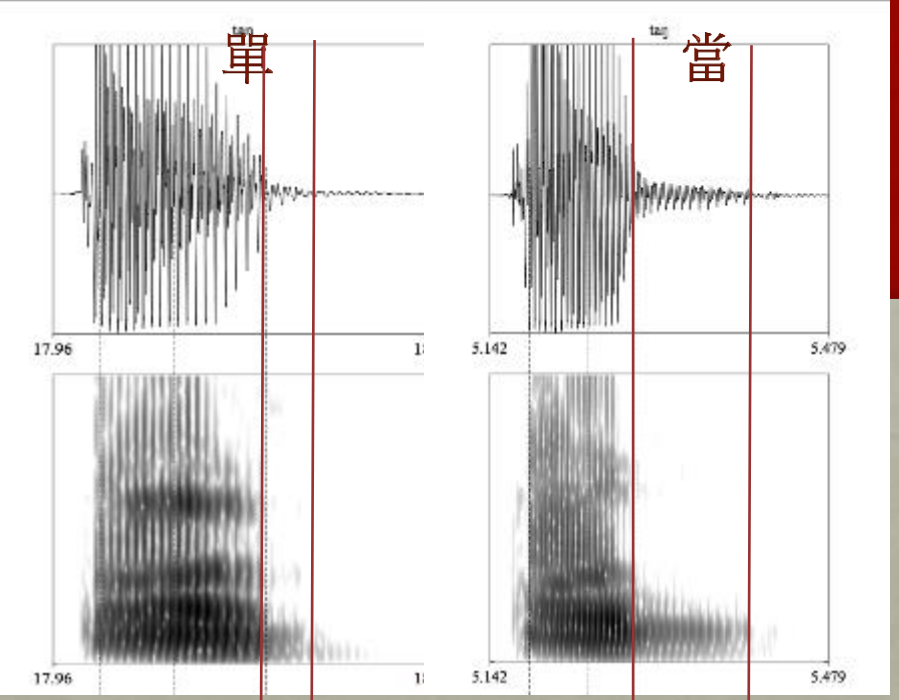
- ➔Vowels have more nasality in SC than that in TM.
- ➔Nasal coda's duration is longer in TM than that in SC.
- ➔/n/ is much shorter than /ŋ/ in SC than that in TM.
- ➔Vowel preceding /n/ is more nasalized than /ŋ/ in SC, but not in TM and TSM.

	TM	SC	TSM
n	31.0%	51.0%	19.6%
ŋ	33.8%	50.3%	21.7%

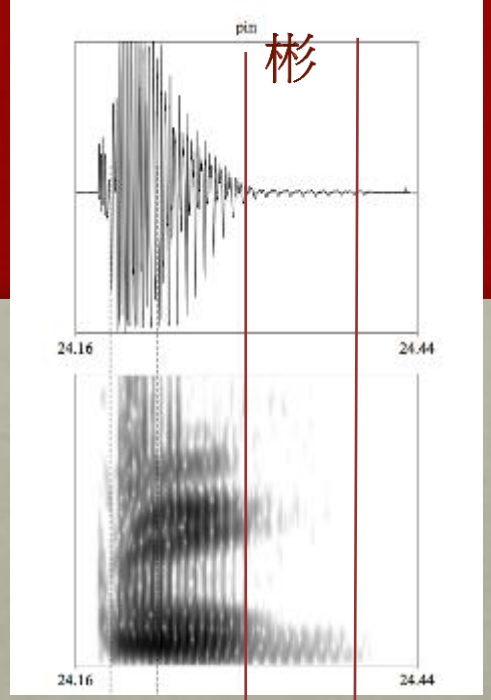
NasalFlow%

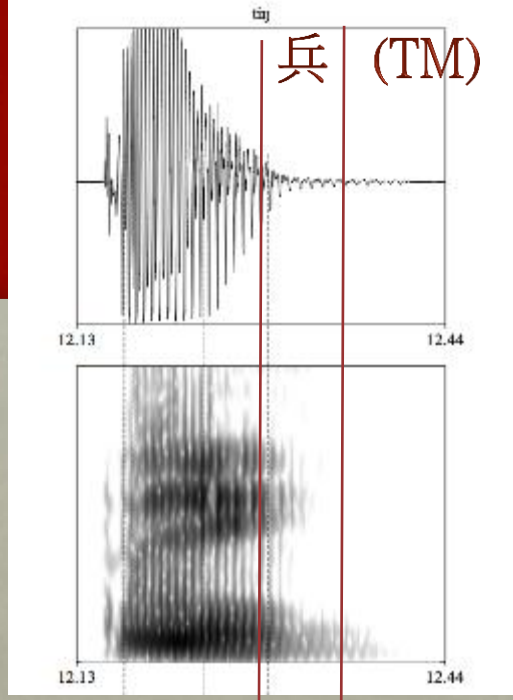


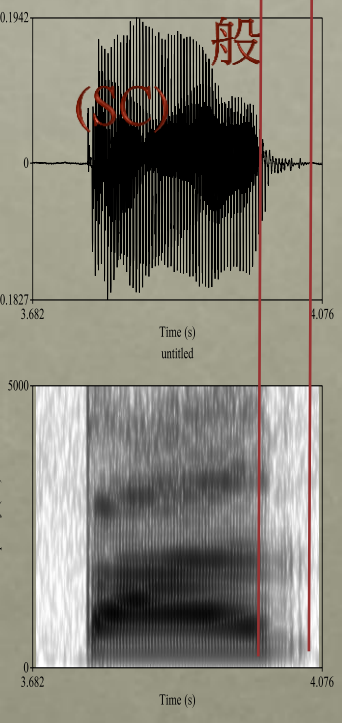
Nasal coda's duration (in ms.)

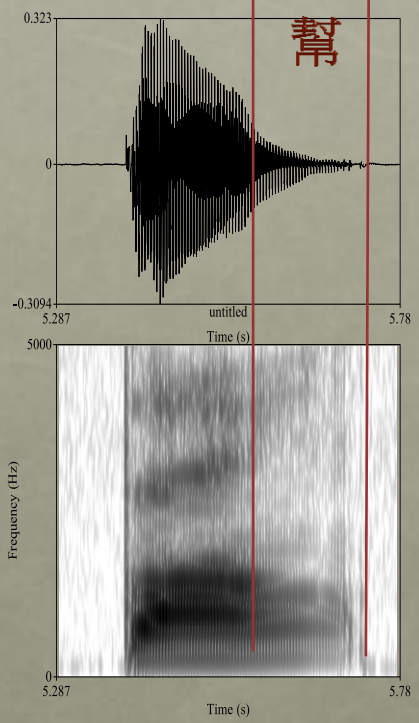

單
17.96
17.96

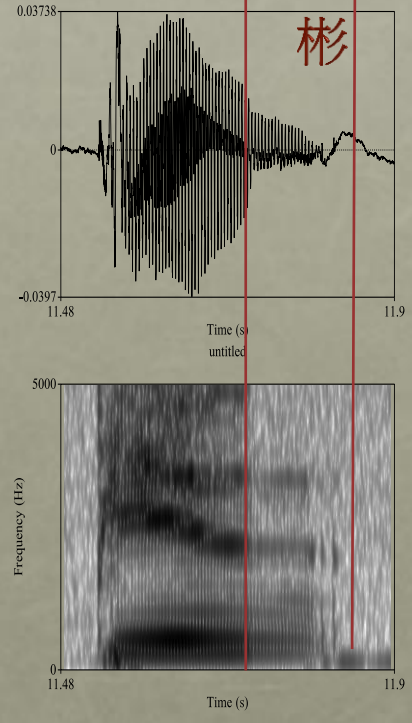
當
5.142
5.479
5.142
5.479

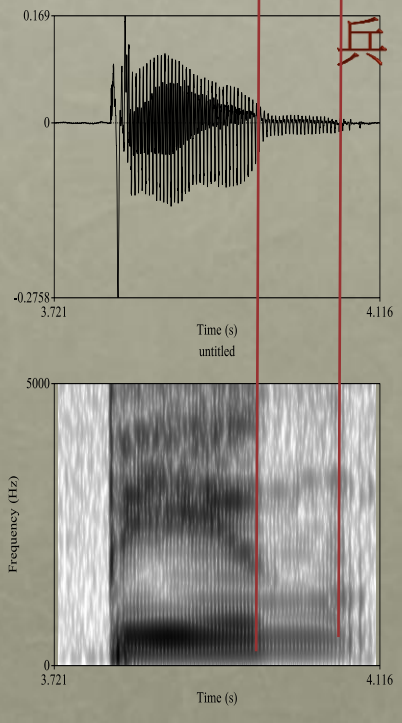

彬
24.16
24.44
24.16
24.44


兵 (TM)
12.13
12.44
12.13
12.44


般
(SC)
0.1942
0
0.1827
3.682
4.076
Time (s)
untitled
5000
0
3.682
4.076
Time (s)


幫
0.323
0
-0.3094
5.287
untitled
5.78
Time (s)
5000
Frequency (Hz)
0
5.287
5.78
Time (s)


彬
0.03738
0
-0.0397
11.48
11.9
Time (s)
untitled
5000
Frequency (Hz)
0
11.48
11.9
Time (s)


兵
0.169
0
-0.2758
3.721
4.116
Time (s)
untitled
5000
Frequency (Hz)
0
3.721
4.116
Time (s)

MORE ON NASAL CODAS IN TAIWANESE MANDARIN

MERGER OF NASAL CODAS IN TAIWANESE MANDARIN

- Previous studies show that there is contextual place neutralization of nasal codas in TM, especially for the pairs /ən/ and /əŋ/, and /in/ and /iŋ/.
- In our study, impressionistically speaking,

✓ all speakers distinguished between /an/ and /aŋ/

✓ 85%~89% of speakers distinguished between /ən/ and /əŋ/

✓ 74%~79% of speakers distinguished between /in/ and /iŋ/.

INTRODUCING "N"

- Due to the nature of the airflow experiment, it is oftentimes difficult to accurately identify the place of articulation of a coda nasal.
- In our study, "N" is used to refer to the tokens that are not easily identifiable.
- In this work, we focused on the following rimes:

  /an/ vs. /aŋ/

  /ən/ vs. /əŋ/

  /in/ vs. /iŋ/.

DISTRIBUTION OF "N"

Our impressionistic results show that /in/ and /iŋ/ are most "confusable", meaning that they are more likely to be transcribed as "N" (in average 23.5% for the coda /ŋ/ vs. 13% for the coda /n/).

Coda identified as	n	ŋ	N
an	100%		
ən	89%		11%
in	79%		21%
aŋ		100%	
əŋ		85%	15%
iŋ		74%	26%

DIFFERENCES IN NASAL FLOW %

We measured the nasality and the duration of the nasal coda. If we don't take the pair /an/ and /aŋ/ into consideration, /n/ and /ŋ/ have similar magnitude of nasal flow volume% (79.7% VS. 81.5%), and their magnitude is higher than that of /N/ (76.4%~77.4%).

NasalFlow%	n	N(<n)	NasalFlow%	ŋ	N(<ŋ)
an	71.0%		aŋ	58.7%	
			<		
ən	78.5%	71.7%	əŋ	79.4%	72.3%
			<		
in	80.9%	81.1%	iŋ	83.6%	82.4%

DIFFERENCES IN DURATION

The coda /ŋ/ is significantly longer than the coda /n/ (157 ms. vs. 137 ms, $p<0.05$).
/N/ is shorter than /ŋ/ and /n/. (115 ms.~129 ms.)

(in ms.)

Duration	n	N(<n)	Duration	ŋ	N(<ŋ)
an	117		aŋ	149	
ən	130	109	əŋ	148	131
in	145	121	iŋ	166	127

NASAL FLOW INDUCED

- Vowels followed by /ŋ/ are more “nasalized” than those followed by /n/ in nasal flow volume% ($p>0.05$).
- Vowels followed by /N/ have a degree of nasalization (32.8%~33.3%) less than those followed by /n/ (35.3%) and /ŋ/ (36.9%)

NasalFlow%	n	N(<n)	ŋ	N(<ŋ)
a	28.8%		< 33.7%	
ə	27.2%	26.7%	< 29.2%	27.5%
i	43.4%	38.8%	< 44.5%	39.1%

SUMMARY

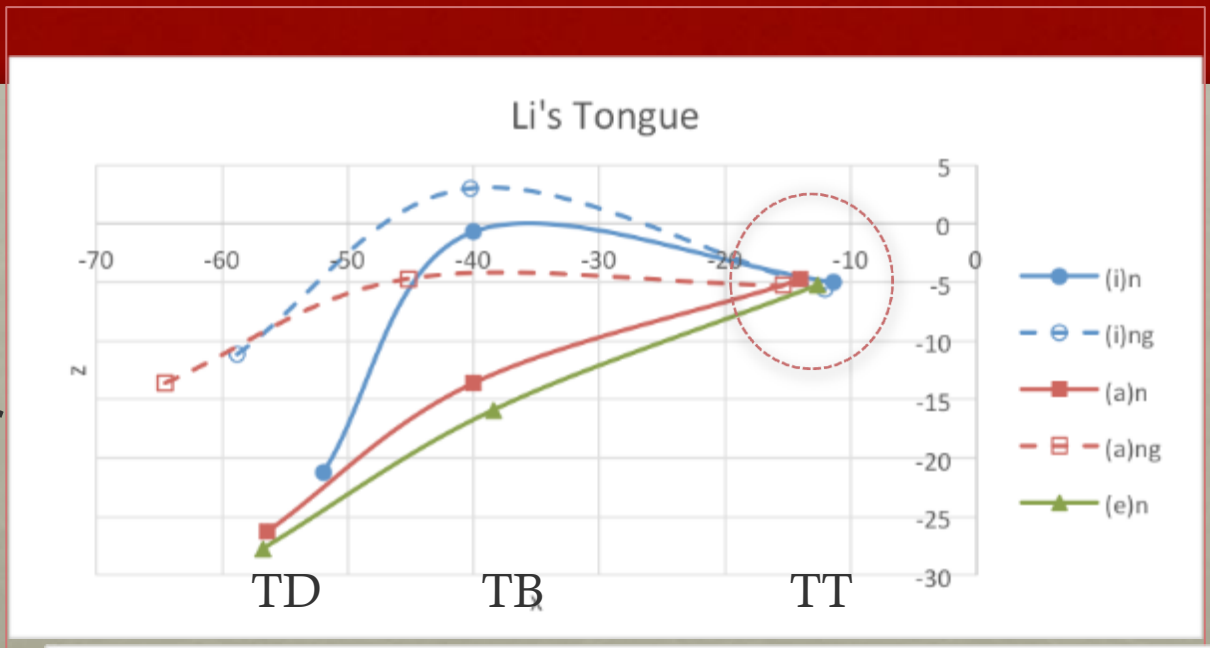
- Coda [N] is different from [n] and [ŋ]:
  - Coda duration: N < n < ŋ
  - NasalFlow%: N < n < ŋ
  - NasalFlow% induced in vowel : N < n < ŋ
- [N] can be regarded as an instance of "incomplete neutralization," unlike previous studies.
- Further issue: Is [N] attributable to language contact (with Taiwanese Southern Min)?

ARTICULATORY CHARACTERISTICS

EMA DATA

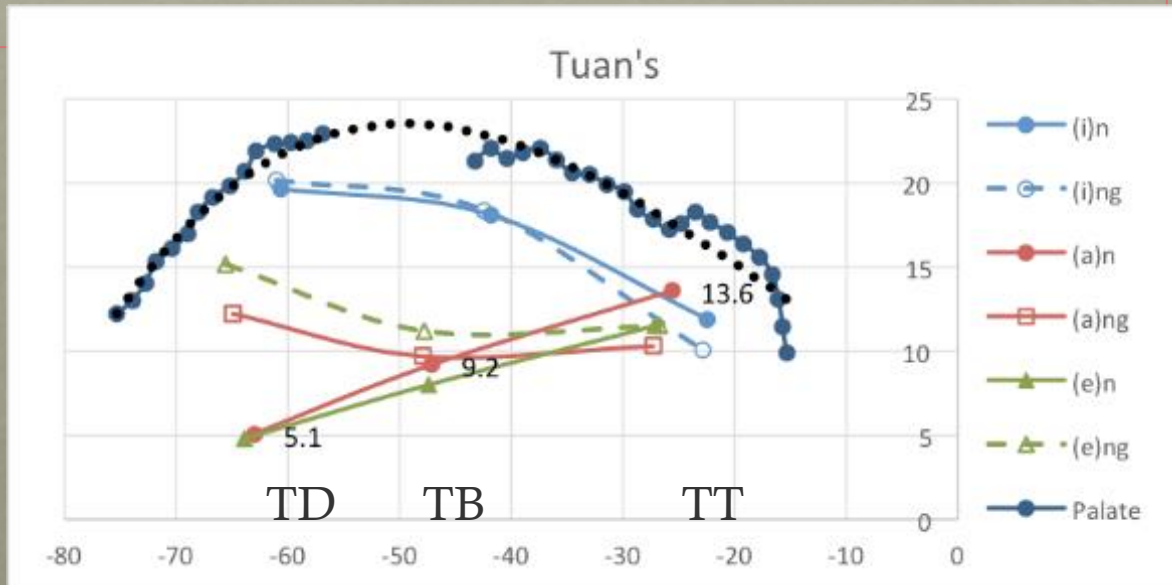
Speaker M1:

/ŋ/ has both TT and TD gesture for /aŋ/ and /iŋ/



Speaker F1:

- /in/ > /iŋ/
- /əŋ/ has both TT and TD gesture

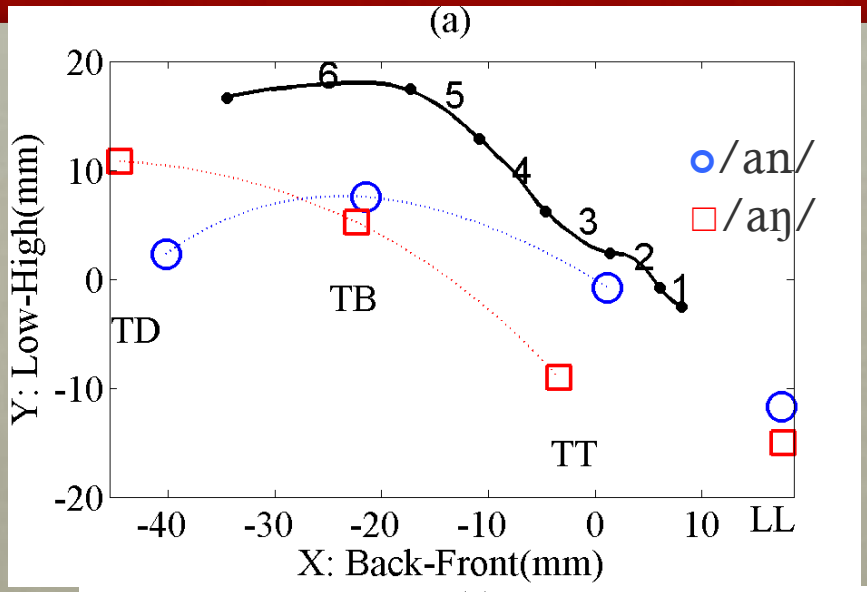


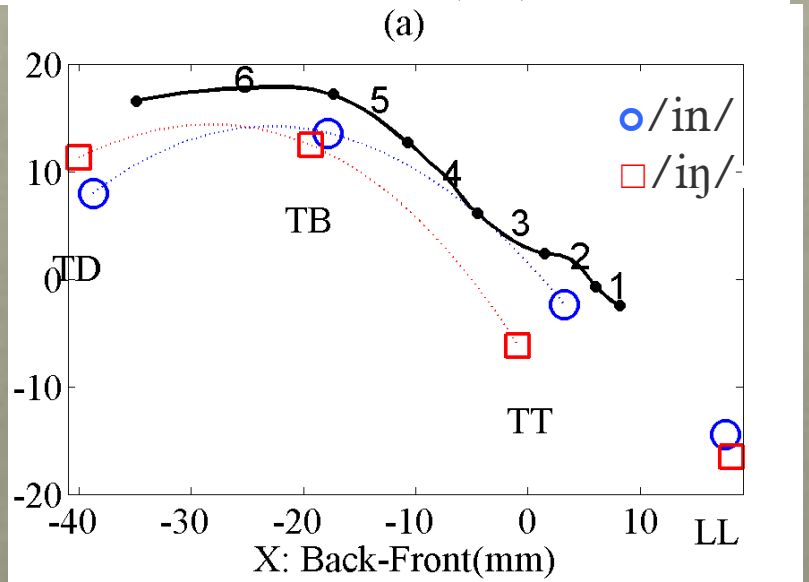
EMA DATA (CONT.)

Speaker M2:

/in/ shows both TT and TD gestures in [in].

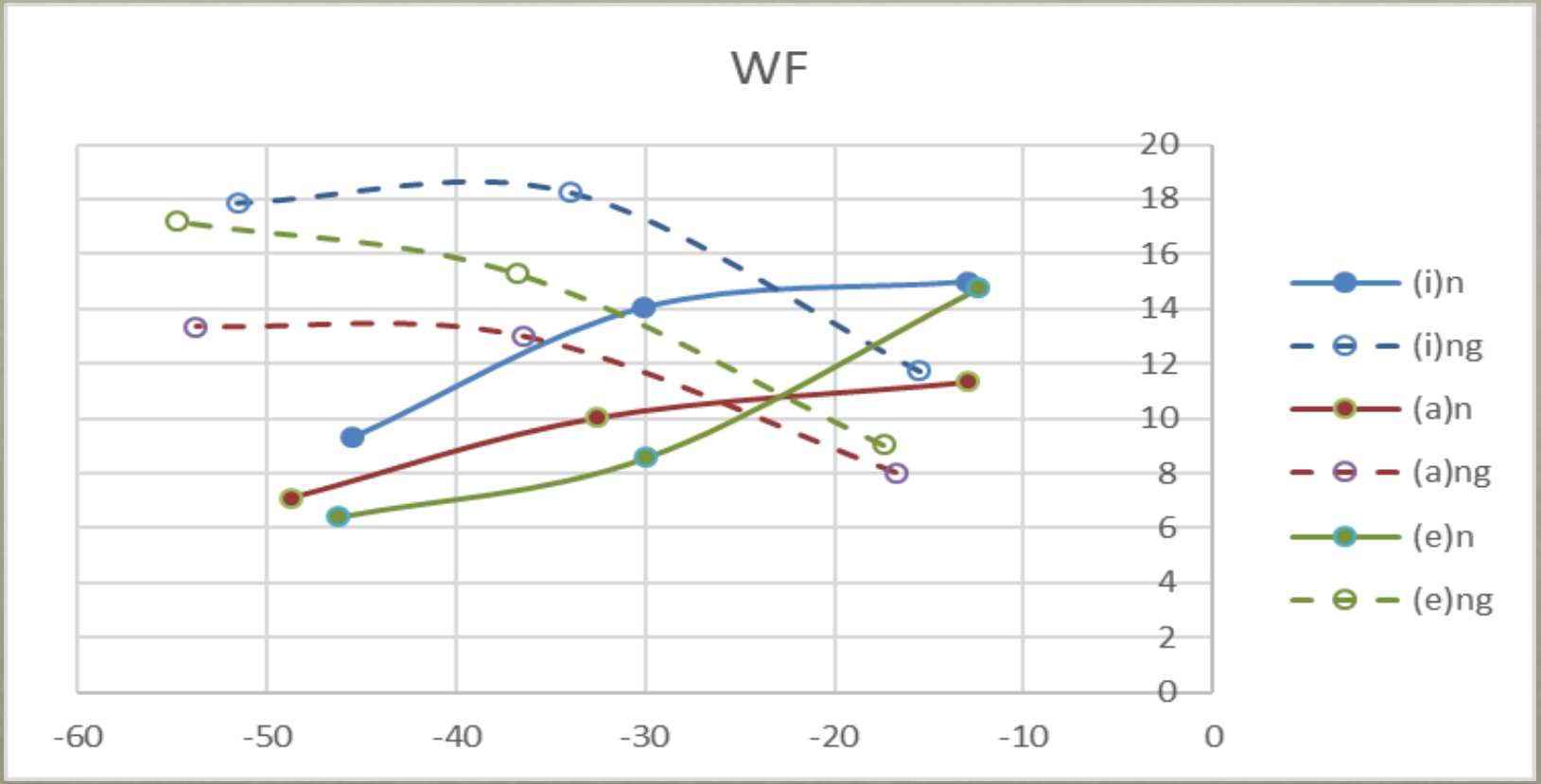
- There seems to be inter-speaker variation in the production of VN rimes.





EMA DATA (STANDARD CHINESE)

- SC speaker: different articulatory gestures for /n/ and /ŋ/.



CONCLUSION

- Take-home messages:
  - Regarding /in/ vs. /iŋ/, we found that [iN] is different from [in] and [iŋ] with respect to airflow and duration (incomplete neutralization).
  - Articulatorily speaking, [N] may have two gestures, TT and TD.

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Thank you!

Comments?