

## Segmental duration changes due to variations in stress, vowel, place of articulation, and voicing of stop consonants in Greek

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unstressed syllables. The literature has been vague, however, about whether syllables that have undergone tone deletion as a result of destressing and underlyingly atonic syllables show the same surface pitch pattern. This experiment examined these lexical tones in stressed and unstressed contexts, and then compared unstressed tone patterns to that of the neutral tone. The experiment focused on duration and pitch range as effective correlates of stress. Unstressed syllables were found to be significantly shorter in duration than stressed syllables, corroborating previous studies. Pitch range was also significantly reduced in unstressed contexts in all cases except one. The data unexpectedly showed that changes in pitch range are a function of the pitch peak only; pitch valleys did not significantly change. Finally, the results provide evidence that unstressed syllables with underlying tones do not neutralize completely, but remain distinct from the neutral tone.

**2aSP21. Preaspiration in Icelandic: Production and perception.** J rgen Pind (Inst. of Lexicography, Univ. of Iceland, Neshaga 16, 107 Reykjav k, Iceland)

Preaspiration in Icelandic occurs, e.g., when a vowel in a stressed syllable is followed orthographically by "pp", "tt", or "kk," and is commonly transcribed as [h] before a short stop. Stressed syllables in Icelandic thus present a three way contrast (involving stops) between word forms such as *baka* [ba:ga], "to bake," (type V:C), *bagga*, [ba:ga], "burden" (acc.sg.) (type VC:), and *bakka*, [bahga], "to turn back" (type VhC). Durational measurements showed wide variability in segment durations depending on context. However, results also indicate that the ratio of the preaspiration to the vowel duration is reasonably constant and can be viewed as a higher-order invariant, comparable to the vowel/rhyme ratio in the quantity opposition [J. Pind, *Phonetica* 43, 116-139 (1986)]. Perception experiments showed that preaspiration can be cued by voice offset time, a speech cue analogous to voice onset time. The experiments further showed that durational relationships within the syllable rhyme influenced the perception of preaspiration to a great extent while factors outside the rhyme had a minor influence on the placement of the phoneme boundaries, indicating perceptual constancy.

**2aSP22. VOT values of voiceless and voiced stop contrasts in Hindi and Kannada.** H. S. Gopal (Dept. of Linguist., Univ. of California at Santa Barbara, Santa Barbara, CA 93106)

A number of languages from the subcontinent of India have a four-way voicing contrast—the aspirated voiceless, the unaspirated voiceless, the unaspirated voiced, and the breathy voiced stops (for example, [p<sup>h</sup>, p, b, b<sup>h</sup>]). It has been suggested that the primary difference between the unaspirated voiceless and the unaspirated voiced stop consonants (for example, [p] vs [b]) is one of voice onset time (VOT). This study investigated whether VOT adequately separates the unaspirated voiceless and the unaspirated voiced stop consonants in two languages, Hindi and Kannada. Hindi is primarily a north Indian language and Kannada is primarily a South Indian language. Using four speakers, VOT values were measured for these two stop consonant series at four places of articulation—bilabial, dental, retroflex, and velar. The results will be discussed with reference to the adequacy of VOT as the primary acoustic feature distinguishing these two stop contrasts in the two languages.

**2aSP23. Segmental duration changes due to variations in stress, vowel, place of articulation, and voicing of stop consonants in Greek.** H. B. Kollia (City Univ. of New York, and Haskins Labs., 270 Crown St., New Haven, CT 06511)

Although Lisker and Abramson (1967) found no effect of the following vowel on the VOT of a stop consonant, Port and Rotunno (1979) found VOT to have greater values for voiceless stops followed by tense than by lax vowels. The purpose of the present study was to obtain a complete database on the VOT characteristics of voiced and voiceless initial stop consonants in Greek, and to examine the contextual effects on the VOT of the post-consonantal vowel, the stress pattern, and the distance of the stress from the initial stop consonant. The question here was whether the vowel effects found by Port and Rotunno for English would be seen in Greek, a language whose two stop categories have voicing lead and medium lag. Speakers read isolated disyllabic

and trisyllabic words of four stress patterns. The utterance-initial stops /p, t, k, b, d, g/ were followed by the five vowels of Greek, /a, e, i, o, u/. Results indicated that both voicing lead and voicing lag increased for stops followed by higher than by lower vowels. Fourakis (1986) found that stress changes did not affect VOT of /p,t/, only of /k/. In this study, stress variations affected VOT for all stops. Furthermore, these effects were vowel dependent. [Work supported by NIH Grant Nos. DC-00121 and DC-00594 to Haskins Laboratories.]

**2aSP24. Do women listen to men's voices with men's mouths in mind?** Keith Johnson (Dept. of Biocommun., Univ. of Alabama, Birmingham, AL 35205), Peter Ladefoged, and Joyce McDonough (UCLA, Los Angeles, CA 90024-1543)

This paper reports the results of an acoustic study of vowels produced by Navajo speakers, which was supplemented by perception data using the method of adjustment. Analyses of vowels produced by male and female speakers showed these two groups distinguished long and short vowels differently. Male speakers had about the same formant values for both members of the long/short vowel pairs, while female speakers tended to distinguish long and short vowels by means of both a length and a vowel quality distinction. The perception data showed that when listening to a "male" synthetic voice all listeners (irrespective of sex) collapsed long and short vowels in the perceptual vowel space, selecting vowels that were similar to those in the male production data, but with more extreme formant values than those produced by the male speakers. One hypothesis is that Navajo women produce different long and short vowels, but when listening to a male speaker's vowels select as matches long and short vowels that do not differ significantly in quality. It is not known whether the men would listen to women's voices with women's mouths in mind.

**2aSP25. Let your synthesizer breathe.** D. H. Whalen (Haskins Labs., 270 Crown St., New Haven, CT 06511) and Charles E. Hoequist (BNR, Research Triangle Park, NC 27709)

Although synthesizers do not have any air flow, they are representing creatures that do. While it is quite common to have long stretches of speech without audible intake (especially with speakers trained in acting and broadcasting), synthesis might be somewhat less artificial with the intake of breath added. To see whether adding an audible intake would affect the perception of synthetic speech, breath intake (naturally produced) was introduced in a synthesis transcription task. Subjects received the breath-added stimuli on either the first half of the test or the second. The largest effect was a typical one of increased performance in the second half, due to increased experience with the synthesizer. However, those subjects who received the breath second had a much larger improvement than those who had it first, who were essentially the same in the second condition as the first. The results indicate that, as with almost anything that increases naturalness, allowing computers to breathe will improve the perception of synthetic speech. [Work supported by NIH Grant No. HD-01994.]

**2aSP26. Spectral shape cues for vowels that predict the perception of multiple-tone steady-state stimuli.** Stephen A. Zahorian, Zhong-Jiang Zhang, and Zaki B. Nossair (Dept. of Elec. and Comput. Eng., Old Dominion Univ., Norfolk, VA 23529)

In previous experiments for which multiple tone stimuli were synthesized such that either the formants or global spectral shape were matched to that of naturally spoken vowel tokens, it was found for both cases that vowel identity and quality was not well preserved [S. A. Zahorian and Z.-J. Zhong, *J. Acoust. Soc. Am.* 92, 2414-2415 (1992)]. In the present study several additional criteria were tested for selecting the amplitudes and frequencies of sinusoids with the objective that stimuli synthesized from these sinusoids would be perceived as most similar to original "target" vowel tokens. Of the methods investigated, vowel quality from stimuli synthesized from *N* sinusoids was best preserved if these sinusoids match the *N* largest peaks in the magnitude spectrum of the original vowels. Depending on the vowel, between 5 and 10 sinusoids are required such that the synthesized token is perceived as sounding nearly identical to the original token. A new metric for spectral shape that yields acoustically invariant cues to vowel perception in a manner