An acoustic-perceptual explanation for debuccalization in 10th century Dravidian

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LSA 2025, Philadelphia
January 11, 2025

Background

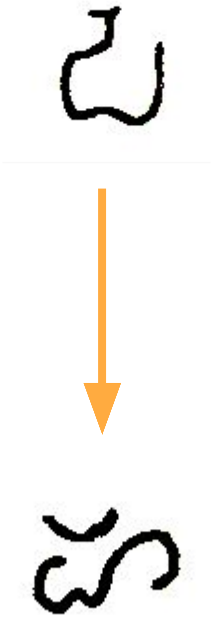
Kannada (South Dravidian) has ***h*** where closely related Dravidian languages (e.g., Tamil, Malayalam) have ***p***

Ta.	paːl	pɪnnaːl	pire	puː	poː
Ma.	paːl	pɪnnɪl	pira	puːʋu	poːgu
Ka.	haːlu	hɪnd̪e	hire	huːʋu	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 reflected the ***h-*** pronunciation



Brief typology of debuccalization

Typical path for obstruents losing their oral place features and changing manner (especially in prosodically strong positions) involves an intervening frication 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*

Research question

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

Absent this evidence, can we explain the rapid shift (over the course of 200 years) of *p* > *h*?

Yes! → there an **internal motivation** for the debuccalization of *p* (à la Sweet, Ohala, Lindblom, Beddor)

Proposal

Bilabials have **quiet release bursts** (relative to lingually articulated stops); F2 transitions are short (Kewley-Port, 1982)

- [pV] is **predicted to be misperceived** more than other places of articulation → the direction of misperception is toward *placeless* [h]

The *seeds* of the debuccalization change are found in the natural aero-acoustic consequences of short-lag bilabial stops and their perceptual consequences

Proposal

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, $P_{sub} > P_o$

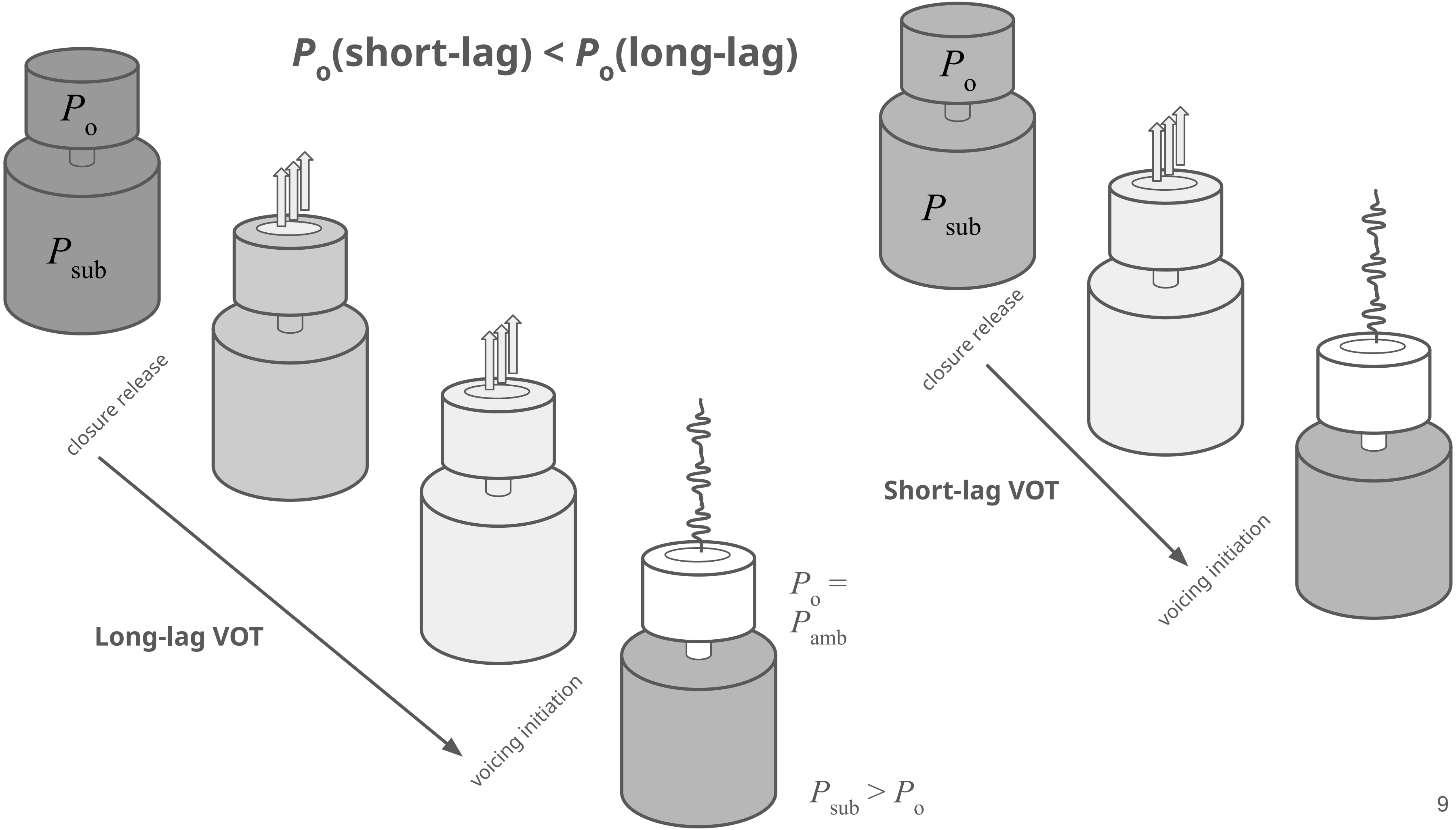
Voicing initiation occurs very soon after the release of the oral constriction

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

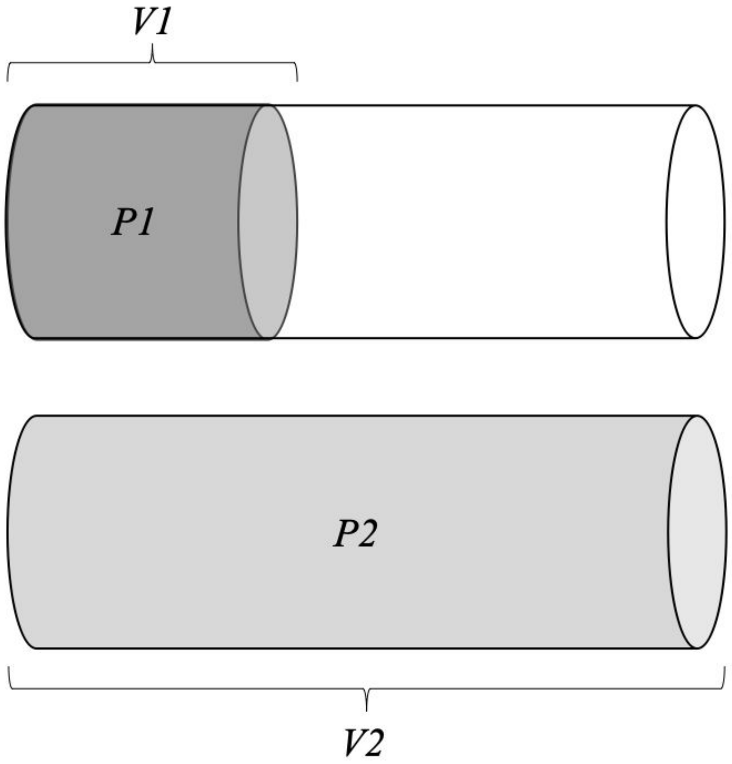
Fast voicing initiation → P_o should be sufficiently low such that on release of the oral constriction, P_o is rapidly equalized with P_{amb}

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

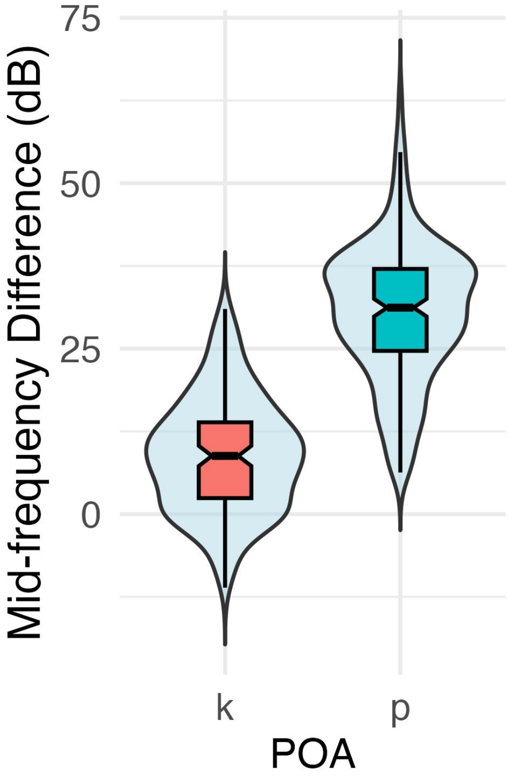


Lower amplitude of release burst across the spectrum in bilabials relative to lingual constrictions

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 being a possible source of 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?

Tamil as a proxy for Old Kannada

Modern Tamil is a conservative South Dravidian language

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

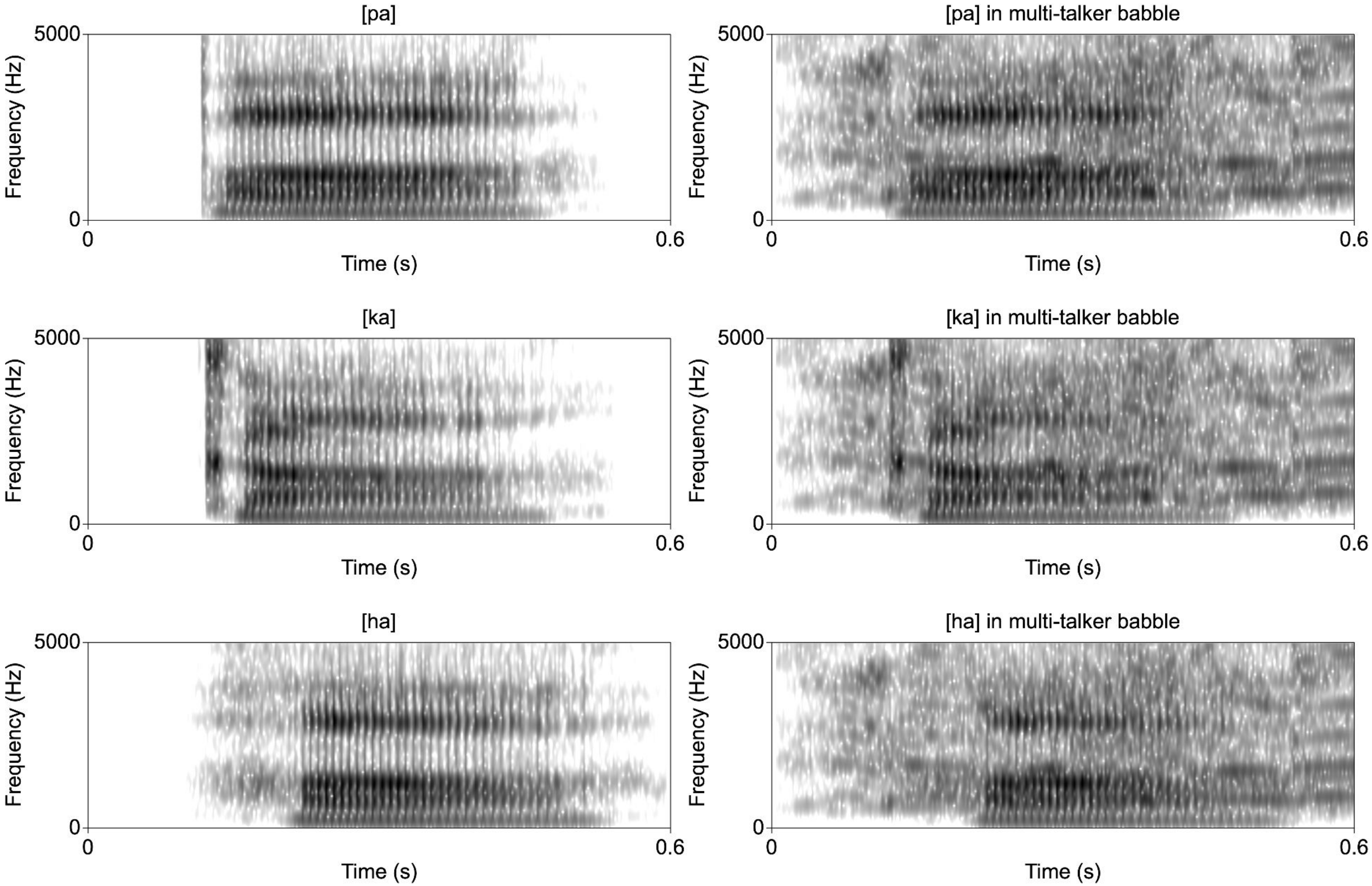
Tamil-speaking listeners (*n*=64)

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
Time (s)
0.6

Experiment 1: AX Results

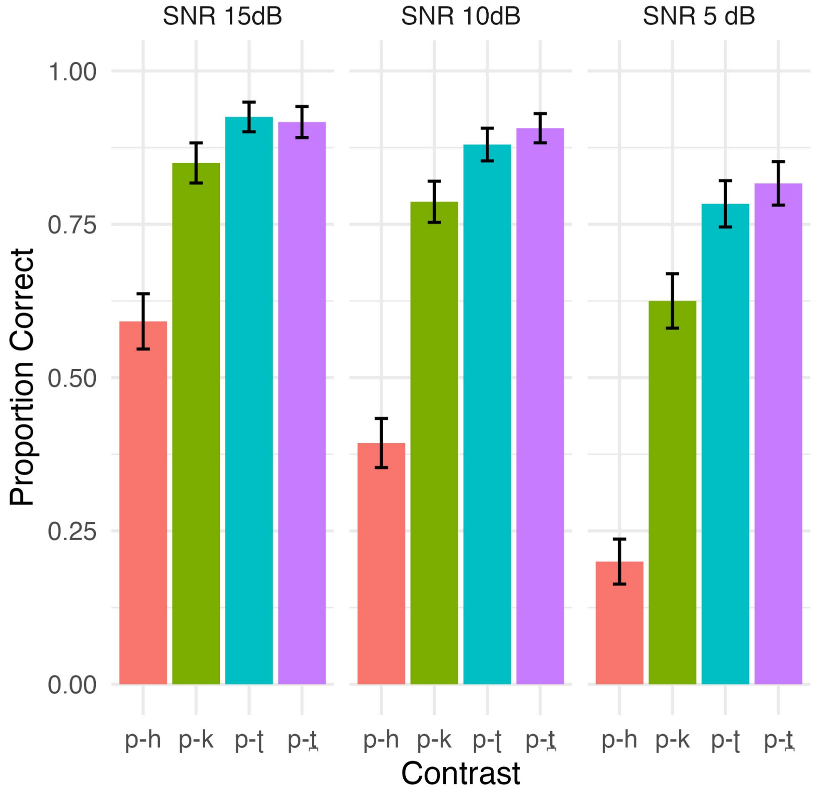
```
Accuracy ~ Contrast * Noise +     (1
   |vowel) + (1 | sub)
```

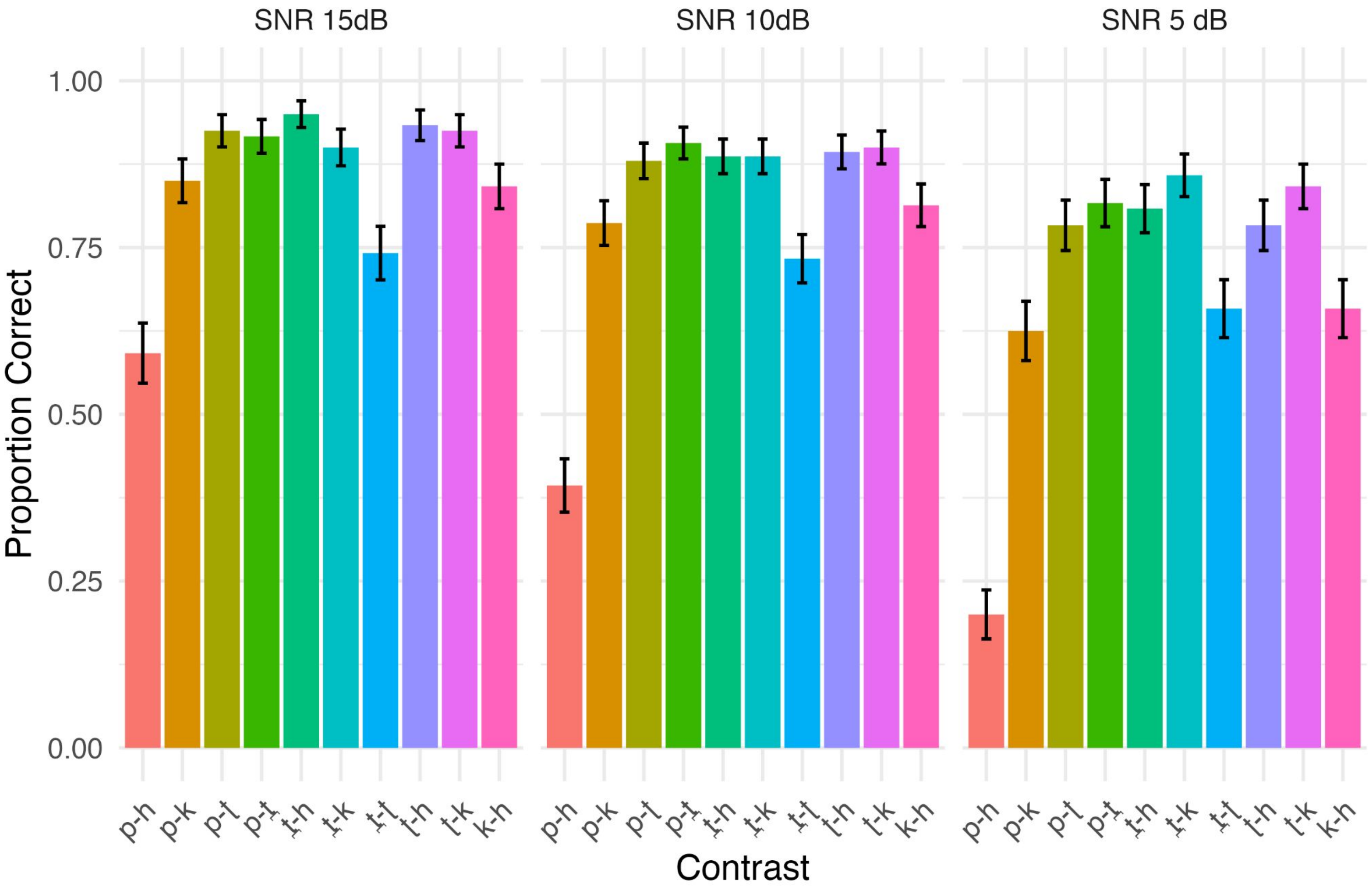
For bilabial contrasts:

- ➢ 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-t̪
t̪-h
t̪-k
t̪-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

Clean

Response \ Signal	ʈ	t̪	p	k	h
ʈ	164	2	6	2	10
t̪	62	229	14	10	12
p	7	5	170	9	10
k	2	3	19	207	18
h	8	4	34	15	193

p → “h” **14%**

10dB SNR

Response \ Signal	ʈ	t̪	p	k	h
ʈ	148	7	16	8	15
t̪	65	206	23	13	13
p	6	5	50	18	38
k	4	5	33	152	31
h	20	20	121	52	146

p → “h” **50%**

Discussion

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

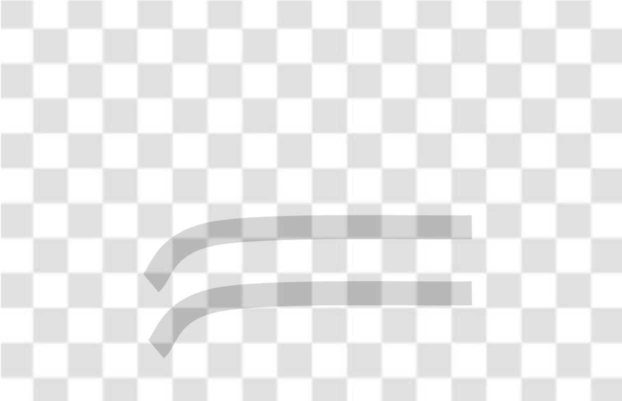
- Accuracy for all obstruents decreases with noise
- Disproportionately (and dramatically) affects *p* which is identified as *h* 50% of the time

Vowel context

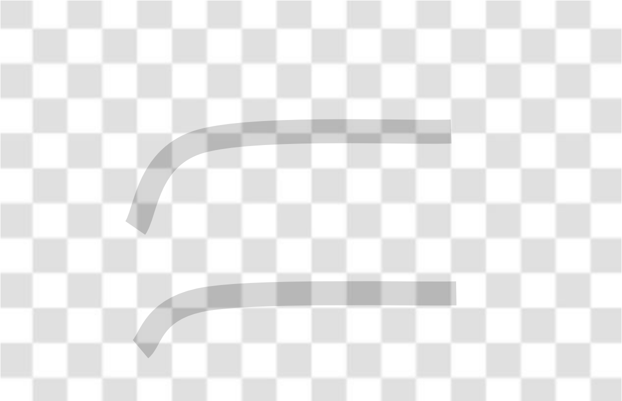
Data were subset by vowel context

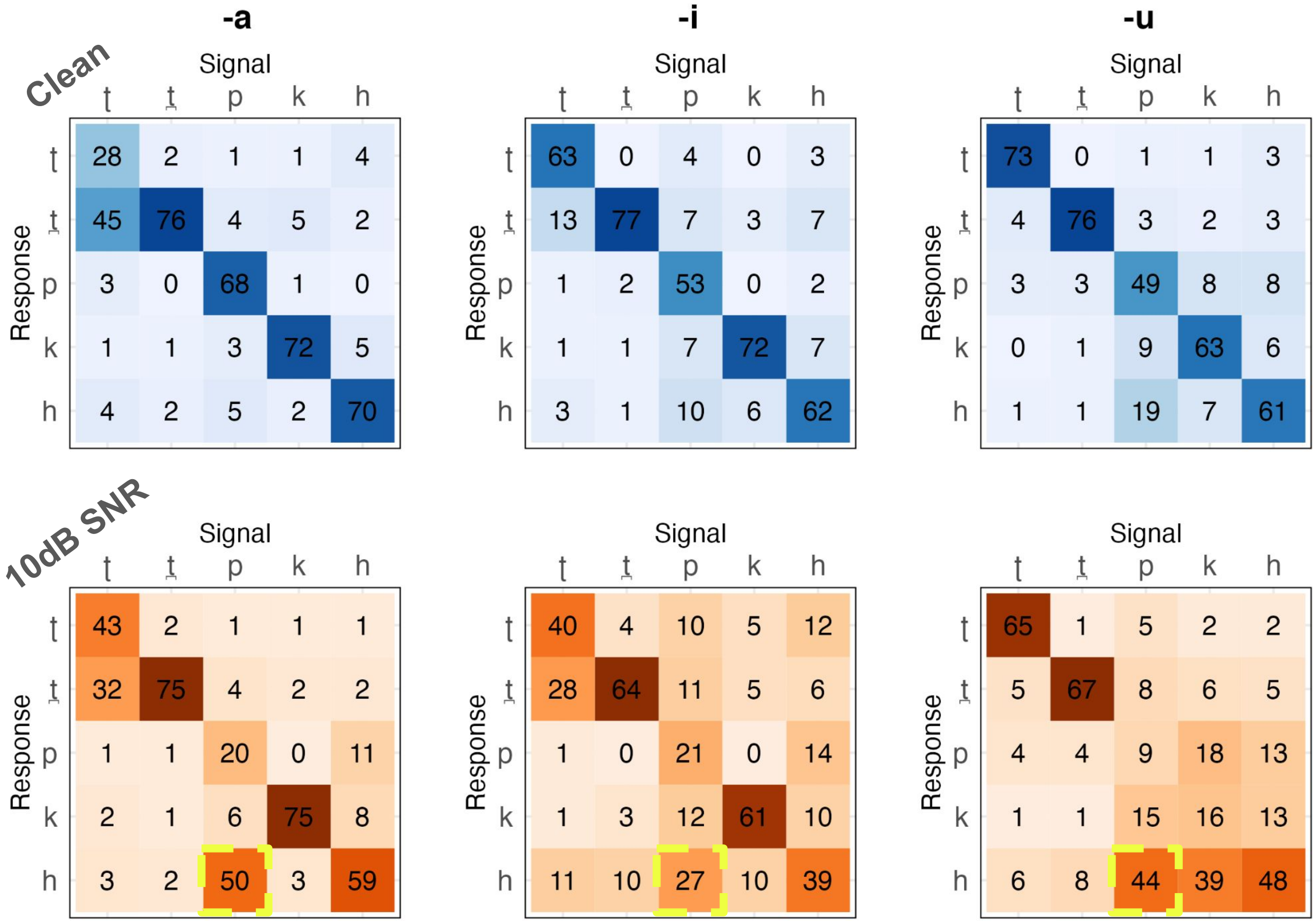
> Burst would be implicated in misperception if *p* is misidentified as *h* in the back vowel context (-a, -u) than in front vowel context (-i)

Back vowel/Low F2



Front vowel/High F2

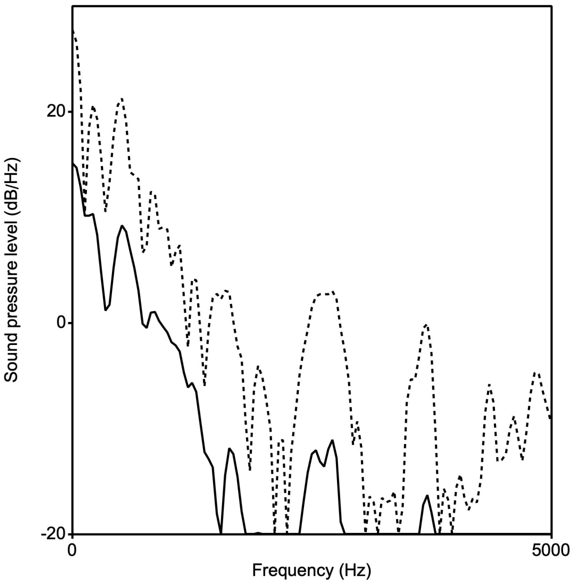




More misperceptions of *p* as “h” in back vowel contexts in noise condition

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

Clean

Signal (columns) / Response (rows)

Response \ Signal	ʈ	t̪	p	k	h
ʈ	128	4	14	6	7
t̪	55	183	13	6	8
p	9	5	163	5	14
k	9	9	14	188	12
h	24	24	21	20	184

p → "h" **9%**
(down from 14%)

10dB SNR

Signal (columns) / Response (rows)

Response \ Signal	ʈ	t̪	p	k	h
ʈ	164	9	21	6	17
t̪	34	191	39	16	16
p	8	3	112	14	40
k	5	8	24	143	26
h	14	14	29	46	126

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 aspiration/frication stage in the 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

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