Effects of phonological contrast on phonetic variation in Hindi and English stops

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Introduction: Work on phonetic variation has largely focused on between-category variation or covariation, while less attention has been paid to within-category variation (though see Baese-Berk & Morril, 2015). Lindblom (1986) offers a hypothesis about what relative amounts of within-category variation should be expected between languages: "the phonetic values of vowel phonemes should exhibit more variation in small than in large systems." While this intuitive prediction is often assumed to be true, questions arise when trying to explicitly test it, especially when extending the prediction outside of vowels: What counts as a "system"? What does it mean for a system to be "large" or "small"? How is variation measured? This study seeks to clarify these questions by examining within-category variation in Hindi and English stop consonants. The results show that within-category variation cannot always be predicted by phoneme inventory size and a more nuanced approach is proposed.

Hindi has four stops at each place of articulation and English has two. If we consider the stop inventory to be the relevant system under Lindblom's hypothesis, Hindi stops should vary less relative to English because there are more stop phonemes in Hindi. Therefore, we might expect that voiceless aspirated stops in Hindi will vary less in voice onset time (VOT; unvoiced lag time) relative to English (Fig. 1, left panel). If we define the "system" according to phonetic dimensions instead of number of phonemes, we expect no difference in VOT variation because both languages use the VOT dimension to distinguish one contrast (Table 1). We do expect more variation in degree of *prevoicing* in English relative to Hindi. Hindi uses the voicing dimension for additional contrasts which English does not have. To preview the results, English speakers were more variable in production of prevoicing, but the amount of VOT variation was similar in both languages, in accordance with the revised hypotheses.

Table 1: Phonetic dimensions in Hindi and English stops

	voiced			unvoiced		
	aspiration			VOT		
Hindi:	g	↔	g^h	k	↔	k^h
English:	∅	↮	∅	g	↔	k^h

Methods: Hindi and English stops were elicited in a lab. The participants were 7 native speakers each of Hindi and English, all between the ages of 20-30. In both languages, the stimuli were CVC words and non-words with vowels [i a u] in carrier phrases ("Say X again" in English; "Dobara X doharao" in Hindi). All stops were elicited in the word initial context. In Hindi, expected free variation occurred between [f] and [p^h] in the word initial context so voiceless aspirated labials were excluded from the anaylsis.

Results: VOT was measured on voiceless aspirated stops in both languages from the start of the burst to the onset of voicing. To abstract over differences in mean values between speakers, VOT values were centered around within-speaker means for each phonological category. The results shown in Fig. 1 are collapsed over speaker (Levene's Test showed no significant difference in variation between speakers of each language). Lindblom's hypothesis predicts less variation in Hindi (left panel). The experimental results for coronal stops (right panel) are representative of the results for the other places of articulation and show similar amounts of within-category variation in both languages (Levene's Tests not significant).

Prevoicing on all stops was classified according to three categories: no prevoicing (voicing through 0-25% of the stop closure), partial prevoicing (25-75%), and full prevoicing (75-100%).

Figure 1: Predicted VOT distributions (left) and actual experimental distributions (right), VOT in ms

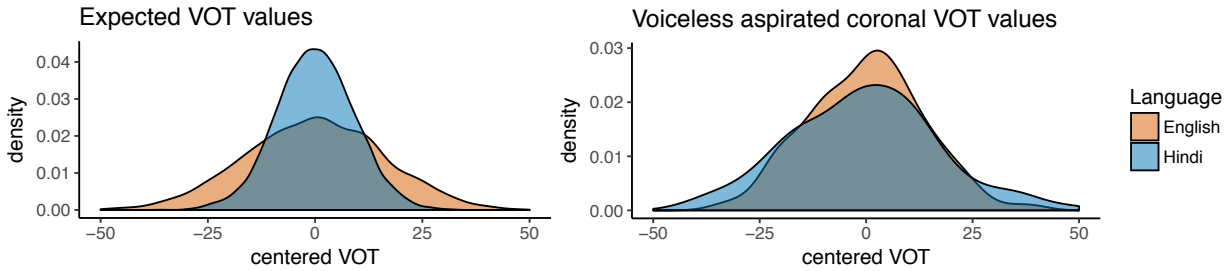
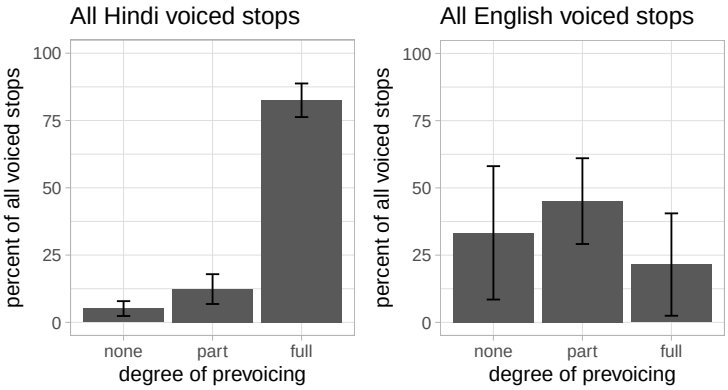


Fig. 2 shows results for phonologically voiced stops; error bars show standard deviation between speakers. In Hindi, almost all voiced stops are produced with full prevoicing and this is consistent across speakers. In English, there is more variation in degree of prevoicing both within and between-speaker. While Hindi speakers all consistently fully prevoice voiced stops, English speakers show individual preferences for degree of prevoicing. Some English speakers fully prevoice almost all voiced stops while others have no prevoicing on almost all voiced stops.

Figure 2: Degree of prevoicing on voiced stops



Discussion: We observed similar amounts of VOT variation in both languages, but Hindi speakers were less variable than English speakers in degree of prevoicing. The observed prevoicing variation in English is in line with previous work on American English which has documented prevoicing in Southern and African-American varieties (Jacewicz et al, 2009; Herd et al., 2016). However, none of the speakers in the present study are speakers of either dialect, suggesting that prevoicing in English may be more widespread than previously documented. This has potential implications for considering laryngeal realism (e.g. Honeybone 2005, Beckman et al. 2013; cf. Cyran 2014) in the featural representation of English stops. Hunnicutt & Morris (2016) provide a potential phonological analysis of English prevoicing.

These results offer some clarity on how to further develop Lindblom's original hypothesis. Based on this data, we propose that the "systems" for comparing within-category variation are best defined by phonetic dimensions instead of general phonological inventory categories like "stops" or "vowels". If we consider the VOT dimension as a system, Hindi and English are similar. They both use VOT (unvoiced lag time) to distinguish one phonological contrast. Therefore, no variation difference should be expected and no difference was observed. The voicing dimension distinguishes at least one contrast in Hindi, but no contrasts in English. Hindi speakers therefore are expected to constrain variation relative to English speakers, which was observed.

Referring to dimensions of contrast provides a more nuanced and generalizeable approach to Lindblom's original claim by incorporating the fact that phonological contrasts simultaneously exploit multiple phonetic dimensions. Relatively less within-category variation should be expected along phonetic dimensions which are primary cues to the perception of a phonological contrast (prevoicing on Hindi stops). Non-primary phonetic cues (prevoicing on English stops) are predicted to show more variation both within and between-speaker as this variation does not threaten the maintenance of phonological contrast.