Development of voicing contrast: A comparison of voice onset time in stop production

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Abstract

The study investigated the development of voicing contrast in normal Kannada speaking children in the age range of 4-7 years and adults. Six children in the age range of 4-5, 5-6 and 6-7 years and 6 adults participated the study. They spoke 6 Kannada words with stop consonants in the initial position 5 times that were recorded and analyzed to measure voice onset time (VOT). The results indicated that voiced stops were characterized by lead VOT and unvoiced stops were characterized by lag VOT. Also a development trend was observed.

Key words: Kannada, Voice onset time, S-ratio

Voice onset time (VOT) denotes the time difference between the release of a complete articulatory constriction and the onset of phonation (Lisker & Abramson, 1964). In voiced stop consonants the voicing precedes the release of the articulator and hence is termed lead VOT. In unvoiced stops, the voicing follows the articulatory release and is termed lag VOT. VOT has been the one of the acoustic features investigated to indicate development of voicing contrast. The acquisition of voicing contrast using VOT is of interest as (a) a wide variety of languages employ VOT to distinguish homorganic stop consonants, (b) languages partition the VOT continuum yielding varied voicing contrast among homorganic stops, (c) infants are able to perceive some characteristics of voicing in stop consonants from soon after birth, and (d) linguistic experience has been shown to effect the discrimination of certain categories of voicing in stop consonants. Earlier investigations have shown that VOT is affected by language (Ravanan, 1993), age (Menyuk & Klatt, 1975), and gender (Ravishankar, 1981).

Research on speech development in children has indicated VOT to be longer during early childhood (Preston, Yeni-Komshian & Stark, 1967). Also, the changes in VOT distribution that occur during the first six years of life appear to be fairly systematic. VOT is also helpful to assess the general process of motor skill acquisition since VOT production distributions are appropriate to the children's language that is acquired during the period of speech sound learning (Eguchi & Hirsh, 1969). Macken & Barton (1980) report three stages in the acquisition of voicing contrast – (a) with no contrast, (b) with short lag, and (c) voiced and voiceless contrast. A shorter VOT for children compared to adults and a clear distinction between voiced and voiceless cognates by the age of 6 years is reported (Zlatin & Koenegskenecht, 1976).

The above studies are mostly in English and therefore, do not provide sufficient data for generalization to other languages. There is a need for studies with large number of subjects across various age groups in different languages. In this context a project was undertaken to investigate the development of voicing contrast in Kannada speaking normal children in the age range of 4-7 years. This paper presents the results of investigation on development of VOT in such children.

Method

Material: Three voiceless unaspirated plosive (velar /k/, dental /t̪/ and bilabial /p/) and their voiced cognates (/g/, /d̪/ and /b/) in the initial position of six Kannada words (kadi, gadi, tada, dada, padi, badi) formed the material.

Subjects: Six Kannada speaking normal children each in the age ranges of 4-5, 5-6, and 6-7 years and 6 adults participated in the study. All the subjects had normal speech and hearing. The study is on development of voicing contrast. Therefore, in order to observe whether development was complete by 7 years of age, adults were considered.

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Procedure: Subject's speaking of the words five times were audio-recorded and subjected to acoustic analysis. The samples were fed to DSP Sonograph 5500 (Kay Elemetrics) and the waveform along with wide band spectrograms were displayed on the dual channel. VOT was measured as the time duration between the burst and the onset of phonation. Lag VOT in unvoiced stops and cessation of voicing, if any, were noted.

Analysis: The data was tabulated and mean, range of VOT and S-ratio (difference between VOT of voiced and unvoiced stops) were calculated.

Results

Voiced stops were characterized by lead VOT and unvoiced stops were characterized by lag VOT. Among unvoiced stops VOT was longest in velar /k/ and in voiced stops in alveolar /t/. Lag VOT (unvoiced stops) was longer and lead VOT was shorter in children compared to adults. Lead VOT decreased from 4 years to 7 years. But there was no specific change in lag VOT. Table 1 shows the mean VOT in all groups.

	Unvoiced stops			Voice stops		
Age in years	k	t	p	g	d	b
4-5	37	21	15	-66	-74	-56
5-6	53	31	21	-76	-69	-59
6-7	36	21	18	-41	-47	-54
Average	42	24	18	-61	-63	-56
Adults	33	15	19	-80	-85	-85

Table 1: Mean VOT (ms) in children and adults

The range of VOT was wider in children compared to adults. The range decreased from 4 years to 7 years. Also, the range was wider for voiced stops compared to unvoiced stops in both children and adults. Table 2 shows the range of VOT in all groups.

	Unvoiced stops			Voice stops		
Age in years	k	t	p	g	d	b
4-5	20-58 (38)	11-42 (31)	6-37 (31)	-102 –35 (73)	-113-67 (46)	-93-29 (65)
5-6	34-68 (34)	19-46 (27)	17-35 (18)	-103-63 (40)	-96-60 (36)	-88-38 (50)
6-7	24-46 (22)	13-38 (25)	8-30 (10)	-72-36 (36)	-79-21 (58)	-87-86 (46)
Average	26-57 (31)	14-35 (27)	10-30 (20)	-89-44 (56)	-72-49 (46)	-87-34 (53)
Adults	27-45 (18)	10-21 (11)	6-1 (11)	-126-60 (66)	-105-71 (34)	-112-68 (44)

Table 2: Range of VOT (ms) in children and adults

S ratios were higher in children compared to adults. Also, S ratio decreased from 4 to 7 years except in p/b. Table 3 shows the S ratio in all groups.

Age in years	**k/g**	**t/d**	**p/b**
4-5	103	95	71
5-6	129	100	80
6-7	77	68	72
Average	103	100	104
Adults	113	87	74

Table 3: S ratio (ms) in all groups

Children in the age group of 4-5 years showed lag VOT for voiced stops. The mean lag voicing was 3.3 ms, 13.2 ms, and 9.9 ms in 4-5, 5-6, and 6-7 years, respectively. None of the adults had lag VOT for voiced stops. Also, children showed cessation of voicing in voiced stops. The mean duration of voicing cessation was 9.9 ms, 16.4 ms, and 3.3 ms in 4-5, 5-6, and 6-7 years, respectively. Voicing cessation was not observed in adults.

Discussion

The results revealed several points of interest. First of all voiced stops were characterized by lead VOT and unvoiced stops were characterized by lag VOT. This is in consonance with the results of earlier studies in Kannada (Lisker & Abramson, 1964; Sridevi, 1990). The expiratory air is utilized in vocal fold vibration in voiced stops resulting in lead VOT. In unvoiced stops, the subglottal and supraglottal pressure is equal during closure. Voicing starts when the transglottal pressure drop is sufficient to initiate voicing after the articulatory release.

Second, VOT, and the range of VOT decreased non-linearly from 4 to 7 years indicating a developmental trend. However, even at 7 years of age, it was not adult like. The development could be attributed to better co-ordination, and maturation of speech mechanism as children grow. It appears that as children grow, their articulation becomes more precise and hence follows more adult like patters. However, it is implied that the co-ordination and maturation in 7 year old Kannada speaking children is not as well developed as in adults.

Third, voicing cessation was observed in some children. A prerequisite for voicing is a difference in supraglottal and subglottal pressure. In children, owing to the small vocal tract, the supraglottal pressure equals to the subglottal pressure very fast. Mueller & Brown (1980) report of two mechanisms facilitating voicing (a) glottal and supraglottal articulatory adjustments, and (b) internal laryngeal adjustments. It has also been reported that voicing can be continued by active or passive expansion of pharynx and opening of nasopharyngeal port. However, children might not have developed these mechanisms resulting in cessation of voicing during closure of voiced stops.

To summarize, the study indicated a developmental trend in VOT in children from 4 to 7 years. However, even at the age of 7 years children don't appear to acquire adult like patterns. This warrants continuation of study till the age at which children acquire adult like patterns.

Conclusions

Previous studies on voice onset time in various languages have indicated that unvoiced stops are characterized by lag VOT and voiced stops are characterized by lead VOT. The results of the present study is in consonance with the previous studies in that in Kannada, voiced stops were characterized by lead VOT and unvoiced stops were characterized by lag VOT. Also a development trend in VOT was observed.

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