Explaining the decreased ability of infants around 8-10 months of age to distinguish at least some phonological contrasts absent from their native language (Werker & Tees, 1984) has constituted a theoretical challenge. Since infants of that age do not yet appear to have acquired the phonological system of the ambient language, how is it that the structure of that phonology is nonetheless active in shaping their perceptual behavior? A promising recent solution to this puzzle is provided by Maye et al. (2002), who have argued that the distributional structure of the infant’s input (i.e., adult speech), combined with infants’ statistical sensitivities, could account for changes in early perception. Supporting this idea, they manipulated the distributional properties of a VOT continuum (voiced to voiceless unaspirated), exposing infants to unimodal vs. bimodal distributions in an experimental session. Bimodal distributions led infants to perceptually discriminate items taken from the distinct modes, whereas they did not discriminate these items when their experience was unimodal.

While this is a promising theoretical account, it begs the questions of how real-world input, which is connected speech, is decomposed by infants into discrete items whose statistical properties can be accumulated and what the relevant dimensions are along which statistics are kept. Potential answers to these questions are provided by a different, though complementary, approach to modeling the infants’ developmental course in perception and production, namely, the articulatory organ (AO) hypothesis (Goldstein & Fowler, 2003; Best & McRoberts, 2003). Under this hypothesis, infants can decompose the oral-facial system into distinct organs (e.g., lips vs. tongue tip vs. tongue dorsum) from very early in life (as consistent with neonates’ ability to perform facial mimicry: Melzoff & Moore, 1997), and they are sensitive to the actions of these organs in producing constrictions within the vocal tract. This hypothesis predicts that contrasts involving actions of distinct organs (e.g., /b/ vs. /d/) should be mastered relatively early, while those involving quantitatively different actions of the same organ (e.g., /ð/ vs. /d/), should be acquired only when the infant (or child) has attuned sufficiently to the distributional properties of the organ’s constrictions. Results from children’s early word productions are consistent with this hypothesis (Goldstein, 2003), and several perceptual findings can be explained with reference to it (Best & McRoberts, 2003).

Werker’s original experiments demonstrating the loss of ability to discriminate non-native contrasts are clear examples of within-organ contrasts: Hindi dental and retroflex stops are tongue tip constrictions (differing in the location of constriction), and Nthlakapmx velar and uvular stops are tongue dorsum constrictions (also differing in location). Thus loss of ability of English-learning infants to discriminate these stimuli could be explained as a result of their experience with a unimodal distribution of tongue tip or tongue dorsum constrictions, while Hindi- and Nthlakapmx-learning infants would presumably experience bimodal distributions.

Reasonable as this account seems, there are no data to support the hypothesis of bimodality of tongue tip distributions in Hindi (or tongue dorsum distributions in Nthlakapmx). Even though a bimodal distribution might be expected, it is possible that contextual variation in tongue tip positioning (or distributional asymmetries within the language) might obscure an underlying contrast in constriction location, at least in the surface articulation (and resulting sound). We therefore collected data on tongue tip constrictions in running (adult) speech in Hindi, across a range of phonetic contexts, and compared it to data from English.

Method. A female Hindi speaker was recorded reading an approximately 6000-word story, while the positions of her lips, tongue tip, tongue body and jaw were measured using EMMA. Locations of coronal stops were identified from the acoustics, and time during that stop at which the tongue tip receiver was closest to the palate was algorithmically determined. The horizontal position (advanced-retracted) of the tongue tip (TTx) at that maximally constricted time for each stop was logged and the distribution of TTx...
values was plotted. For comparison, English data from the Wisconsin X-ray database was analyzed for 6 read paragraphs using the same procedures. Because there were fewer coronals in these paragraphs than in the Hindi story, the analysis was carried out for 3 of the X-ray subjects, 2 male and 1 female. The data from each subject (both Hindi and English) was normalized to the range 0 (most advanced) to 1 (most retracted).

**Results.** As shown in Fig. 1a, the distribution of TTx was bimodal in Hindi. None of the 3 English subjects showed a bimodal distribution. The results pooled across English subjects are shown in Fig. 1b.

![Figure 1](image)

While the Hindi distribution appears bimodal, the distribution of retroflexes is fairly broad, and it is important to know whether the overall distribution would afford the learning of two distinct constriction categories. To test this, the observed normalized TTx values were input to a Hebbian learning model that has been shown to result in self-organization of discrete phonetic categories from continuous input (Oudeyer, 2006; Nam et al., in press). With the Hindi data as input, the model converged on two sharply distinct categories of neural units, while with the data from any of the English subjects, or with the pooled data, only a single mode developed.

**Conclusion.** The adult data collected in this study suggest that if infants track distributional properties of tongue tip constrictions within more naturalistic connected speech (however they manage to do that), they will arrive at 2 categories of tongue tip behavior in stops in a Hindi environment, but a single category in an English environment. This, in turn, provides evidence in support of distributional attunement as a possible basis for changes in perceptual discrimination in the case of within-organ contrasts.

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**References**


In Chitoran, I., Coupé,C., Marisco, E., & Pellegrino, F. (Eds.), *Approaches to Phonological Complexity.* Berlin: Mouton.
