

## THE ACOUSTIC PARAMETERS OF STRESS IN RELATION TO SYLLABLE POSITION, SPEECH LOUDNESS AND RATE

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There is considerable evidence showing that the most consistent acoustic correlates of English stress are the increased magnitudes of fundamental frequency, duration, and amplitude of stressed syllabics in relation to unstressed syllabics (Tiffany 1959, Tiffin and Steer 1937, Fry 1955, 1958, Lehiste and Peterson 1959, Lieberman 1960). Yet it is clear that none of these acoustic features always accompanies the occurrence of stress. Thus, at the acoustic level stress is characterized by a kind of complex trading relationship among its features wherein the predominant feature varies from situation to situation. This is at least partially due to the fact that syllabic fundamental frequency, duration, and amplitude are conditioned by phonetic quality and context (Black 1949, Delattre 1962, House and Fairbanks 1953, House 1961, Peterson and Lehiste 1960). This investor felt that certain additional speech variables might also exert consistent influences on the acoustic character of stress.

The general shape of the normal intonation contour of American English would dictate that a syllabic occurring in the central portion of the contour have a higher fundamental frequency than a syllabic occurring in the terminal portion. Thus, syllable position within the total intonation contour should have consistent effects on the degree of fundamental frequency contrast between syllabics in different portions of the contour. The same point could also be made for syllabic duration which tends to increase in the terminal portion of an utterance.

There is evidence suggesting that as the regulatory mechanism controlling fundamental frequency and amplitude approaches the lower limits of the chest register the degree of adjustment needed for stress contrast is significantly constrained (Murray 1970). Thus, it was anticipated that during soft speech, and possibly loud speech, the degree of fundamental frequency and amplitude contrast between stressed and unstressed syllabics would be minimal.

Due to the stress-timed nature of English, increases in speech rate are achieved primarily through the shortening of unstressed syllabics versus stressed syllabics (Lehiste 1970). This would suggest that at increased speaking rates the degree of duration contrast between stressed and unstressed syllabics should increase.

On the basis of the above considerations a descriptive acoustic analysis of stress

was performed wherein stressed syllable position, speech loudness and rate were systematically varied by speakers.

### 1. METHOD

Ten male speakers of General American English were asked to produce the sentences 'Say /'sasa/ please' and 'Say /sa'sa/ please' at normal, increased, and decreased rates and loudnesses of utterance. Each utterance was recorded five times, and spectrographic and oscilloscopic procedures were used to extract the fundamental frequency, duration, and peak amplitude of the stressed and unstressed syllabics of /'sasa/ and /sa'sa/ of the middle three utterances. The acoustic values for the three utterances were then averaged for purposes of data analysis.

### 2. RESULTS AND DISCUSSION

1. *Syllable Position Effects.* — It was found that 72% of initial stressed syllabics were higher in fundamental frequency than corresponding final stressed syllabics, and that 82% of initial unstressed syllabics were higher in fundamental frequency than corresponding final unstressed syllabics. In addition 100% of final stressed syllabics were found to be longer in duration than corresponding initial stressed syllabics, and 94% of final unstressed syllabics were longer in duration than corresponding initial unstressed syllabics. For syllabic amplitude no consistent tendencies were observed.

On the basis of the syllable position effects for fundamental frequency and duration, one would expect fundamental frequency contrast between stressed and unstressed syllabics to be greater in /'sasa/ than /sa'sa/, while for duration the reverse should be true. This was in fact the case; for in comparing the stressed-to-unstressed syllabic ratios for the two test words, it was found that fundamental frequency ratios were greater in /'sasa/ than /sa'sa/ in 92% of the cases and duration ratios were greater in /sa'sa/ than /'sasa/ in 96% of the cases.

The observed increase in fundamental frequency associated with initial syllabics was probably due to syllabic interaction with the intonation contours of subjects' utterances. The tendency for syllabic duration to increase in final syllabics may be due, as Lindblom suggests, to a general relaxation of the speech mechanism occurring in the terminal portion of the phrase contour (Lindblom 1967). Whatever the underlying causes of the apparent trade off between syllabic fundamental frequency and duration, these data suggest that syllable position may be an important variable in listener recognition of stress contrasts. More specifically, the relative psycho-acoustical powers of fundamental frequency and duration as cues to stress may be significantly determined by phrase contour position.

3. *Loudness Effects* — The effects of increased and decreased loudness of utterance on degree of stress contrast were evaluated by comparing the stressed-to-unstressed syllabic ratios of loud and soft speech to those for normal speech. No significant differences were found in the loud-to-normal speech comparisons for any of the three acoustic parameters. For the soft-to-normal speech comparisons, however, amplitude and fundamental frequency contrast were found to be significantly less during soft speech. Duration contrast during soft speech did not differ significantly from normal speech duration contrast. These data suggest that duration may be the predominant acoustic feature of stress during soft speech.

4. *Rate Effects* — Duration contrasts during slow and fast speech were not found to differ significantly from normal speech duration contrast. In light of the notion that English is a stress-timed language, it is somewhat surprising that duration contrast did not increase during fast speech. The observations made, however, may have been due to some speaker constraint peculiar to this experiment.

Summarizing the major findings of this investigation, syllable position and decreased speech loudness were found to be significant conditioners of the acoustic character of stress.

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#### REFERENCES

- Black, J.  
1949 "Natural Frequency, Duration, and Intensity of Vowels in Reading", *Journal of Speech and Hearing Research* 14:216.
- Delattre, P.  
1962 "Some Factors of Vowel Duration and Their Cross-Linguistic Validity", *Journal of the Acoustical Society of America* 34:1141.
- Fry, D.  
1955 "Duration and Intensity as Physical Correlates of Linguistic Stress", *Journal of the Acoustical Society of America* 27:765.  
1958 "Experiments in the Perception of Stress", *Language and Speech* 1:126.
- House, A.  
1961 "On Vowel Duration in English", *Journal of the Acoustical Society of America* 33:1174.
- House, A. and G. Fairbanks  
1953 "The Influence of Consonant Environment Upon the Secondary Characteristics of Vowels", *Journal of the Acoustical Society of America* 105.
- Lehiste, I.  
1970 *Suprasegmentals* (Cambridge, M.I.T. Press).
- Lehiste, I. and G. Peterson  
1959 "Vowel Amplitude and Phonemic Stress in American English", *Journal of the Acoustical Society of America* 31:428.
- Lieberman, P.  
1960 "Some Acoustic Correlates of Word Stress in American English", *Journal of the Acoustical Society of America* 32:451.

- Lindblom, B.  
1967 "Temporal Patterning in Syllable Production", *STL-QPSR* 2-3:1 (Stockholm).
- Murray, T.  
1970 "Intensity Variation During Vocal Fry Phonation", *Journal of the Acoustical Society of America* 41:119.
- Peterson, G. and I. Lehiste  
1960 "Duration of Syllable Nuclei in English", *Journal of the Acoustical Society of America* 32:693.
- Tiffany, W.  
1959 "Non-Random Sources of Variation in Vowel Quality", *Journal of Speech and Hearing Research* 2:305.
- Tiffin, J. and M. Steer  
1937 "An Experimental Analysis of Emphasis", *Speech Monographs* 6:69.

#### DISCUSSION

VANDERSLICE (New York)

It doesn't seem to me surprising that post-nuclear unstressed syllables are lower in pitch than pre-nuclear ones, because citation form utterances have a pitch drop after the nuclear syllable. (The *please* is merely an enclitic.) What would be significant would be a comparison of 'say *sásá* to your bróther-in-law' vs. "say *sásá* to your bróther-in-law" or the like, where the unstressed syllable is prenuclear in both.

MCCLEAN

I must confess that I was not entirely satisfied with the carrier phrase employed after having run the experiment, and I hope to study similar stress contrasts in a wider variety of phrase contour positions in the future. At the same time, however, I know of nowhere in the experimental literature where this type of interaction between disyllabic stress and intonation contour is reported.

KORNFELD (Cambridge, Mass.)

Is it correct that your subjects were simply asked to 'increase their rate upon repetition', without regard to the AMOUNT of rate change?

MCCLEAN

Subjects were asked to speak at a rate which they judged to be twice as fast as normal. Some means of self monitoring could have been provided for the speakers, but it was felt that more natural utterances would be obtained without such monitoring. There is evidence suggesting that significant individual differences exist among speakers in terms of their ability to achieve specific increases in speech rate.