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Age-Related Effects on the Production of Voice Onset Time in Thai Word-Initial Stops

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Abstract

Voice onset time (VOT) productions associated with three bilabial stops (/b p ph/), three alveolar stops (/d t th/), and two velar stops (/k kh/) were measured in 10 young and 10 old normal adults. Mean VOTs differed significantly as a function of age for /ph/ and /th/ only. Relative frequency distributions of VOT values showed no or minimal overlap for homorganic stop consonants in either age group. VOT variability did not differ significantly as a function of age. For both young and old speakers, voiceless unaspirated stops were less variable than either voiced or voiceless aspirated. Findings are compared to Sweeting and Baken's (1982) study of VOT in an English-speaking normal-aged population.

Voice onset time (VOT) is defined as the temporal relation between the onset of glottal pulsing and the release of the initial stop consonant (Lisker & Abramson, 1964). In word-initial stops, Thai exhibits a three-way contrast in voicing at the bilabial (/b p ph/) and alveolar (/d t th/) places of articulation, and a two-way contrast at the velar (/k kh/) place of articulation. Previous investigations of VOT production in Thai word-initial stops have focused on young normal adults (Gandour, 1985; Lisker & Abramson, 1964), older adult aphasics and dysarthrics (Gandour & Dardarananda, 1984), laryngectomized adults (Gandour, Weinberg, Holasuit Petty, & Dardarananda, 1987), and normally developing children (Gandour, Holasuit Petty, Dardarananda, Dechongkit, & Mukngoen, 1986).

One of the most pervasive characteristics of aging is reduction in speed due to neural and muscular changes (Sweeting & Baken, 1982, and references therein). The fine motor control required to adjust the timing and coordination of the larynx and supralaryngeal articulators in the production of VOT might be expected to change as a function of normal aging. The purpose of this study, therefore, was to obtain measures of VOT in healthy older adults in order to extend our knowledge base about acoustic phonetic characteristics of Thai word-initial stops to the later years.

Method

Subjects

Twenty normal adult speakers of Thai participated in the study: 10 'young normal' adults and 10 'old normal' adults. All 10 speakers in the young normal group were male and had completed 13 years of formal education; the average age of the young normal group was 26.7 (SD = 2.6). Five of the speakers in the old normal group were male, five were female; all had completed 4 years of formal education; the average age of the old normal group was 56.7 (SD = 2.6). None had any known speech or hearing impairment.

Speech Materials

The materials consisted of eight monosyllabic real words: a minimal triplet for the three-category distinction in VOT at each of the bilabial (/baan/ 'to bloom,' /paan/ 'birthmark,' /phaan/ 'ignorant') and alveolar (/dam/ 'black,' /tam/ 'to pound,' /tham/ 'to do' places of articulation, and a minimal pair for the two-category distinction in VOT at the velar (/kan/ 'to prevent,' /khan/ 'to itch') place of articulation. All words thus contained an initial stop consonant followed by a low back unrounded vowel and a final nasal consonant. Tone (mid) was held constant across all eight words.

Recording Procedure

All eight words were printed in large Thai letters on 3" x 5" cards. A total of 80 cards (8 words x 10 repetitions) were presented in random order to subjects. They were instructed to read the words in isolation. To avoid start and end effects in the production of these utterances, extra cards were placed at the top and bottom of the deck. Subjects were tested in a reasonably quiet room in a single session. Their utterances were recorded using a Sony ECM-66B microphone and a Marantz PMD-420 taperecorder.

Measurement Procedure

A total of 1,600 utterances were analyzed using a Kay Elemetrics DSP Sona-Graph model 5500-1 with a wide-band spectrogram plus waveform and amplitude display. A vertical cursor was positioned on the spectrograms at the release of the stop consonant. Stop release was identified by the onset of a burst of frication noise following the closure interval and concomitant abrupt rise in amplitude. Another cursor was positioned at the onset of voicing. In the case of voicing lag, the "sudden onset of vertical striations in the second and higher formants" (Klatt, 1975: p. 687) was taken to represent the onset of voicing following the stop release; in the case of voicing lead, the sudden onset of low energy vertical striations in the absence of acoustic energy in the formant frequency range was taken to represent the onset of voicing preceding the stop release (Lisker & Abramson, 1964 : p. 389) Adopting the convention of assigning a timing value of zero to the moment of stop release, measurements of VOT after the stop release (voicing lag) were stated as positive numbers, while measurements of VOT before the stop release (voicing lead) were stated as negative numbers (Lisker & Abramson, 1964 : p. 389). Each utterance was measured to the nearest 1.6 ms (cf. Gandour, 1985; Gandour & Dardarananda, 1984). About 10% of the utterances were remeasured on a separate occasion by one investigator as well as independently by another investigator. Both intrajudge (r = 0.97) and interjudge (r = 0.95) measurement reliability were high.

Results

Mean VOT values for each stop consonant for each age group are presented in Figure 1. For the young group, mean VOT values were 79, 10, 96, -69, 14, 94, 26, and 112 ms for /b/, /p/, /ph/, /d/, /t/, /th/, /k/, and /kh/, respectively; for the old group, -83, 10, 72, -72, 11, 70, 26, and 94 ms, respectively. Results of a three-factor (Age x Voicing Category x Place of

Articulation) analysis of variance with repeated measures on two factors (Voicing Category x Place of Articulation) showed that mean VOT differed significantly as a function of age [F(1, 18)=11.93, p<.0028], voicing category within place of articulation [F(5, 90)=478.98, p<.0001], and age x voicing category interaction [F(5, 90)= 3.23, p<.0100]. This outcome indicated that the effect of age was dependent on the voicing category of the stop consonant. Separate one-way analyses of variance at each of the three places of articulation revealed age effects for /ph/ [F(1, 18)=18.57, p<.0004] and /th/ [F(1, 18)=19.07, p<.0004]. The age effect for /kh/ just failed to reach significance [F(1, 18)=3.76, p<.0682]. There were no significant differences in mean VOT between age groups for voiced (/b d/) or voiceless unaspirated (/p t k/) stop consonants.

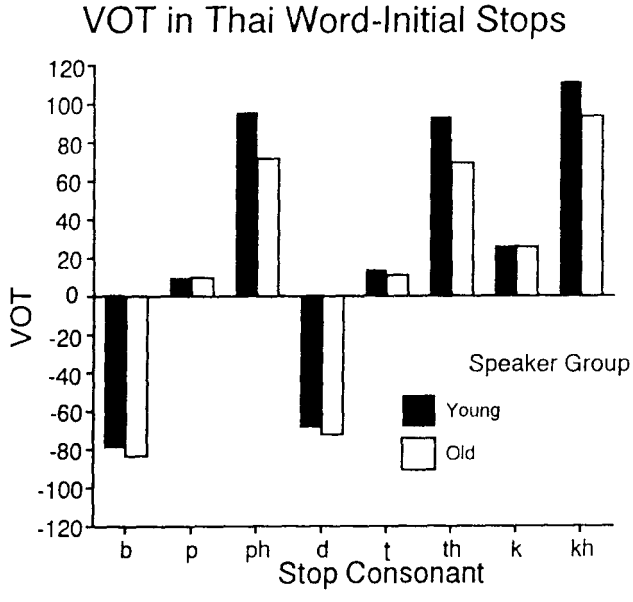

Figure 1. Mean VOT values for eight Thai word-initial stop consonants produced by groups of young and old speakers.

Results of the three-factor anslysis of variance also revealed a place of articulation main effect [F(2, 36)=388.96, p<.0001] in the absence of an age x place of articulation interaction [F(2, 36)=0.046, p<.9547], meaning that VOT generally increased from /p/ to /t/ to /k/ and from /ph/ to /th/ to /kh/ for both young and old speakers alike. This finding is consistent with previous reports on VOT in Thai (Gandour, 1985; Lisker & Abramson, 1964) as well as VOT data from other languages Lisker & Abramson, 1964).

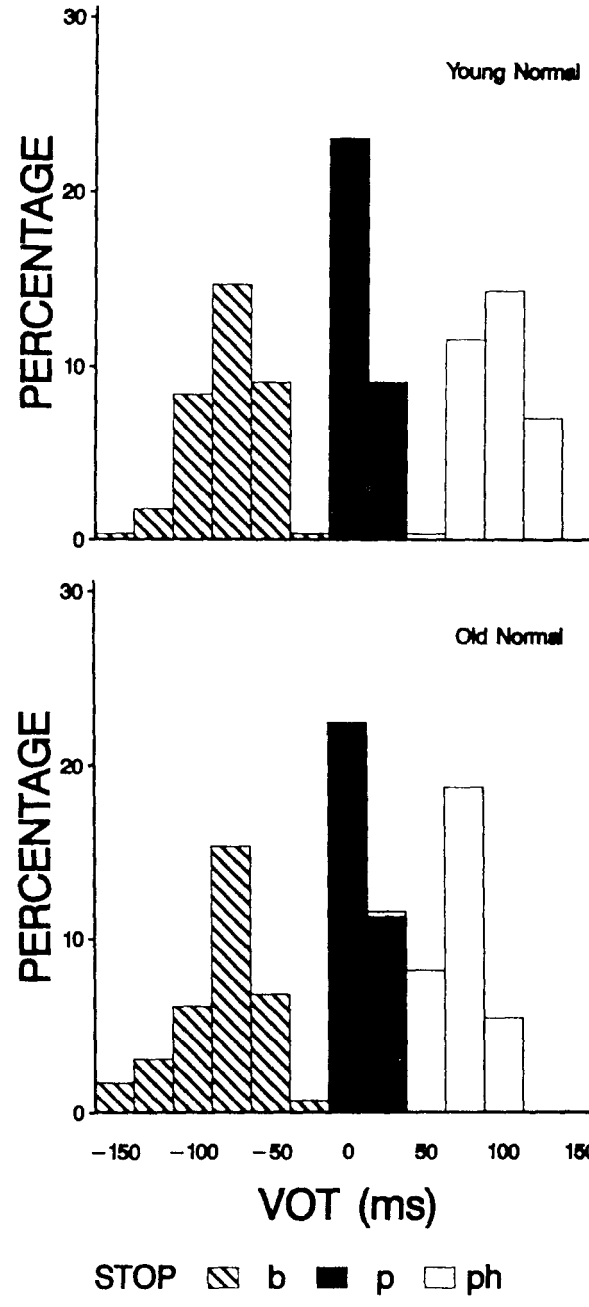

Figure 2. Relative frequency distribution of VOT productions for bilabial stop consonants in word-initial position for groups of young and old speakers.

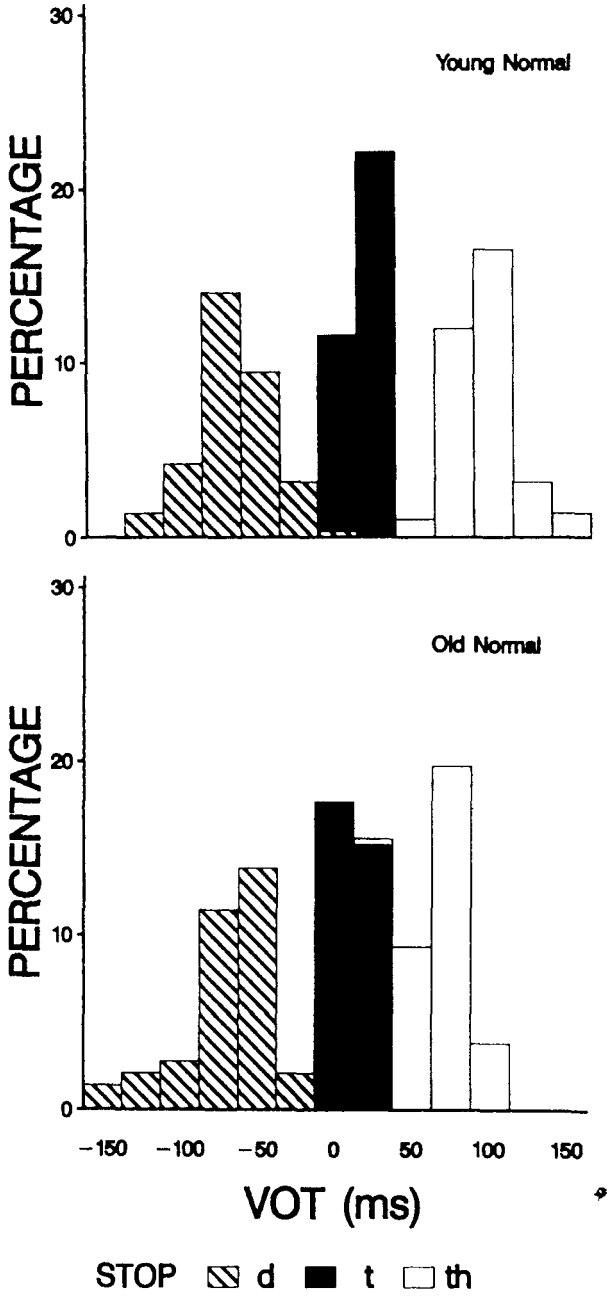

Figure 3. Relative frequency distribution of VOT productions for alveolar stop consonants in word-initial position for groups of young and old speakers.

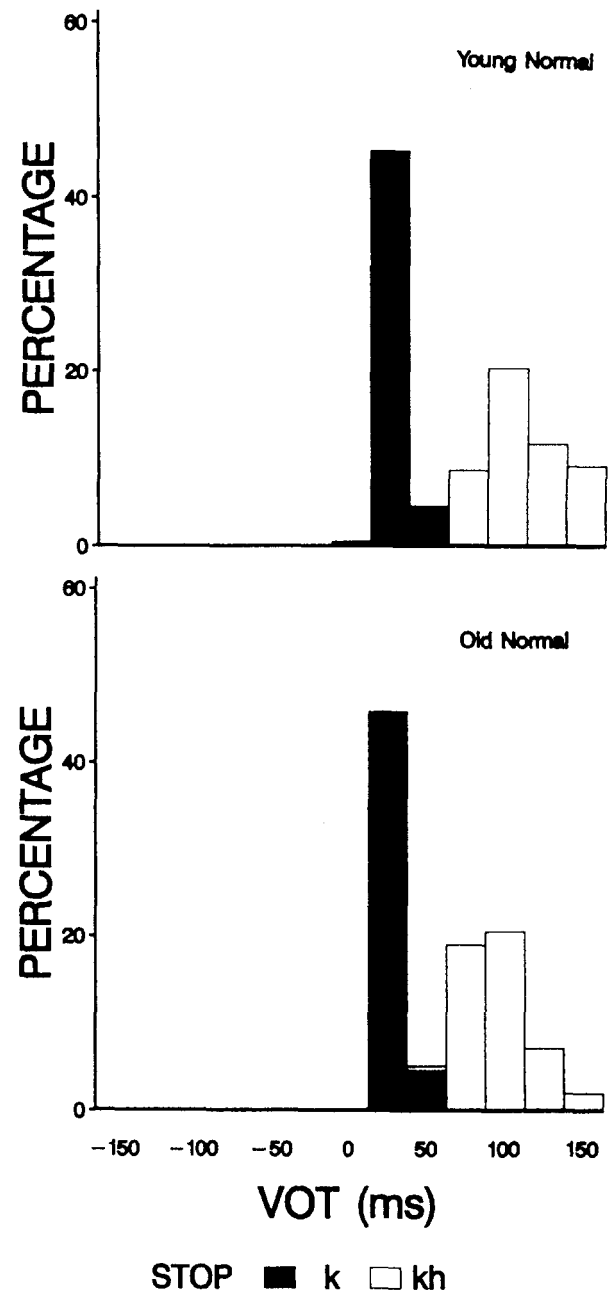

Figure 4. Relative frequency distribution of VOT productions for velar stop consonants in word-initial possition for groups of young and old speakers.

Another result from the three-factor analysis of variance was the absence of a main effect for speakers nested within groups [F(18, 38)=1.869, n.s.], indicating that both speaker groups were homogeneous in terms of VOT production. In a separate three-factor analysis of variance, no significant gender effect was found between male and female speakers in the older group [F(1, 8)=0.092, n.s.], nor were any of the two-way interactions significant.

Relative frequency distributions of VOT values for each of the age groups at the bilabial, alveolar, and velar places of articulation are displayed in Figures 2, 3, and 4, respectively. There is minimal to no overlap between any of the homorganic stop consonants for either age group. VOT values for all stop categories cluster into discrete regions along the continuum. VOT values for /b/ and /d/ lie in the long voicing lead region; for /ph/, /th/, and /kh/ in the long voicing lag region; and for /p/, /t/, and /k/ at zero or in the short voicing lag region. This finding is consistent with previous investigations of VOT production in Thai (Gandour, 1985; Lisker & Abramson, 1964).

Standard deviations for each stop consonant by age group are presented in Table 1. To assess changes in VOT variability with age, a three-factor (Voicing Category x Age x Place of Articulation) analysis of variance was performed on the standard deviations of each subject's productions of each of the eight stop consonants. Results indicated a significant main effect for voicing category [F(5, 90)=36.99, $p<.0001$]. No other main effects or two-way interactions were significant, meaning that the pattern of VOT variability across stop consonants was the same for both speaker groups. Posthoc Newman-Keuls comparisons established that the voiceless unaspirated stops /p t k/ were significantly (alphs=.01) less variable than homorganic voiced (/b d/) or voiceless aspirated (/ph th kh/) stops and, in addition, that /d/ was more variable than /th/. Though /b/ was greater in variability than /ph/, the difference failed to reach statistical significance.

Discussion

The findings from the present study indicate that there is a compression of the VOT continuum due to shorter mean VOTs for voiceless aspirated stops (/ph th kh/) as a function of normal aging. Mean VOTs for voiced (/b d/) and voiceless unaspirated (/p t k/) stops remain relatively stable in later years. On the basis of articulatory and aerodynamic considerations, zero or short lag stops are easier to produce than either long lag stops or stops with voicing lead (Kewley-Port & Preston, 1974). No claims are made about the relative complexity of stops with long voicing lag vs. stops with long voicing lead. The shorter voicing lags for /ph th kh/ in older speakers' VOT productions suggest that stops with long voicing lag may be more difficult to produce than those with long voicing lead. However, the later emergence of Thai voiced stops as opposed to voiceless aspirated stops in normally-developing children would suggest just the opposite (Gandour et al., 1986)

Despite the shorter lag when producing the voiceless aspirated stops, the older speakers maintained a distinctly trimodal frequency distribution of VOT for bilabials and alveolars, a bimodal frequency distribution for velars. That is, the phonemic separation of homorganic word-initial stops continues to be robust in the face of diminished precision of neural and muscular timing functions that comes with advancing age.

In Sweeting and Baken's (1982) study of VOT in English word-initial bilabial stops, mean VOTs did not differ significantly across age groups for either /b/ or /p/. Nonetheless, the mean VOT for /p/ was shorter in their 75-and-over age group when compared to the other age groups. This finding is consistent with the shorter lag of the Thai voiceless aspirated stops observed in the older speaker group in the present study. The compression of the VOT continuum, however, was not observed

in their subjects aged 65-74. It is difficult to account for the seemingly earlier developmental compression of the VOT continuum in Thai as opposed to English. This may be attributed perhaps to a discrepancy between chronological age and physiological age. The older Thai speakers may have aged more physiologically as a group than their chronological age would indicate. To the extent that chronological age is not a valid reflection of physiological age, the analysis of the relationship of normal aging to VOT production may be confounded.

There was no significant increase in variability of VOT productions by older speakers in this study. In the Sweeting and Baken (1982) study of English VOT, the older speaker groups included subjects aged 65-74 and subjects over 75. Increased variability in VOT productions was evident in their oldest group only. Both of their aged subject groups were considerably older than the one in this study. Older subjects' in this study were between 53 and 60 years of age. Thus, our findings are not in conflict with those of Sweeting and Baken's, but point to the need to extend our developmental model of Thai stop production to an even older population.

Table 1
Variability in VOT Production

	Stop							
Group	/b/	/p/	/ph/	/d/	/t/	/th/	/k/	/kh/
Young	22.6	4.0	18.2	23.9	5.1	20.1	8.1	27.5
old	27.6	4.6	15.2	29.6	6.0	13.8	8.7	20.1

Note. Values are standard deviations expressed in ms.

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