Exploring voice onset time, place of articulation, and vowel context in children

ELAINE R. HITCHCOCK[1] **LAURA L. KOENIG**[2,3] **LAURA C. OCHS**[1]

[1]*Montclair state University* [2]*Adelphi University* [3]*Haskins Laboratories*

Introduction. Voicing acquisition in English-learning children has been widely studied using VOT [1]: the interval between oral release and the onset of glottal vibration. VOT has been found to vary according to place of articulation [POA] (velar > alveolar > bilabial) and vowel context. However, magnitudes of effect vary across studies and the nature of the vowel effect is not clear [2–7], with the majority of data focused on adult speech behaviors (but cf. [8-9]). Moreover, no past work has evaluated the degree to which such effects are consistent over time for a single speaker. The primary aim of the present longitudinal study was to explore how VOT varies in children with respect to vowel and consonant POA.

Methods and Analysis. Nine typically-developing English-speaking children aged 5;3–7;6 were recruited for participation. All participants scored within normal limits on standardized speech and language assessments, an oral mechanism examination, and a hearing screening. Recordings were collected every 2–4 weeks over a 10–month period for a total of 18 sessions. A minimum of 18 tokens per bilabial (/b, p/), alveolar (/d, t/), and velar (/g, k/) voiced and voiceless targets across two vowel contexts was attempted in each recording session to establish VOT distributional characteristics. Verbal prompts were used to elicit responses. Stimuli were images of monosyllabic words presented in a PowerPoint presentation format randomized for each session. VOT was measured in CV/CVC monosyllabic minimal pairs: *beach-peach/boo-pooh, dock-tock/doe-toe*, *gay-kay/goat-coat.* Bilabial and velar cognate pairs targeted a front-back vowel difference (/i/-/u/, /e/-/o/), while alveolar cognate pairs targeted a mid high-low vowel difference (/o/-/ɑ/). VOT variability over time was also evaluated.

Recordings were made in a quiet room using a Marantz (PMD660) portable digital recorder. A Pentax lapel microphone (Model 3502) was attached to the child's clothing approximately 6 in. from the mouth for a favorable signal-to-noise ratio and minimal feedback distortion. Data was transferred from the Marantz to the Pentax Computer Speech Laboratory (Model #4500), where it was analyzed for VOT using both acoustic waveforms and spectrograms. In total, 17,496 tokens were included in the analysis.

Results. *Group POA effects* based on summary data (means/SD) and accuracy percentages (# of total productions produced in the expected direction) reveal a robust effect with VOT values for velars greater than those of alveolars and bilabials. Observed differences were consistent with >75% of all comparisons showing the expected effect (see Table 1a).

Table 1a. Group POA effects on VOT

	/d–b/	/g–d/		/t–p/	/k–t/
mean (ms)	7.0	3.9		6.6	7.2
SD	13.5	13.3		8.4	9.5
%	74.7%	76.5%		77.8%	79.0%

Table 1b. Group vowel effects on VOT

	/b/	/d/	/g/	/p/	/t/	/k/
	/u–i/	/o–a/	/o–e/	/u–i/	/o–a/	/o–e/
mean (ms)	-3.9	-6.2	-2.4	3.1	12.6	-5.6
SD	24.5	19.2	21.8	13.2	15.0	11.5
%	50.0%	48.8%	55.6%	63.0%	84.6%	32.7%

Group vowel effects based on summary data and accuracy percentages show a clear effect of vowel height (mid vs. low) on VOT in /t/ productions; the expected /to-ta/ difference was observed in 85% of cases. The same effect was not seen for /d/. No obvious differences were evident between front versus back vowels (see Table 1b).

Individual patterns.

Visual inspection of *POA patterns over time* show wide individual variation in the POA effect. More stability was observed over time for older participants compared to younger participants (see Figure 1). Similarly, a review of the data for all speakers shows marked individual variation in the magnitude of the vowel effects, but again, less variation across vowel contexts was observed in older participants (see Figure 2).

Figure 1. POA effects for two children aged 5;3 and 7;6, respectively.

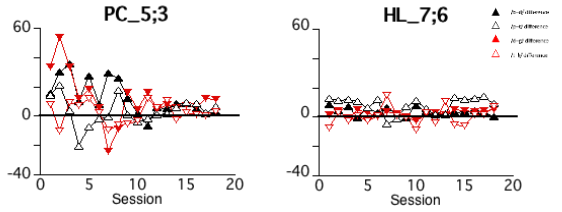
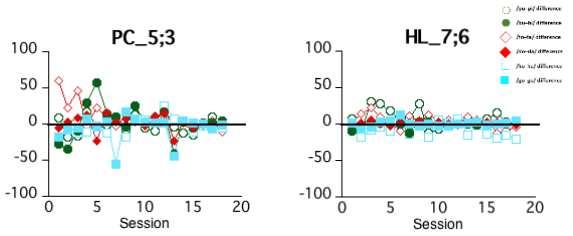


Figure 2. Vowel effects for two children aged 5;3 and 7;6, respectively.



Token-by-token analyses for each speaker, measured over the duration of the study, reveal decreases in range and standard deviations for target consonants. These decreases align with smaller percentages of overlap between voicing categories and a reduction in POA/vowel effects over time.

Discussion. On the whole, POA and vowel context variation revealed several trends. Overall, VOT increases as POA moves posteriorly and all *average POA differences* are positive with magnitudes towards the *high* end of what has been reported for adults [3,10]. However, vowel effects are less clear than POA effects. Vowel height shows the most obvious effect with consistently longer VOT values recorded for /t/ before mid-high vowels. Front versus back vowel VOT differences are not observed for any stop in the present study; however, it is possible that supraglottal conditions may affect aspiration and closure voicing differently. Further research, such as a systematic comparison of the relationships between high-mid, mid-low and high-low vowel differences for vowels measured over time, is needed to further explore the relationship between the VOT and vowel effects. Such data would provide greater insight into the effects of lingual posture and voicing contrasts.

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