

# The Development of VOT Perception in School-Aged Children

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## 1. INTRODUCTION

Voice onset time (VOT) refers to the time elapse between the release of the oral constriction and the onset of vocal cord vibration during articulation of pre-vocalic stops. Since the seminal study by Lisker & Abramson (1964), VOT has frequently been demonstrated to be the primary acoustic correlate for voicing contrast in stop production and perception in English (Docherty, 1992; Klatt, 1975). VOT has also been employed in studying infant speech perception. By varying VOT in equal steps to form a continuum between /ba/ and /pa/, Eimas, Siqueland, Jusczyk, & Vigorito (1971) discovered that 1- and 4-month old infants are able to discriminate the voicing contrast in a way similar to adults. However, such seemingly innate discriminatory abilities in infants are only suggestive of auditory perceptual acuity but not category recognition; the latter requires years of linguistic experience to form. Subsequent studies on children indicate that speech perception in identifying stop categories based on VOT continues to progress beyond infancy (Zlatin & Koenigsknecht, 1975; Flege & Eefting, 1986). In particular, Zlatin & Koenigsknecht (1975) compared two-year olds and six-year olds in their identification performance of three stop cognates: /b/-/p/, /t/-/d/, and /k/-/g/. They found the greatest age-related differences in children's perception of the velar pair (/k/-/g/), such that two-year olds exhibited longer phoneme boundary VOT values than six-year olds and adults. Further, a more recent study by Hazan & Barrett (2000) suggests that twelve-year olds have yet to reach adult-like phonemic contrast proficiency, as their identification curve of the /k/-/g/ pair is not as consistent as that of adults.

To our knowledge, no previous study has examined stop phonemic perception in all three places of articulation (labial, alveolar, and velar) in school-aged children. The present study presents preliminary results of an on-going research project that aims to investigate the development of pre-vocalic stop categorization in children aged 4 to 9. The purpose of our study is twofold: 1) to examine whether there exists age-related perceptual differences in school-aged children 2) to investigate whether developmental differences in phonemic categorization vary as a function of stop place of articulation. Based on previous research, we predict that children continue to refine their identification functions throughout childhood. Further, we expect to find an interaction between stop consonantal place of articulation and developmental curves. Specifically, the approximation towards an adult-like pattern should occur first in labial and alveolar stops and last in velar stops.

## 2. METHODS

Natural stimuli were recorded and edited to create VOT continua for three minimal pairs: *bear/pear*, *deer/tear*, and *goat/coat*. The VOT values ranged from -70 ms to 70 ms, separated by 10 ms steps, yielding a total of 45 tokens (15 tokens \* 3 pairs). In addition, approximately 10% of the stimuli were included as repetitions to gauge intra-subject reliability. All stimuli were randomized over trials.

A total of 48 children aged 4 to 9 participated in the study (5 four year olds, 8 five year olds, 8 six year olds, 5 seven year olds, 17 eight year olds, and 4 nine year olds). All participants self-reported (questionnaire addressed to parents) as normal hearing individuals with no known language, speech, or learning delays. An identification task was employed to examine participants' speech perception. Children sat in front of a computer monitor while speech stimuli were played over computer speakers. The child was asked to click on the image (one of six) matching the token that they heard.

## 3. RESULTS

Findings revealed that the boundary location and slope of perceptual identification function varied with age; older children demonstrated a sharper transition between phonemic categories as well as a more precise phonemic boundary location. In addition, this developmental trend observed in relation to the slope of identification and boundary location, differentiated according to the three places of articulation of the perception stimuli (labial, alveolar, and velar). In terms of the labial (*bear/pear*) stop discrimination, the VOT boundary identification across the age groups was fairly consistent, falling around the 20-30ms range at the 50% crossover, while, the slope of identification demonstrated a clear developmental trend becoming steeper with the accession of age, reaching its steepest point around 9 years of age (see figure 1). The alveolar (*tear/deer*) discriminatory pair revealed less consistency in boundary identification across the age groups, fluctuating between the 40-60ms range at the 50% crossover, with the identification function reaching its steepest point at age 9 (see figure 2). Lastly, the velar pair (*goat/coat*) revealed far less consistency in location and precision of boundaries. Boundary location identification was located between 30-70ms at the 50% crossover. The identification curve becomes progressively steeper as children's age increases (see figure 3).

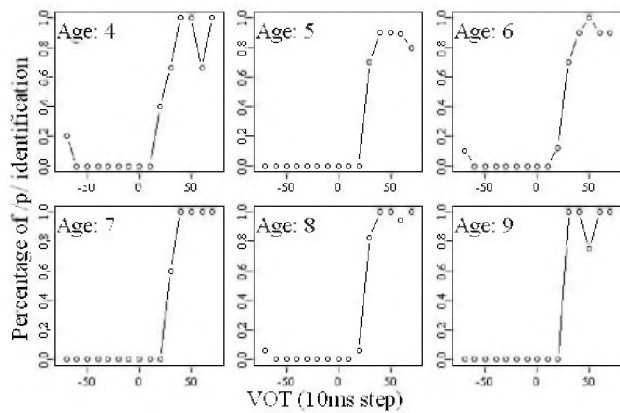


Figure 1. Mean identification scores for the labial pair for children aged 4 to 9

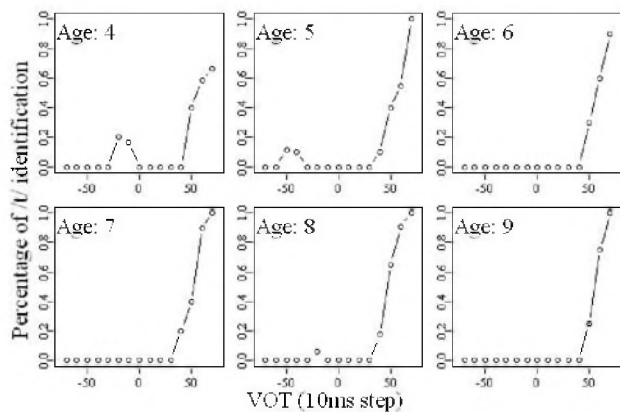


Figure 2. Mean identification scores for the alveolar pair for children aged 4 to 9

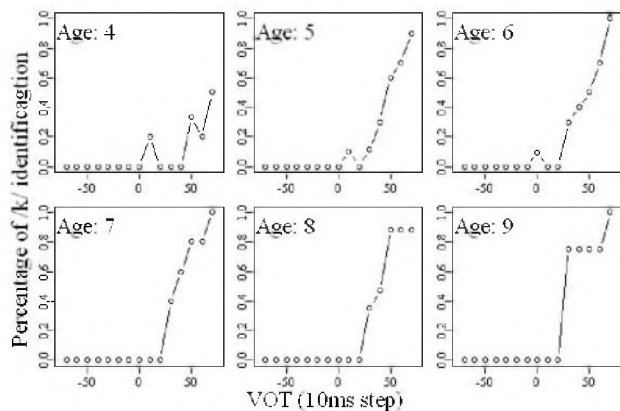


Figure 3. Mean identification scores for the velar pair for children aged 4 to 9

#### 4. DISCUSSION

The results of the present study suggest that the perception identification of certain phonemic contrasts is still

attuning in school-aged children. Even in the older children, the VOT parameter of minimal pair discrimination does not appear to have been fully established for all phonemic contrasts, specifically for those of the velar tokens. Consistent with previous research (e.g. Zlatin & Koenigsnecht, 1975), more developmental difference was found in the velar pair than in the labial and alveolar pair, suggesting later mastery of perceptual norms for the velar stops. As a whole, the slope of identification became sharper with age, revealing more uniformity among the older children. One explanation for this developmental perceptual progress is the role of language experience where language abilities, such as identifying speech token contrasts, generally improve with longer exposure. Moreover, linguistic boundary solidification in VOT perception development observed in the present study parallels the reported production development sequence, with the phonemic categorization pattern being consistent with the suggested sequence of emergence of these articulators, where children have been reported to produce labial stops first, followed by alveolar and velar stops (e.g. Smit, Hand, Freilinger, Bernthal, & Bird, 1990). This sequence of phoneme development may be interpreted by anatomical ease of articulatory gestures, with the stop discriminatory pairs (i.e. /p/-b/, /t/-d/, /k/-g/) generally being acquired at different stages of phonological development, respectively, possibly owing to differences in articulatory complexity. These findings have theoretical implications in broadening our understanding of the development of VOT perception of phonemic contrasts in mid to late childhood.

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