Debuccalization without spirantization *or* Why 10th century Kannada lost its lips

Chandan Narayan
York University

Buffalo Linguistics
April 25, 2025

Background

Here is the setting of our story:

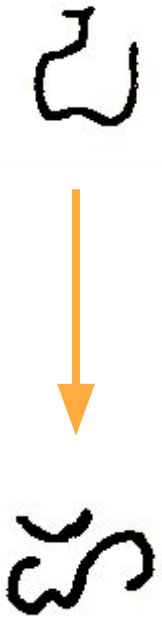
Modern Kannada (South Dravidian) has ***h-*** where closely related Dravidian languages (e.g., Tamil, Malayalam) have ***p-***

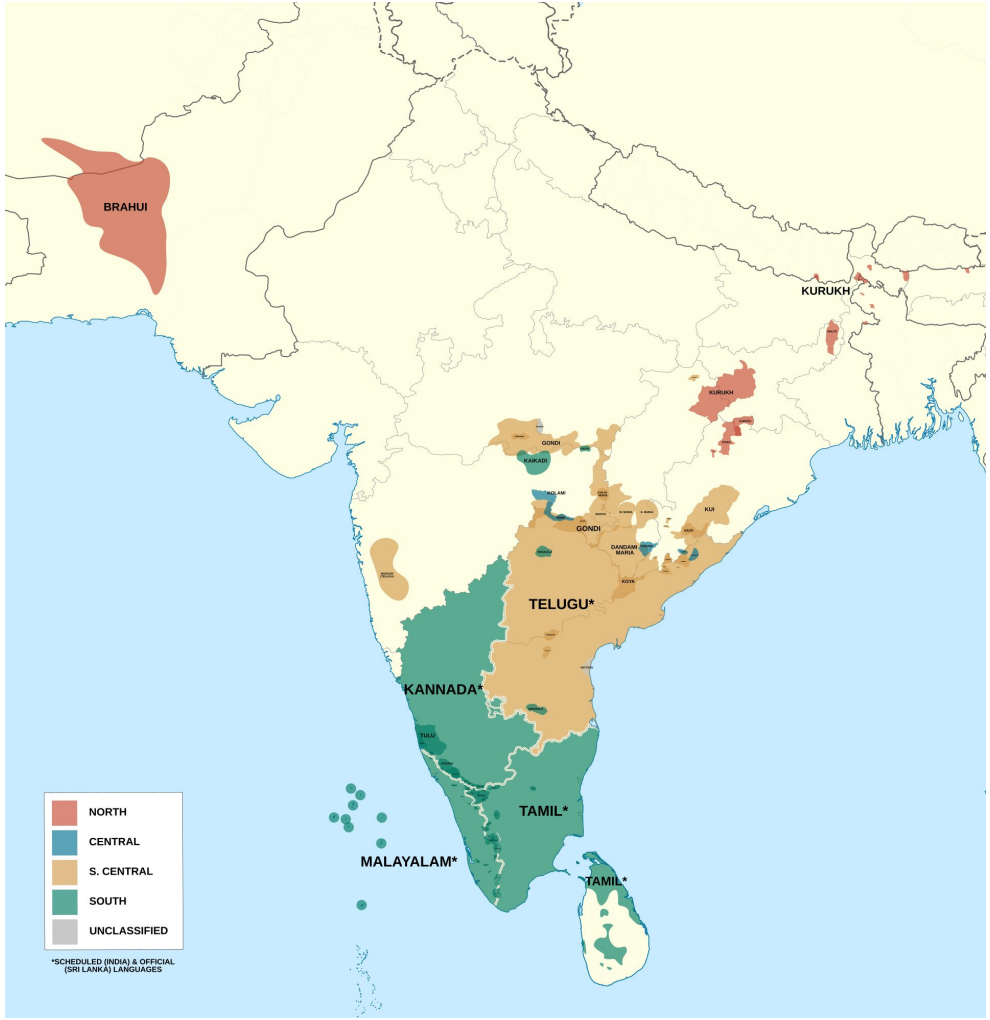
Ta.	paːl	pɪnnaːl	pire	puː	poː
Ma.	paːl	pɪnnɪl	pira	puːʊu	poːgu
Ka.	haːlu	hɪnḍe	hire	huːʊu	hoːgu
	‘milk’	‘behind’	‘gourd’	‘flower’	‘go’

Background

Extensive stone and copper plate inscriptions from Kannada-speaking regions, suggest debuccalization started between the 10th and 11th centuries CE

By the 14th century nearly all ***p***-initial Kannada words and Sanskrit borrowings show the ***h-*** pronunciation





https://shorturl.at/emRFO

https://shorturl.at/6kf2l

Brief typology of debuccalization

The typical path for obstruents losing their oral place features and changing manner (especially in prosodically strong positions) involves an intervening **spirantization** stage with an oral constriction (O'Brien, 2012)

- *h* developing from earlier fricative, e.g., Middle Chinese χ > *h* (Pulleyblank, 1984)
- aspiration with intermediate fricative stage, e.g., PIE *$b^h olh_3$-yom* > Latin *folium* > Occitan *huelha*

Debuccalization in Kannada does not follow either of these paths, developing from an **unaspirated** bilabial plosive

Comparable scenarios

1. Armenian

   PIE **p* > Ar. *h* (Beekes, 2003) [*Most like the Kannada case*]

2. Rotuman and Sa'a

   Proto-Oceanic **p* > *h*; but Tongan, Samoan suggest intervening **f* stage

3. Japanese

   Old Japanese *p* > Early Mod. Japanese [ɸ] > Mod. Japanese *h*

Direct move from *p* > *h*

Kannada inscriptions move directly from ***p*** to ***h*** without an intervening spirant (frication) stage

Crucially, the glyph representing the aspirated bilabial stop $\boldsymbol{p^{h}}$ was available to Kannada scribes—Extensive use of Sanskrit (with a full set of aspirated stops) in the epigraphical record

If Kannada ***p*** were produced (at some point prior to the change) with spirantization, we might have expected scribes to use glyphs representing $\boldsymbol{p^{h}}$ (but they didn’t)

Extant theories of Kannada debuccalization

Despite the absence of epigraphical evidence of a spirantization stage, early 20th C. Dravidian philologists nonetheless proposed that ***p*** would have been aspirated at some stage

1. Contact with Indo-Aryan hypothesis
2. Push-chain hypothesis

Contact hypothesis

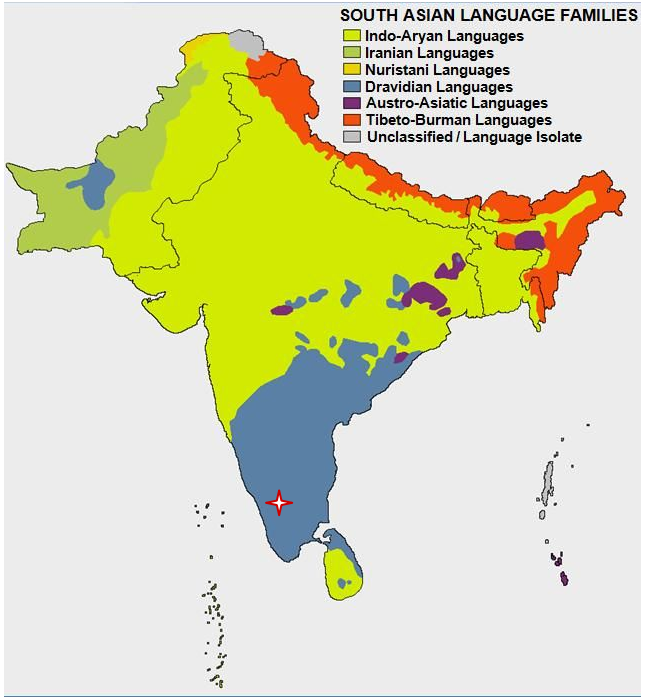
Subbaiya (1909) suggests that debuccalization was catalyzed by Kannada's contact with Marathi (Indo-Aryan)

Middle Indo-Aryan had debuccalized ***bh-*** to ***h-***,

E.g., Sanskrit ***bh****avati* (copula) > MIA ***h****oti*

"*p* seems to have first become aspirated as *ph* and then changed to *h*"

If this were correct, we would expect a geographically constrained distribution of early Kannada ***h-*** forms…but we don't



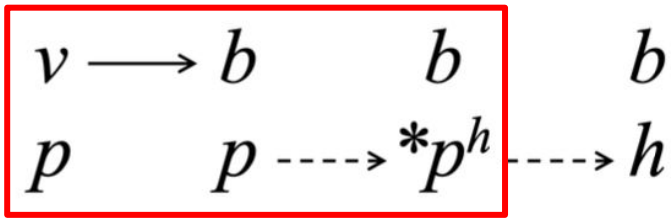
Push chain hypothesis

Tuttle (1929) appealed to another sound change that occurred in pre-Old Kannada at or before the debuccalization

> Drav., IA ***v-*** > Ka. ***b-***, e.g. Skt. *vana*, Ka. *bana* ‘forest’; Tamil *va-*, Ka. *ba-* ‘come’

“In order to make the difference clearer, many persons strengthened *p* to *ph*, which later developt [*sic*] thru *f* to *h*” (Tuttle, 1929, p.154)

> Stopping of ***v*** to ***b*** exerted phonological pressure on *p* (acoustically similar to *b*)



Road map

1. Testing the push-chain hypothesis

   Can we mimic the phonological conditions of 10th C. Kannada in an artificial word-learning experiment?

   Do the results definitively support a push-chain source for Kannada debuccalization? (Hint: they don’t)

2. New proposal: basic acoustics and perception of unaspirated *p*

Testing the push-chain hypothesis

How do we recreate the linguistic milieu of 10th century south India?

Can we find a language, which has a phonological inventory comparable to Old Kannada, i.e., lacking ***b*** as well as lacking aspiration?

Would introducing ***b*** cause listener/speakers to change their production of ***p***?

Modern Tamil as proxy for Old Kannada

Tamil is a conservative South Dravidian language retaining many features of Proto-Dravidian → lacks phonemic voicing

Comparable place of articulation inventory to Old Kannada

Unlike Tamil, Old Kannada orthography contrasted the full complement voiced/voiceless and aspirated/unaspirated plosives and glottal fricative to accommodate Indo-Aryan borrowings

Modern Tamil borrows *heavily* from Sanskrit and English → the orthography, however, does not represent voicing or aspiration

Voiced onset borrowings produced with negative VOT (Lisker & Abramson, 1964), aspiration disappears altogether

Experiment 1: Minimal-pair word production

Will Tamil-speaking children adjust their VOTs for common words beginning with unaspirated ***p*** when taught a new word beginning with ***b*****?**

Why children? → less affected by English borrowings than adults

15 monolingual Tamil-speaking/reading children (9-12yo)

Recorded individually in schoolhouses in three villages near Madurai, TN

Part A: Baseline productions of ***p-*** and ***k-*** initial words

Part B: Association of new ***b-*** initial words with an unfamiliar image

Part C: Minimal-pair production task

Part A: Baseline productions

Participants asked to “Name the picture” for 10 *picturable* ***p-*** and ***k-*** initial words: boat, hand, tiger, rock, boy, fruit, cat, etc.

[puli]

[paːnai]

[kaj]

<u>Results:</u>

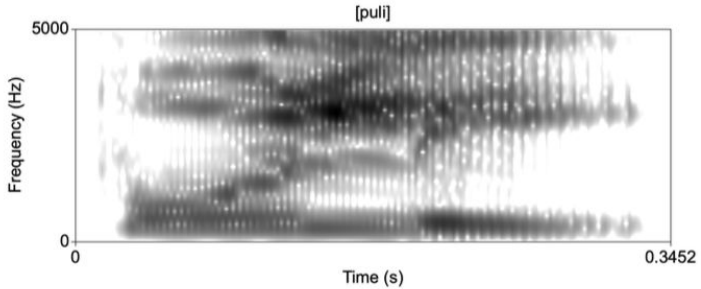
Mean VOT_p = 0.017s (*SD*=0.013)

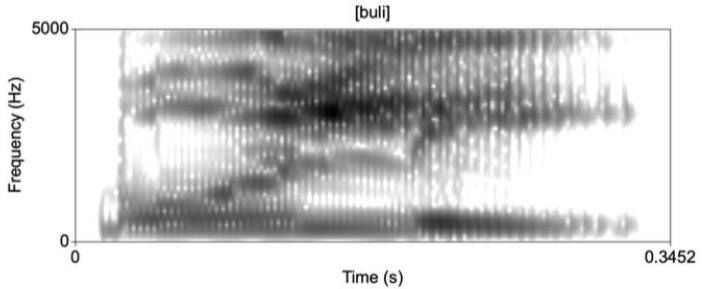
Mean VOT_k = 0.029s (*SD*=0.01)

Nothing remarkable about productions of unaspirated stops. VOTs consistent with known POA effects (e.g., Lisker and Abramson, 1964)

Part B: ***b-*** initial words

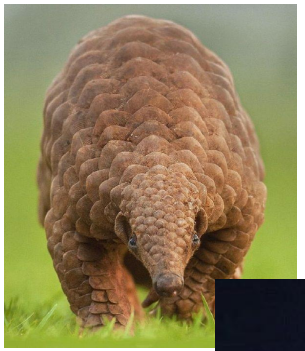
Participants then asked to listen to ***b-*** new/nonce words associated with unfamiliar objects. Words constructed from English ***b-*** initial words (e.g., “bully”), with two cycles of prevoicing and four vocalic cycles of ***b-*** appended to real Tamil ***p-*** initial words





Part B: ***b-*** initial words

Participants were then asked to repeat newly learned words



“[buli]”

“[baːnai]”

. . .

Results:

Mostly lead (negative VOT) in newly “learned” words with Mean VOT_b = -0.04s (*SD*=0.014)

Part C: Minimal pair production

Listeners were told that they were to *teach* the new ***b-*** initial word to a naive Tamil speaker using the sentence frame: “Don’t say [*new* ***b-/p-*** *initial word*], Say [*real* ***b-/p-*** *initial word*]”

Only pictures of the target words were presented

I wanted to induce a differentiation between ***b-/p-*** initial words → background noise was presented in headphones

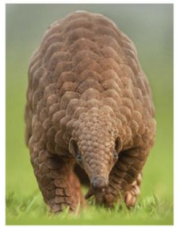
Participants read sentence frame in three different increasing (pink) noise conditions → Lombard effect: no noise, 70dB, 75dB

மரம் என்று சொல்லாதே

பழம் என்று சொல்லுங்கள்

[buli]

[puli]

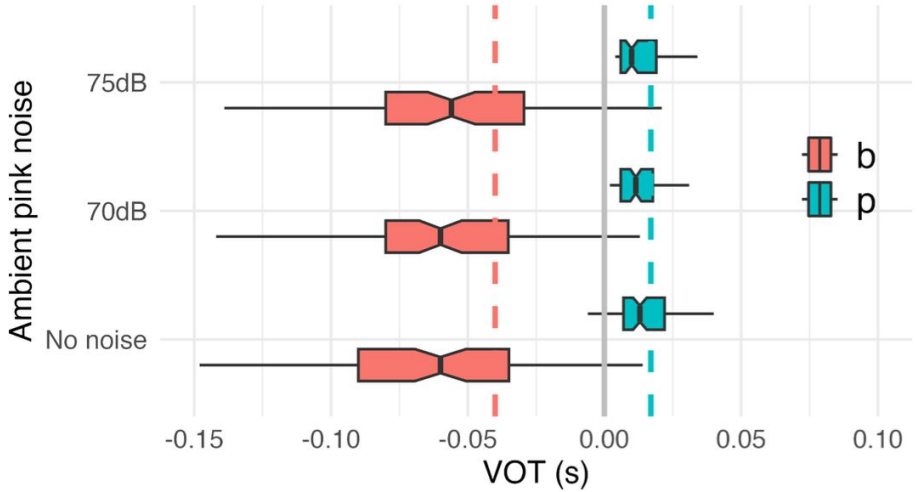


என்று சொல்லாதே

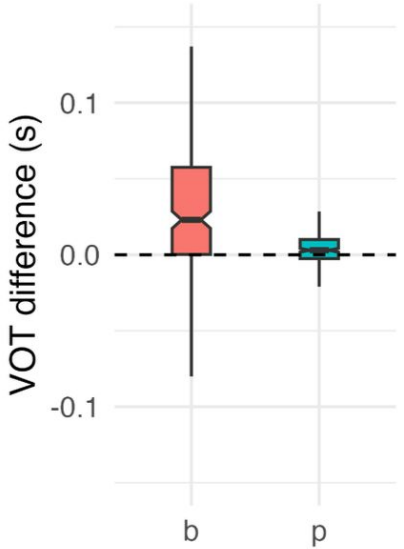
என்று சொல்லுங்கள்

Part C: Results

Distribution of raw VOT values in the minimal pair task



To account for individual variation in VOT, I calculated a measure representing deviation of an individual's VOT in the minimal pair task from their baseline VOT (for each word) → "VOT difference"



`VOT difference ~ Voicing * Noise`

➢ No effect of Noise; Speakers did not adjust productions to produce Lombard effects

`VOT difference ~ Voicing`

➢ VOT difference$_p$ < VOT difference$_b$ (β=-0.04, *SE*=0.008, *t*=-4.81)

➢ Magnitude of change from baseline productions of *b* significantly greater than *p*

Discussion

Tested Tuttle's (1929) hypothesis that speakers of Old Kannada strengthened word initial ***p-*** due to the introduction of ***b-***

Tuttle's reasoning suggested that by strengthening ***p-*** via aspiration speakers maximize the acoustic-perceptual salience of the contrast with ***b-***

Tamil speakers did not aspirate ***p-***initial words when producing minimal pairs (with new ***b-*** initial words), rather they produced longer prevoicing in ***b-*** (relative to baseline productions)

While certainly not definitive, this result challenges Tuttle's push-chain hypothesis

Discussion

What do we make of the increased prevoicing?

Dispersion (Liljencrants and Lindblom, 1972) suggests that contrastive sounds are situated in acoustic space in a way that maximized perceptual distinctiveness

For short-lag stops (like ***p-*** here) there is a limit to how long aspiration can be

> E.g., At slow speaking rates, Tamil ***p-*** has VOTs ~ 30ms, while English ***p^h-*** varies between 80-150ms (Narayan, 2023)

Positively extending VOT for ***p-*** would disrupt the Tamil laryngeal category while accommodating a newly learned one

Extending prevoicing in ***b-*** would be consistent with Dispersion theory

What next?

Absent a clear phonologically motivated explanation for the sound change, how else can we explain debuccalization of ***p*** without an intervening spirantization stage?

In the next section I will outline a new proposal that appeals to a very long history of phonetic explanations for phonological patterns (Ohala, Lindblom, Beddor, Blevins)

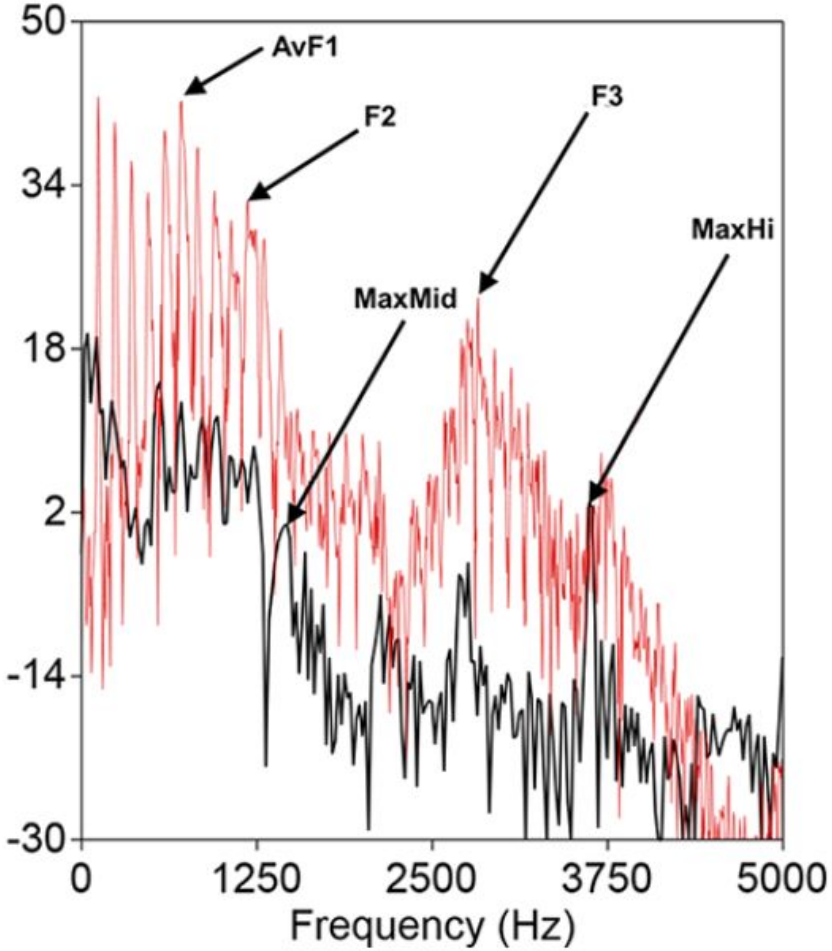
I will conclude that the *seeds* of the sound change are found in the nature of ***p*** itself and we need not appeal to external forces (paradigmatic or contact-induced) to explain how Kannada lost its lips

Proposal → Burst amplitude misperception

Bilabials have naturally **quiet release bursts** (relative to lingually articulated stops)

> What's a burst? → the "pop" of air that escapes your mouth when an oral constriction is released
>
> The amplitude of the burst is related to the place of articulation → ***p's*** are quieter than ***t's*** and ***k's***

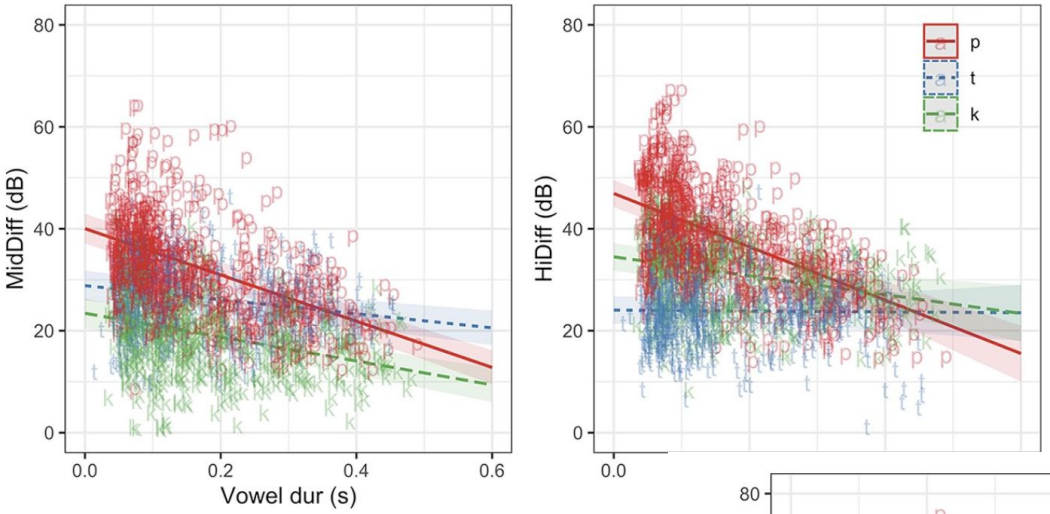
Coupled with the fact that F2 transitions are short in bilabials (Kewley-Port, 1982), [p] is **predicted to be misperceived** more than other places of articulation → the direction of misperception is toward *placeless* [h]



Burst spectrum (black)
Vowel spectrum (red)

In CVs, the difference between burst and vowel spectra amplitudes (in high or mid freq bands) gives a normalized burst amplitude

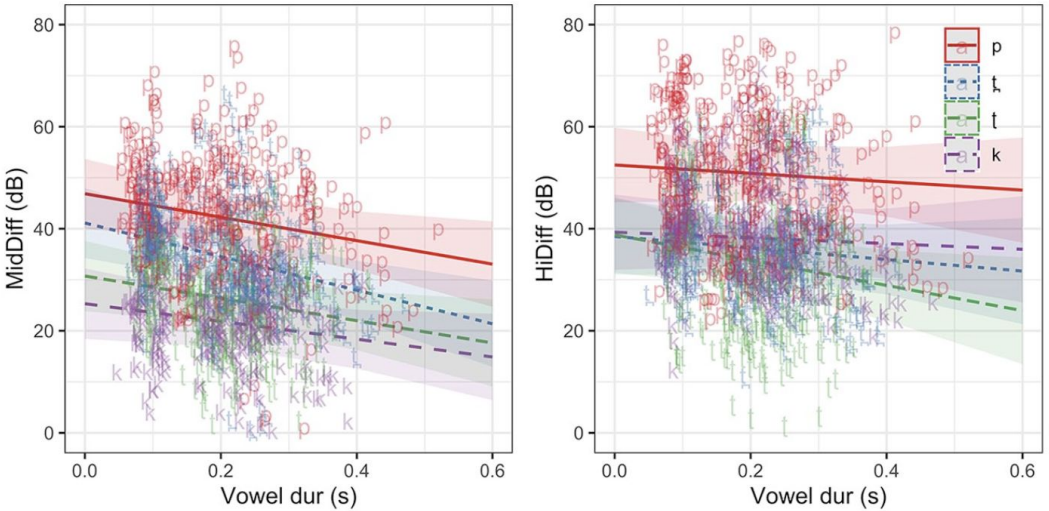
English



<u>English</u>
k > t > p

Tamil
k, t̪, ʈ > p

Tamil



The lower the difference measure, the higher the normalized burst amplitude

Narayan (2023)

Short-lag bilabials are special

Short-lag bilabials have quiet release bursts due to *both* the:

1. The oral pressure dynamics of short-lag VOT
2. The oral pressure dynamics of bilabial plosives

Aerodynamic constraints → Low intensity burst → misperception

1. P_o properties of short-lag plosives

For voicing (vowel) to begin, $P_{subglottal} > P_{oral}$

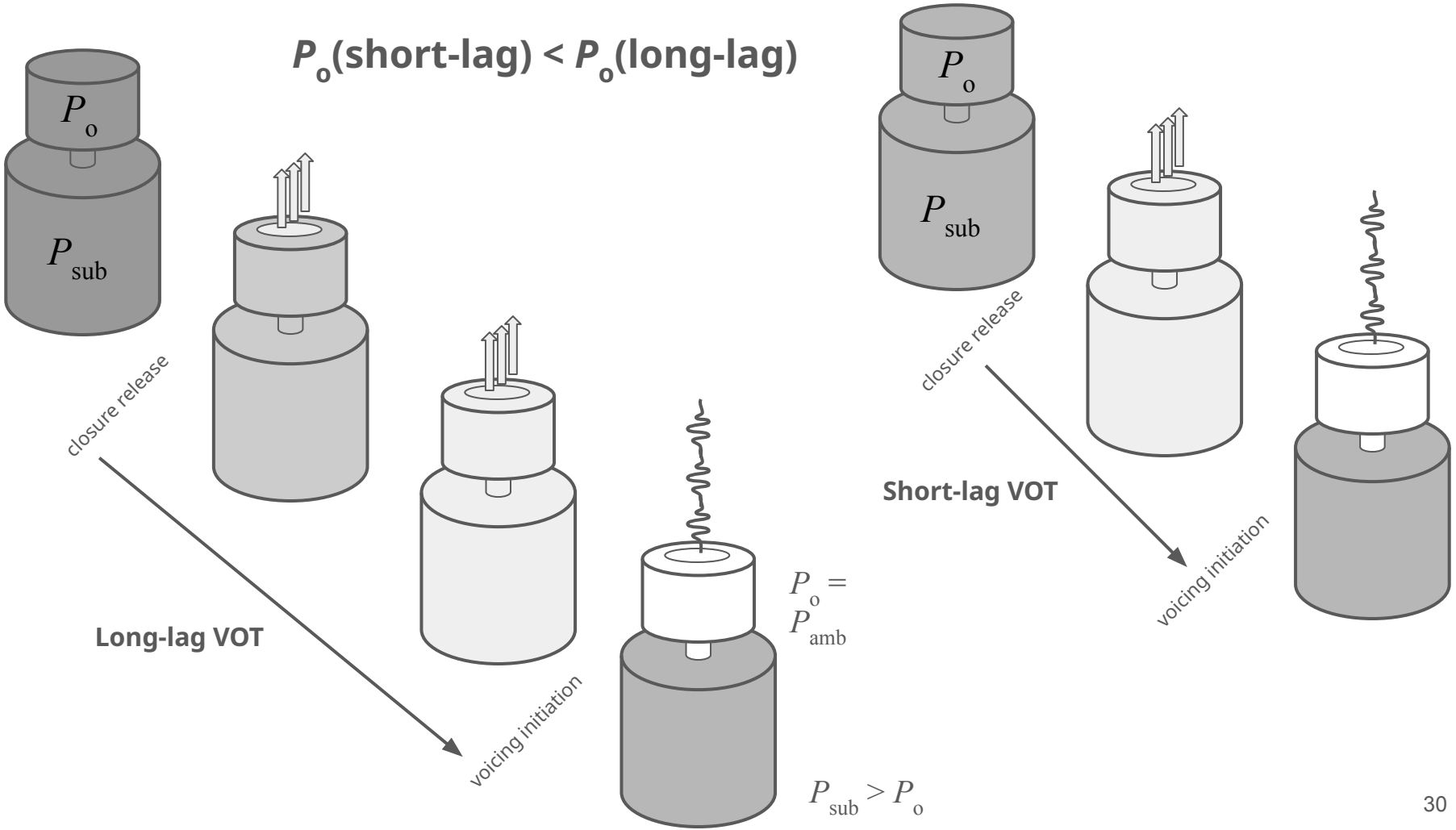
Voicing initiation occurs very soon after the release of the oral constriction

- Short-lag (Tamil), 200ms vowel → 15-20ms VOT
- Long-lag (NA English), 200ms vowel → 45-75ms VOT (Narayan, 2023)

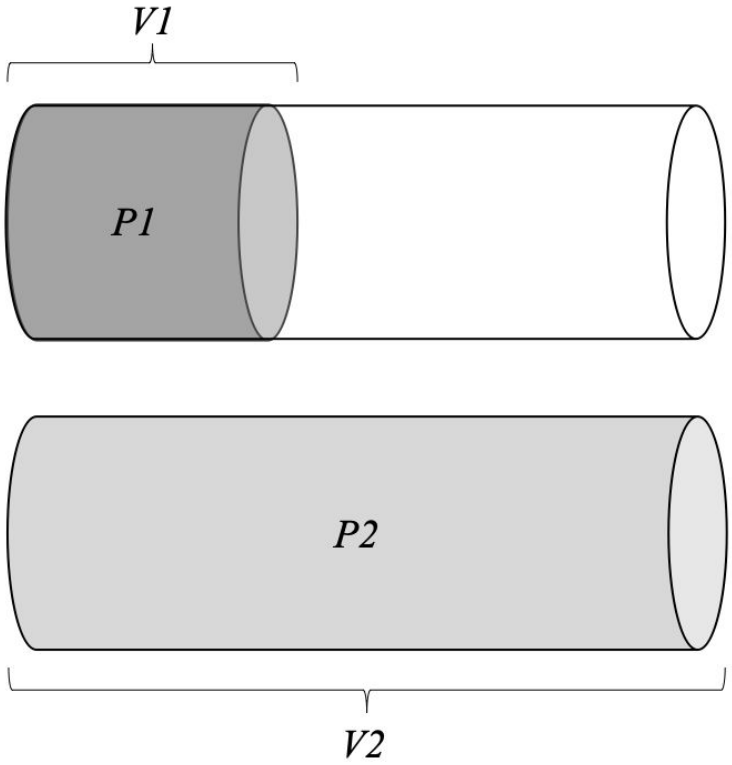
Fast voicing initiation → P_o should be sufficiently low such that on release of the oral constriction, P_o is rapidly equalized with $P_{ambient}$

Short-lag English (voiced) plosives (VOTs comparable to voiceless short-lag) have lower P_o than long-lag counterparts (Arkebauer, et al., 1967; Malécot, 1970)

P_o(short-lag) < P_o(long-lag)



2. P_o in bilabial plosives

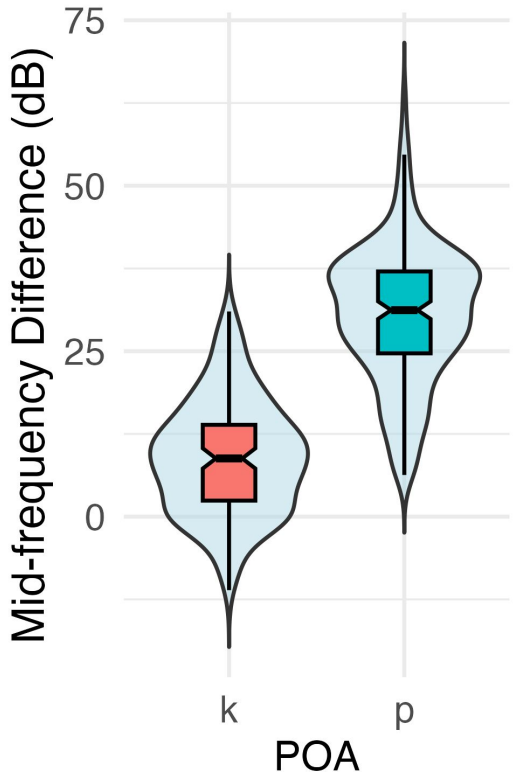


Lower amplitude of release burst across the spectrum in bilabials relative to lingual constrictions

Bilabials → larger oro-pharyngeal volume relative to lingually articulated stops (*Boyle's Law*)

Given comparable mass of air: P_o in bilabial constriction < P_o posterior constrictions (t̪, ʈ, k)

$P_o \rightarrow$ burst amplitude



Envelope of transient energy reflects pressurized intraoral air (P_o) posterior the occlusion

Relative to lingually articulated stops, bilabials have greater difference between burst amplitude energy and amplitude of F1 (Narayan, 2023; Stevens et al., 1999)

Bilabial bursts are less intense than bursts in lingually articulated stops

Consequences of weak bursts: Experiments

Two perception experiments tested the weak-burst-amplitude hypothesis as promoting debuccalization in Old Kannada

1. **Discrimination task** examines the discriminability of CV syllables in three listening conditions → is *pV* confusable with *hV* more than other places of articulation?
2. **Identification/Confusion** in two listening conditions → Do listeners identify *pV* as *hV* disproportionately relative to other places of articulation
    a. Would amplifying *p*-bursts result in more accurate identification?

(Again) Tamil as a proxy for Old Kannada

Like Old Kannada, word-initial plosives in modern Tamil do not exhibit a phonological voicing contrast

h exists as a marginal phoneme in order to accommodate non-Dravidian borrowings (this happened *very* early)

Unlike Old Kannada, Tamil never introduced an aspirate series to accommodate Sanskrit borrowings

Experiment 1: Discrimination

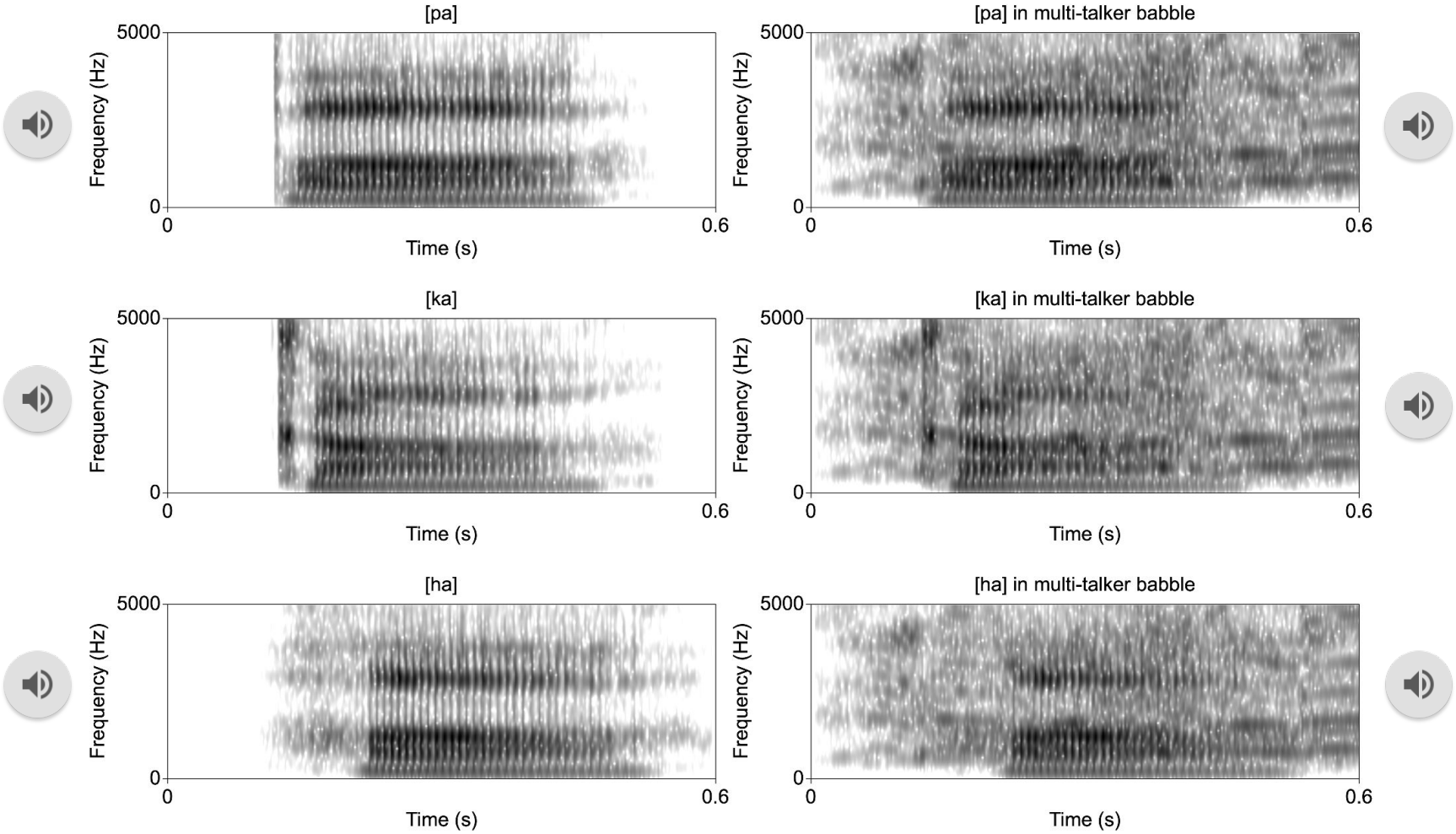
Adult Tamil-speaking listeners (*n*=64)

AX (same-different) task

Stimuli: C_1V-C_2V (C=p,t̪, ʈ, k, h; V=a, i, u), 120 fully crossed AX trials

Listening conditions: 15dB, 10dB, 5dB SNR

Multi-talker babble created from Tamil banter (8-10 males);
Time-reversed to remove word/phrase-level information


[pa]
[pa] in multi-talker babble
[ka]
[ka] in multi-talker babble
[ha]
[ha] in multi-talker babble
Frequency (Hz)
5000
0
0
0.6
Time (s)

Experiment 1: AX Results

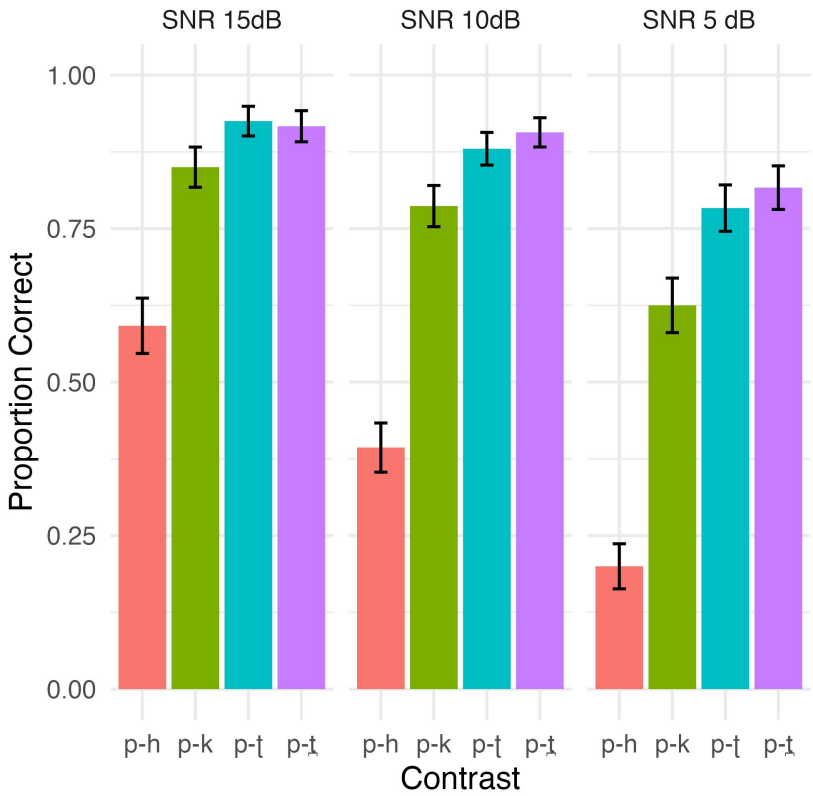
```
Accuracy ~ Contrast * Noise +     (1
  |vowel) + (1 | sub)
```

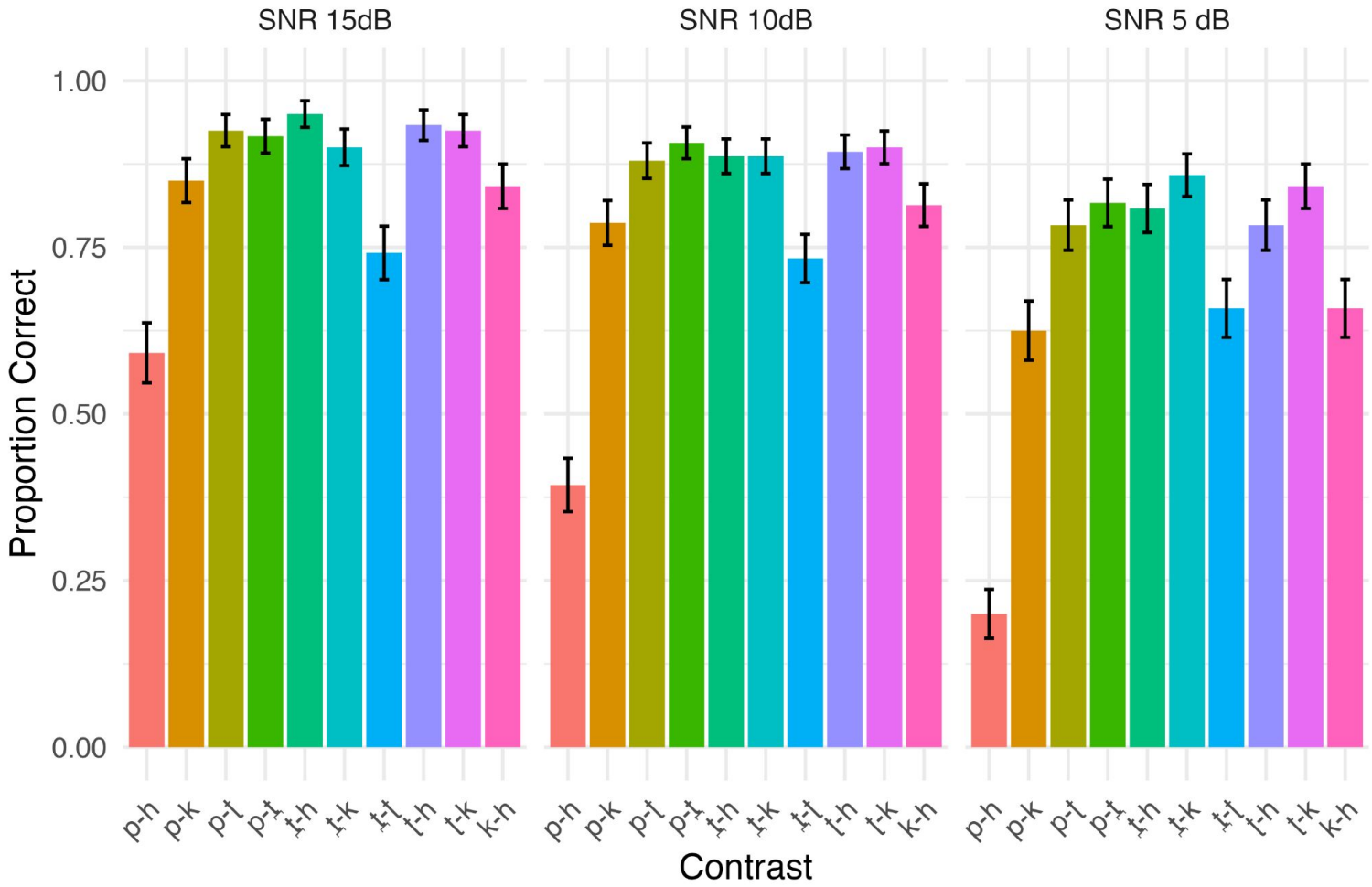
For bilabial contrasts:

- Main effects of **`Contrast`** and **`Noise`**
- *p-h* < *p-t̪*, *p-ʈ*, *p-k*

Lingual contrasts:

- Main effects of **`Noise`**, variable effects of **`Contrast`**
- Pattern of **`Contrast`** similar to other lingual places of articulation




SNR 15dB
SNR 10dB
SNR 5 dB
Proportion Correct
1.00
0.75
0.50
0.25
0.00
p-h
p-k
p-t
p-ɻ
ɻ-h
ɻ-k
ɻ-t
t-h
t-k
k-h
Contrast

Experiment 1: Discussion

p-h contrast is disproportionately affected by multi-talker babble noise relative to *p* in contrast with other places of articulation

Lingual places of articulation, when in contrast with *h*, showed accuracy comparable to contrasts with other stops → *p-h* contrast is different from other contrasts for Tamil speakers

Experiment 1 does not tell us about the inception of the debuccalization change, but rather provides psychoacoustic evidence for the weak perceptual salience of the *p-h* contrast

h was available to Old Kannada speakers (borrowings from Sanskrit and Prakrits)
→ **How readily would listeners identify [pV] as [hV]?**

Experiment 2a: Identification

Tamil-speaking listeners (*n*=27)

5 alternative forced choice task

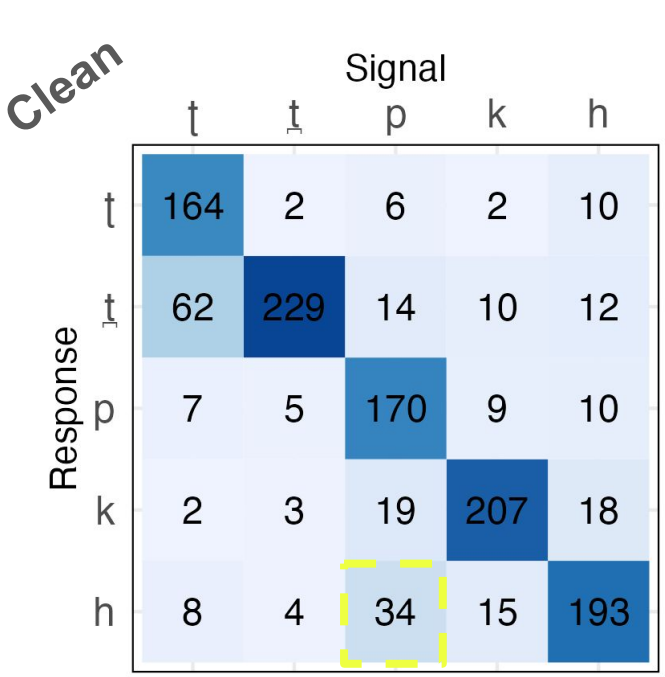
Within-subjects design

Two listening conditions: No noise, 10dB SNR multi-talker babble

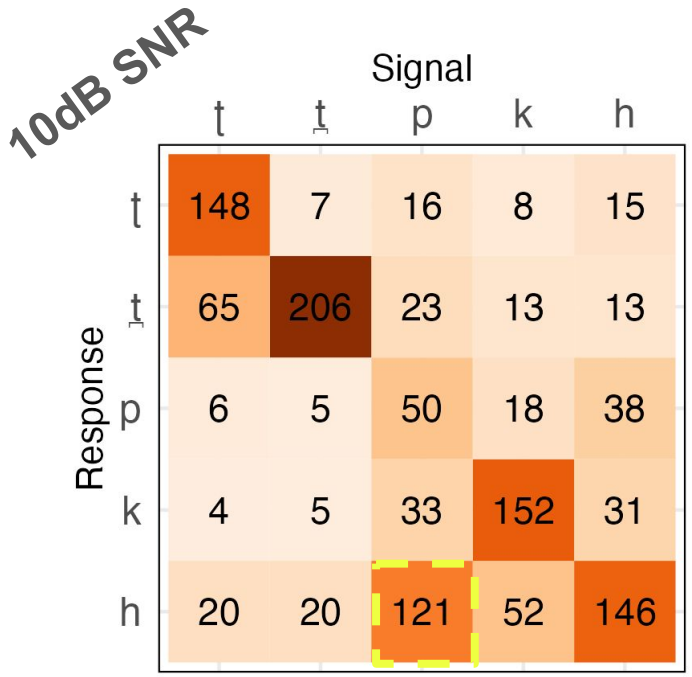
Stimuli: *CV* (C=p,t̪, ʈ, k, h; V=a, i, u), 45 trials per listening condition

Multi-talker babble identical to Experiment 1

Consonant confusions



p → “h” **14%**



p → “h” **50%**

Discussion

There is a clear effect of multi-talker babble (10dB SNR) on the perception of obstruents

Accuracy for all obstruents decreases with noise

Disproportionately (and dramatically) affects *p* which is identified as *h* 50% of the time

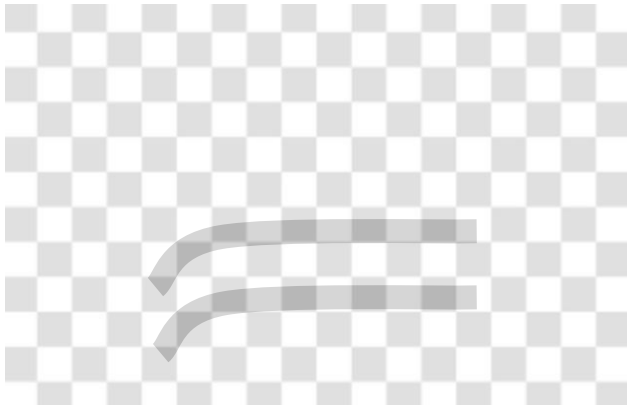
How do we know it’s the burst?

Vowel context

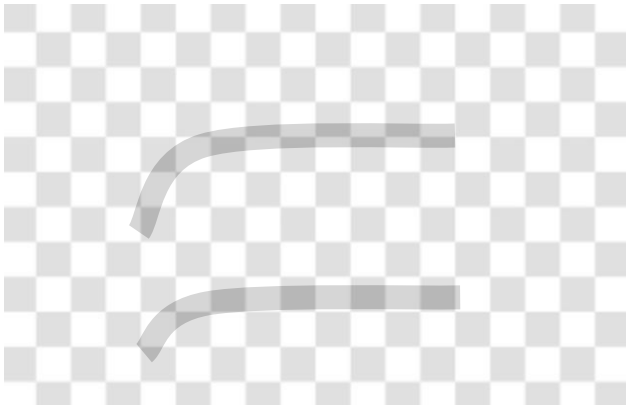
Data were subset by vowel context

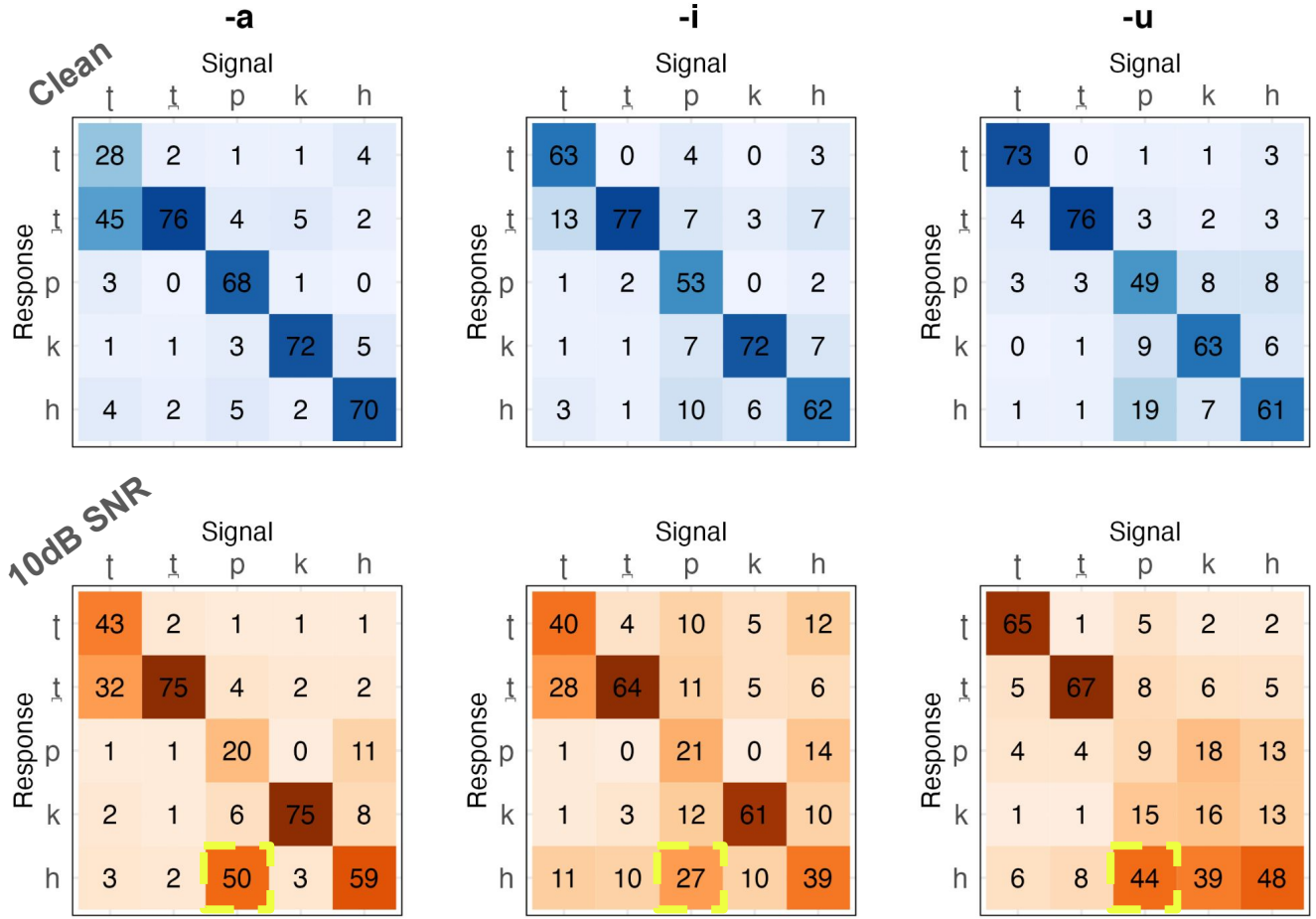
Prediction → Burst would be implicated if *p* is misidentified as *h* in the back vowel context (-*a, -u*) than in front vowel context (-*i*)

Back vowel/Low F2



Front vowel/High F2

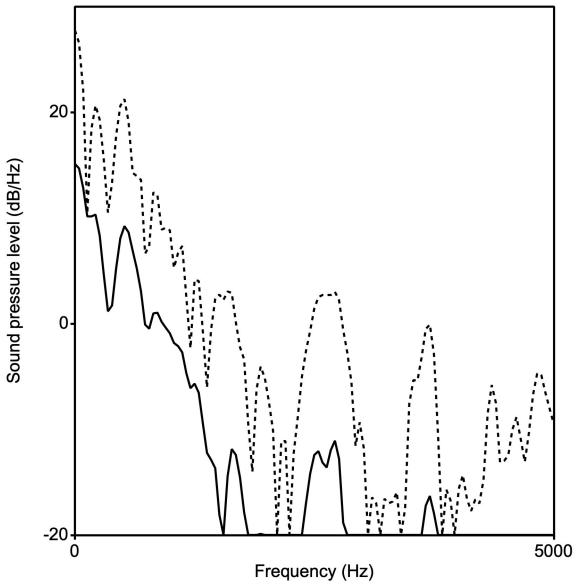




More misperceptions of *p* as "h" in back vowel contexts in noise condition

Suggests that in challenging listening conditions, when the burst is masked, *p* is better identified when F2 characteristics of the following vowel and (bilabial) transition are dissimilar

Experiment 2b: Replication, burst amplified

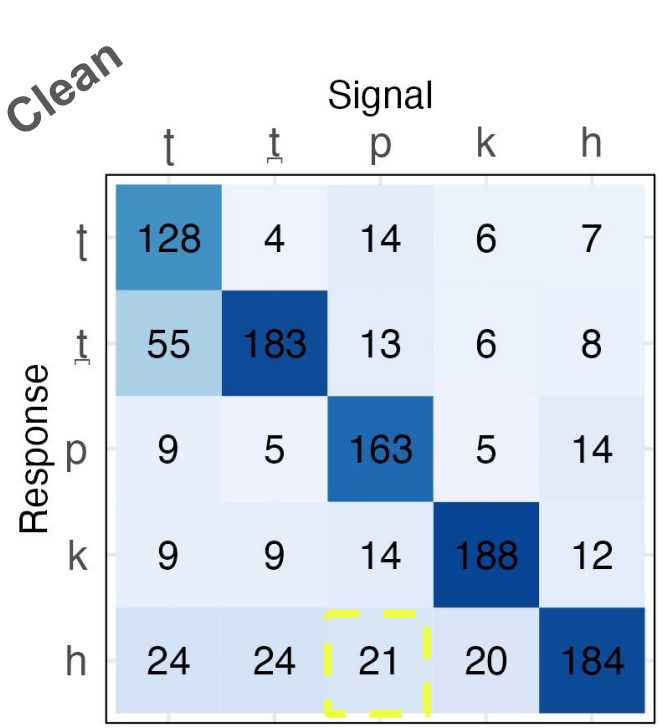


Tamil-speaking listeners (*n*=25)

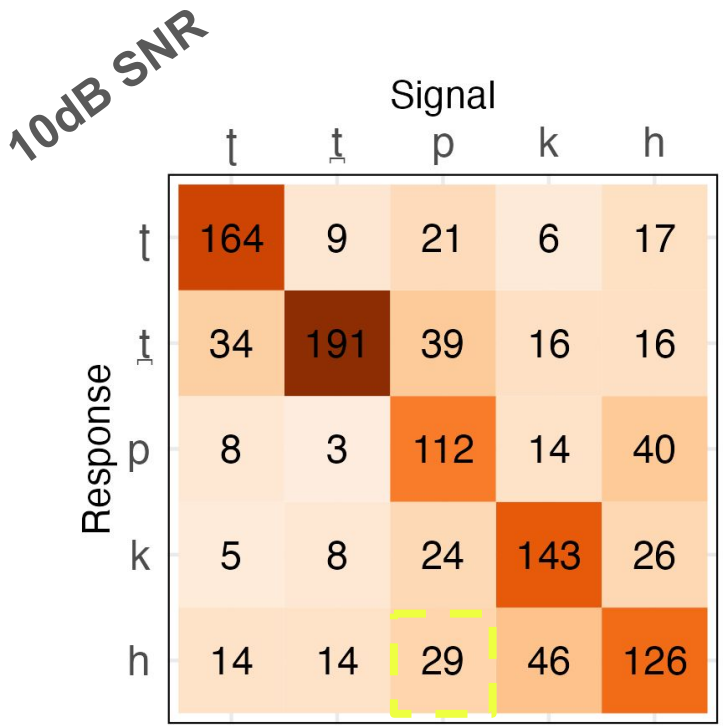
Stimuli identical to Exp. 2a, except *p*-burst amplified by **12dB** (across the spectrum)

Two listening conditions: **Clean** and **10dB SNR**

All other methods identical to Exp. 2a



p → "h" **9%**
(down from 14%)



p → "h" **13%**
(down from 50%)

Discussion/Conclusions

It *is* possible to explain the change from (unaspirated) ***p*** to ***h*** without appealing to an intervening spirantization stage in the historical phonology

Burst amplitude contributes to place perception

- ➢ Short-lag *p* has a low-intensity burst for aerodynamic reasons
- ➢ Low-intensity burst weakens the perceptual salience of place information in challenging listening conditions
- ➢ Listeners disproportionately misperceive *p* as *h* relative to other places of articulation

Language-internal aerodynamic constraints and their perceptual consequences may provide the *seeds* of the debuccalization sound change in Kannada

ಧನ್ಯವಾದಗಳು

Acknowledgements:
Ramprashanth Venkatakrishnan (Field researcher) for carrying out experiments in India; Pam Beddor, Peter Avery, Thomas Kettig, XiaoXiao Cui, Griffin Cahill, Andrew Lubanszky, Jacob Graham for comments; John Ohala for inspiration

Arkebauer, Herbert J, Thomas J Hixon, and James C Hardy. 1967. “Peak intraoral air pressures during speech.” *Journal of Speech and Hearing Research* 10:196–208.

Beekes, Robert S.P. 2003. “Historical phonology of Classical Armenian.” Armeniaca: Comparative notes pp. 133–211.

Greenhill, Simon J and Ross Clark. 2011. “POLLEX-Online: The Polynesian lexicon project online.” Oceanic Linguistics 50:551–559.

Kewley-Port, Diane. 1982. “Measurement of formant transitions in naturally produced stop consonant–vowel syllables.” *The Journal of the Acoustical Society of America*, 72:379–389.

Narayan, Chandan R. 2023. “Speaking rate, oro-laryngeal timing, and place of articulation effects on burst amplitude: Evidence From English and Tamil.” *Language and Speech*, 66:851–869.

Pulleyblank, Edwin G. 1984. Middle Chinese: A study in historical phonology. UBC Press.

O’Brien, Jeremy. 2012. An experimental approach to debuccalization and supplementary gestures. Ph.D. thesis, University of California, Santa Cruz.

Malécot, André. 1970. “The lenis-fortis opposition: its physiological parameters.” *The Journal of the Acoustical Society of America*, 47:1588–1592.

Stevens, Kenneth N., Sharon Y. Manuel, and Melanie Matthies. 1999. “Revisiting place of articulation measures for stop consonants: Implications for models of consonant production.” In *Proceedings of the International Congress of Phonetic Sciences*, pp. 1117–1120.

Subbaiya, K.V. 1909. “A primer of Dravidian phonology.” *The Indian Antiquary* 38:188-200.

Tuttle, Edwin H. 1929. “Dravidian researches.” *The American Journal of Philology* 50:138-155