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# DEVELOPMENT OF LANGUAGE-SPECIFIC INFLUENCES ON SPEECH PERCEPTION AND PRODUCTION IN PRE-VERBAL INFANCY

Catherine T. Best
*Wesleyan University & Haskins Laboratories, USA)*

## ABSTRACT

Adults have difficulty discriminating non-native speech contrasts, yet young infants discriminate both native and non-native contrasts. Language-specific influences appear by 9-10 months for consonants and phonotactic sequences, and by 6 months for vowels. Early experience is still influential in adulthood, when fluent early bilinguals still show L1 rather than L2 effects on consonant discrimination, and those exposed to a language only during their first year show enhanced sensitivity to its contrasts. Preferences for some native prosodic properties appear even earlier. Newborns prefer native over non-native connected speech, while common native syllable structures and stress patterns are preferred by 6 months. Infant babbling displays similar developmental trends, with native prosodic biases present by 6 months and segmental biases emerging by 10 months. These effects take place prior to true word production, and well before morphology and syntax. Thus, they necessarily occur at a pre-lexical level. It is hypothesized, then, that language-specific phonetic learning precedes acquisition of contrastive phonology, a concept of fundamental significance to understanding the nature of phonological knowledge and its function in spoken language.

## 1. ATTUNEMENT TO THE SPEECH ENVIRONMENT

Many non-native segmental contrasts pose substantial perceptual difficulties for adult listeners [e.g., 1], although there is systematic variation in degree of difficulty [2,3]. Young infants, by comparison, can discriminate not only the contrasts from their own language environment, but also non-native phonetic contrasts to which they have never been exposed [4, 5, 6]. Converging evidence from numerous laboratories indicates that the developmental reorganization of speech perception implicit in these adult-infant differences has begun before the emergence of the child's first words. Specifically, the language environment already exerts a strong impact on infants' discrimination of non-native phonetic contrasts by some time during the second half-year of life [7, 8, 9, 10].

Complementing the perceptual findings are reports that children up to at least 5-6 years of age can easily acquire the phonological properties of a second language (L2) and speak it "like a native," whereas most adults speak late-learned second languages with a noticeable accent and continue to show certain perceptual difficulties with L2 consonants and vowels that do not occur in their first language (L1)[11]. These observations suggest that even the youngest children are not listening to speech simply as an end in itself -- they are actively engaged in becoming speakers themselves. The phonetic and phonological properties of the ambient language are thus crucial to attunement of speech production as well as perception. So it is perhaps not surprising that native biases also begin to appear in infants' prelinguistic speechlike vocalizations during the second half-year of life. As we might expect, language-specific influences appear earlier in the prosodic properties of infant vocalizations than in their narrower segmental properties [12, 13, 14, 15].

Such language-specific attunement of speech perception and production provide a window on the acquisition of phonological structure in the native language. At the same time, the developmental path of this attunement may also offer unique insights about the underlying nature of phonological knowledge in general, and its function in spoken language.

### 1.1. Language-specific attunement in speech perception

We turn first to review the evidence on language-specific biases in speech perception during infancy. Much research has focused on perception of non-native consonants, as summarized in the first section below. After that we turn to some more recent studies on perception of vowels and broader suprasegmental properties, including prosodic patterns, which offer additional insights regarding organizational levels in the acquisition of the native phonological system.

#### 1.1.1 Consonant perception

Discrimination of many non-native consonant contrasts shows a dramatic decline by 10 months of age, with the difficulties starting to emerge between 8-10 months. The first direct evidence of this shift was provided by Werker and colleagues [16, 17, 18]. They found that English-learning 6-8 month olds discriminated not only native /b/-/d/, but also non-native Hindi dental vs. retroflex stops and Nthlakampx velar vs. uvular ejective stops. In sharp contrast, 10-12 month olds failed to discriminate either non-native consonant pair, succeeding only with the native consonants. Hindi and Nthlakampx infants, of course, still discriminated their native contrasts at 10-12 months.

That developmental pattern was qualified, though, by findings that English-learning infants discrirminate Zulu click consonants, which are quite different from any English consonants, up to at least 14 months of age [19]. A subsequent study replicated the 10-12 month decline in discrmination of Nthlakampx ejectives, as well as the continued successful discrimination of Zulu clicks, in the same infants [20]. Thus, non-native consonant contrasts vary in difficulty for older infants, as they do for adults [2,3,19].

The finding that click consonants are relatively easy for adults and older infants to discriminate led to the development of the Perceptual Assimilation Model (PAM) of non-native speecvh perception [21, 22, 23]. PAM posits that discrimination depends on the phonetic similarities the listener perceives between the non-native phones and the native phonological system. The model predicts that adults will perceptually assimilate non-native phones to their native phonological system in one of three ways: 1) as categorizable within a native phonological category, where it may either be a near-match for native tokens, a good/acceptable exemplar, or a poor/deviant exemplar; 2) as an uncategorizable speech sound falling into the "uncommitted" phonetic space in between native categories; 3) as a nonspeech sound falling entirely outside native phonological space (i.e., failure of assimilation as a speech segment). Given those possibilities, adults' discrimination of a non-native phonetic *contrast* will depend on assimilation of each phone. Thus, several pairwise assimilation types are possible, including (but not limited to): 1) assimilation of the contrasting non-native phones to Two Categories (TC) in the native phonology, yielding excellent to very good discrimination; 2) assimilation of both non-native phones equally well (or poorly) to a Single Category (SC), yielding poor discrimination; 3) assimilation of both phones to a single native category, but with a Category Goodness difference (CG) in fit to the category, yielding good discrimination but lower than for TC contrasts; or 4) the non-native phones may be too discrepant from any native categories to be assimilated to the native phonological system, instead being heard as Non-Assimilable (NA) nonspeech, yielding fairly good discrimination as non-linguistic sounds.

To test the TC, CG and SC predictions, we began by testing American adults on three additional consonant contrasts from Zulu and one from Tigrinya [23,24]. A Zulu lateral fricative voicing distinction and a Tigrinya ejective bilabial vs. dental stop distinction were both expected to be assimilated as TC contrasts with excellent discrimination. A Zulu voiceless aspirated vs. ejective velar stop distinction was expected to yield CG assimilation and good but lower discrimination. Finally, a Zulu plosive vs. implosive voiced bilabial stop distinction was expected to be assimilated as a SC contrast, with poor discrimination. These assimilation and discrimination predictions for adults were strongly upheld. Therefore, we next tested American English-learning 6-8 and 10-12 month olds on the same contrasts [25,26]. All four contrasts were discriminated by 6-8 month olds, as expected. However, the 10-12 month olds *failed* to discriminate *any* of the Zulu contrasts, including the lateral fricatives (TC contrast for adults) and the Zulu velars (CG contrast for adults). Nonetheless, the older infants discriminated English /s/-/z/, as well as the Tigrinya ejectives (TC contrast for adults). The results suggest that 10-12 month olds may have less detailed internal phonetic organization of native categories than do adults, as evidenced by their failure to discriminate the Zulu CG velar contrast. This lack of phonetic differentiation may have interferred with theolder infants' discrimination of the non-native fricatives (which adults tended to assimilate as impermissible consonant clusters), even though it did *not* hamper discrimination of non-native ejectives (which adults assimilated as singletons).

Two findings suggest that the impact of such early language-specific effects on non-native consonant perception may persist into adulthood. First, fluent bilinguals show an L1 rather than an L2 (or combined) effect on non-native consonant discrimination in adulthood even if their L2 was acquired prior to 5 years [27]. Second, exposure to a language during only the first year of life appears to alleviate difficulties in discriminating consonant contrasts from that language in adulthood [28].

### 1.1.2. Vowel perception

Discrimination of non-native vowels may decline earlier thn discrimination of consonants. A native language impact on vowel perception may already be apparent by 6 months [29], even for some contrasts that adults in the infant's language environment can discriminate well [30, cf. 31]. Specifically, English-learning 4-month-olds discriminated two German high front- vs. back-rounded vowel contrasts (tense, lax), whereas 10-12 month olds failed to discriminate the same contrasts. By comparison, 6-8 month olds showed an asymmetry in which the more English-like vowel of each pair was discriminated after habituation to the less English-like vowel, but discrimination failed in the converse direction [30]. That pattern appears consistent with the discrimination asymmetry reported by Kuhl and colleagues as a "perceptual magnet effect," which American and Swedish 6 month olds each demonstrated for native but not for non-native vowels [29].

In related PAM studies with American adults, we found SC assimilation of the Norwegian high-front unrounded vs. rounded vowel contrast, with predictably poor discrimination accuracy. Instead, the Thai mid- vs. high-back unrounded vowel contrast was assimilated as a CG difference (within English schwa), and were discriminated very well. Three remaining vowel contrasts (French high vs. mid front rounded, French mid-high front vs. central rounded, Norwegian high front unrounded vs. high-central rounded) all showed TC assimilation and excellent discrimination. Finally, the French oral vs. nasal mid-back rounded vowel distinction showed mixed CG/TC assimilation with excellent discrimination [32]. When we tested American English-learning infants with a Norwegian vowel contrast that adults assimilated as a TC type (high front vs. central rounded vowels), we found good discrimination at 3-5 months and a complete lack of discrimination at 10-12 months [33]. But we found a discrimination asymemtry at 6-8 months in which the high front-rounded vowel, which is more peripheral in the vowel space than is the high central-rounded vowel, acted like a perceptual magnet [see 31]. In an ongoing extension of that study, we are testing infants' discrimination of the Norwegian vowel contrast that adults assimilate as a SC type (high front rounded vs. unrounded). The results are complete only for the youngest age, 3-5 months. Intriguingly, even this age group failed to discrimiante this particular contrast, which may be consistent with the fact that these two vowels are equally peripheral in the vowel space [see also 31,34,35].

### 1.1.3. Perception of prosodic patterns

Infants show even earlier sensitivity to certain broad prosodic properties of the native language, but this tendency fails to extend to all suprasegmental properties, particularly those that reflect language-specific phonological or syntactic organization. For example, on the one hand, even newborns prefer listening to fluent speech in the native language over that in a non-native language [36]. However, it is not until 9 months of age that infants reliably prefer typical over atypical bisyllabic stress patterns in the native language [37]. And only by 11 months do infants reliably prefer native over non-native phonotactic sequences [38] or show sensitivity to word boundaries in fluent native speech [39]. And when presented with native and non-native prosodic contrasts corresponding to syntactic distinctions, such as the question versus statement distinction, infants surprisingly fail to show language-specific differences in discrimination even as late as 12 months of age [40,41]. Moreover, infants continue to prefer the prosodic patterns of infant-directed speech over adult-directed speech even for unfamiliar non-native languages, until at least 8-10 months [42].

### 2.1. Language-specific attunement in speech production

Production often lags perception developmentally, proceeding at different rates for different organizational levels. As with speech perception of speech, we expect early language-specific differentiation at prosodic levels, with segmental differentiation emerging later. Such a path is compatible with nonsegmental views of child phonology, which suggest the first organizational unit is the syllable, word, or phrase, rather than the phoneme.

### 2.1.1. Production of prosodic patterns

As expected, language-specific influences appear earlier for broader prosodic structures in infant vocalizations than for narrower segmental-level patterns [12,13,14,15]. Certain prosodic properties of the target language are evident in infant babbling as early as 6 months of age [43,44]. For example, the larger proportion of rising than falling intonation for French learners compared with English learners [45] is consistent with this intonational difference in the two languages.

Interestingly, babbled vowels at around 6 months of age show cross-language commonality in their display of intrinsic F0 (IF0), the tendency for high vowels like /i/ and /u/ to have higher F0s than low vowels such as /a/. Groups of infants who were learning continental French versus learning American English both showed higher F0s for high vowels in their babbling, suggesting that IF0 is an automatic consequence of articulation, rather than a learned prosodic property [13].

### 2.1.2. Vowel and consonant production

In contrast, trends toward the native distribution of vowel and consonant categories in infant vocal productions have not been found until around 10 months. At that point, the native-language effect is fairly clear for vowels, but less robust for consonants, though still significant [e.g., 15,46,47].

## 2. UNDERLYING NATURE OF EARLY ATTUNEMENT

Because these effects of language experience to both speech perception and speech production take place prior to the onset of true word use by children, and certainly well before the onset of productive morphology and syntax, it is hypothesized that the experiential effects occur at the pre-lexical rather than at the lexical (or syntactic) level. Thus, the reorganization of perception and production in infancy most likely reflects language-specific *phonetic* learning but does not yet indicate knowledge of contrastive phonology. This developmental pattern suggests that the abstract contrastive units of phonology may not themselves be innate, but rather that they must be discovered by the child through active exploration of the physical, superficial phonetic patterns of the speech around them. Children must learn through experience to recognize the systematic relations that exist between the phonetic patterns of the spoken language and the phonological functions they serve in the language, that is, between the physical details of spoken utterances and the abstract linguistic system that gives rise to them.

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