

The typology and perception of unreleased coda stop contrasts in high vs. low vowels

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Background: The acoustic and perceptual properties of a segment may vary across phonetic contexts [1,2,3] and two contrastive segments may have different perceptual distinction across different phonetic contexts [4,5,6], e.g., [s] vs. [ʃ] less distinct in [i] than [a] [5]. The relative perceptual distinctiveness of sound pairs is found to correlate with phonological typology, with more distinct pairs more frequently observed [5,7,8]. The current study examines a potential connection between the typology and the perceptual distinction of unreleased coda stops in different vowel contexts, through a typological survey and a perceptual experiment.

Typology Survey: Coda stops [-p, -t, -k] widely exist across Chinese dialects, which are unreleased, such as in [sap˥] ‘wet’, [sat˥] ‘knee’, and [sak˥] ‘block’ in Cantonese. A typological survey across 42 Chinese dialects showed that, for a pair of unreleased coda stops (e.g., [-p] vs. [-t]), a place contrast in the high vowel context (e.g., [i] and [u]) generally implies the contrast in the low vowel context (e.g., [a]).

Assuming a connection between perceptual distinction and typological frequencies, this typological pattern motivates a hypothesis that, for the unreleased coda stops [-p, -t, -k], the place contrast is perceptually less distinct in a high vowel context than in a low vowel context.

Perceptual Experiment: To test this hypothesis, a speeded AX discrimination experiment was conducted, which has been shown to access the psychoacoustic distinction of sound pairs and to bypass L1 phonology to a substantial extent [5,9].

The participants were 25 native Mandarin listeners, whose L1 has no coda stops. The audio stimuli were the 12 CV pairs as in **Table 1**, in which the unreleased coda stops contrast in high vowels ([i] and [u]) and low vowels ([æ] and [ɒ]). The stimulus syllables were produced by a native speaker of English, using carrier sentences to facilitate the production of unreleased coda stops, e.g., *I said seek carefully*. A series of manipulation was made, by which (i) the durations and intensities of the onsets and rimes matched the average values as reported in the literature [10,11,12,13,14], (ii) 60 ms of vowel-to-coda formation transition was preserved as in the naturally produced token [15], and (iii) 40 ms of stop closure was kept after the offset of the vocalic portion. For each syllable pair in **Table 1**, identical pairs (e.g., [sip-sip]) and different pairs (e.g., [sip-sit]) were formed. A listener judged if the two syllables in a pair are same or different by pressing buttons on a button box, under time pressure with 0.5 second as a goal, to facilitate psychoacoustic perception on the distinction of sound pairs [9].

The rates of discrimination errors were summarized in **Fig. 1**, with an overall error rate of 0.31 across the different pairs. The high vowels ([i] and [u]) incurred a significantly higher rate of discrimination errors than the low vowels ([æ] and [ɒ]) ($\chi^2=289.75$, $df=1$, $p<.001$) across the three coda place contrasts ([-p vs. -t], [-t vs. -k], and [-k vs. -p]). This suggests that unreleased coda stops are perceptually less distinct in high vowels than in low vowels. For the correct discrimination of [-p vs. -t] and [-k vs. -p] pairs, the response time data as in **Fig. 2** showed that the high vowels ([i] and [u]) introduced a longer response time than the low vowels ([æ] and [ɒ]) ($\chi^2=48.8$, $df=1$, $p<.001$; $\chi^2=21.8$, $df=1$, $p<.001$). Assuming a longer response time to indicate less perceptual distinction, the results further confirmed the relatively less perceptual distinction of [-p vs. -t] and [-k vs. -p] in high vowels than in low vowels.

Discussions and Conclusions: The typological survey showed that, across Chinese dialects, the contrasts of unreleased coda stops are less frequently observed in high vowels than in low vowels. The results of the perceptual experiment suggested that the place contrasts are psychoacoustically less distinct in the high vowel context, in support of a connection between the perceptual distinction of sound pairs and their relative frequencies in cross-linguistic typology.

Keywords: typology, coda stop, perceptual distinction, vowel context

Table 1. Stimulus pairs used in the perceptual experiment

Vowel contexts Coda stop contrasts	High vowels		Low vowels	
	i_	u_	æ_	ʊ_
-p vs. -t	sip sit	sup sut	sæp sæt	sɒp sɒt
-t vs. -k	sit sik	sut suk	sæt sæk	sɒt sɒk
-k vs. -p	sik sip	suk sup	sæk sæp	sɒk sɒp

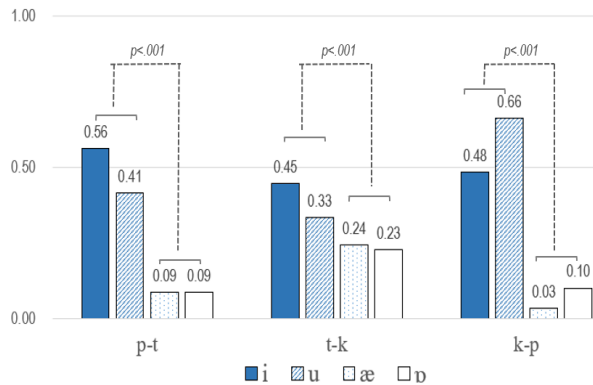


Fig. 1. Rates of discrimination errors of coda stop contrasts in different vowel contexts

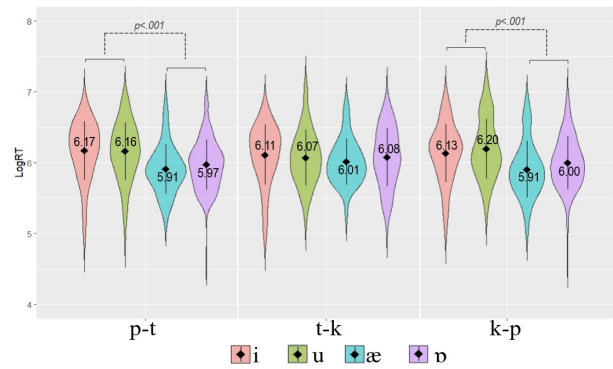


Fig. 2. Mean log response time (LogRT) of coda stop contrasts in different vowel contexts

References:

- [1]. Liberman, A. M., Delattre, P., & Cooper, F. S. (1952). The role of selected stimulus-variables in the perception of unvoiced stop consonants. *Am. J. Psychol.*, 65(4), 497–516.
- [2]. Winitz, H., Scheib, M. E., & Reeds, J. A. (1972). Identification of stops and vowels for the burst portion of /p, t, k/ isolated from conversational speech. *J. Acoust. Soc. Am.*, 51(4B), 1309–1317.
- [3]. Sereno, J. A., Baum, S. R., Marean, G. C., & Lieberman, P. (1987). Acoustic analyses and perceptual data on anticipatory labial coarticulation in adults and children. *J. Acoust. Soc. Am.*, 81(2), 512–519.
- [4]. Steriade, D. (2001). Directional asymmetries in place assimilation: A perceptual account. In E. V. Hume & K. Johnson (eds.), *The role of speech perception in phonology*, 219–250. San Diego: Academic Press.
- [5]. Li, M., & Zhang, J. (2017). Perceptual distinctiveness between dental and palatal sibilants in different vowel contexts and its implications for phonological contrasts. *Lab. Phonol.: J. Assoc. Lab. Phonol.*, 8(1), 18, 1–27.
- [6]. Liu, P. B., & Li, M. (2024). The perceptual distinctiveness of the [n-l] contrast in different vowel and tonal contexts. *J. Acoust. Soc. Am.*, EL 4 (11), 115202.
- [7]. Boersma, P. & Hamann, S. (2008). The evolution of auditory dispersion in bidirectional constraint grammars. *Phonology*, 25, 217–270.
- [8]. Lee-Kim, S.-I. (2014). *Contrast neutralization and enhancement in phoneme inventories: Evidence from sibilant place contrasts and typology*. PhD diss., New York Univ.
- [9]. Johnson, K. & Babel, M. (2010). On the perceptual basis of distinctive features: Evidence from the perception of fricatives by Dutch and English speakers. *J. Phon.*, 38(1), 127–136.
- [10]. Lehiste, I. & Peterson, G. E. (1959). Vowel amplitude and phonemic stress in American English. *J. Acoust. Soc. Am.*, 31(4), 428–435.
- [11]. Peterson, G. E., & Lehiste, I. (1960). Duration of syllable nuclei in English. *J. Acoust. Soc. Am.*, 32(6), 693–703.
- [12]. Soli, S. D. (1981). Second formants in fricatives: Acoustic consequences of fricative-vowel coarticulation. *J. Acoust. Soc. Am.*, 70(4), 976–984.
- [13]. Jongman, A. (1989). Duration of frication noise required for identification of English fricatives. *J. Acoust. Soc. Am.*, 85(4), 1718–1725.
- [14]. Iskarous, K., Shadle, C. H., & Proctor, M. I. (2011). Articulatory-acoustic kinematics: The production of American English /s/. *J. Acoust. Soc. Am.*, 129(2), 944–954.
- [15]. Raphael, L. J., Dorman, M. F., & Liberman, A. M. (1980). On defining the vowel duration that cues voicing in final position. *Lang. Speech*, 23(3), 297–307.