THE NUCLEAR STRESS RULE AND THE DESCRIPTION OF ENGLISH STRESS*

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1. PROBLEM

This presentation is a discussion of the correlation between syntactic structure and stress contours in American English. The problem was made more tractable within this framework by using the recent and well-known work of Chomsky and Halle described in *The Sound Pattern of English* (1968) as a point of reference.

Correlation has been sought between the output of the Nuclear Stress Rule (NSR) when applied to a right-branching syntactic structure and the fundamental frequency and intensity parameters in the speech wave. In other words: WHAT DO THE STRESS CONTOURS THAT ARE THE OUTPUTS OF THIS RULE MEAN IN TERMS OF THE PHONETIC FACTS?

Central in this presentation is an attempt to discover regularities in the aforementioned parameters that might lead to the formulation of rules that more adequately express the relevant factors in the correlation between surface structure and the speech wave.

2. EXPERIMENTAL PROCEDURES AND SPEECH MATERIALS

Special attention was given to the construction of the test phrases. The syntactic structure has been strictly defined and methodically expanded. Starting with a simple two-constituent tree 'big pants',a right branching tree was built up by expanding the construction to the left.

Figure 1 is a summary of the material used in this study presented in terms of its derivation. Sentence *A* represents the syntax in its longest form and below sentence *A* is the derivation of its stress contour through the cyclical application of the NSR. The phrases 1-7 below the stress level numerals are the phrases used as test utterances in this study. They are positioned so that the numerals above these sentences represent both a step in the cyclical derivation of the stress contour of sentence *A* and

* Read by Björn Lindblom.

SPEECH MATERIALS

Sentence A	He	kicked	the	cop	who	thought	that	Dick	should	have	bought	the	belt	for his	big	pants
Cycle 1		1		1		1		1			1		1		2	1
Phrase 1															big	pants
Cycle 2		1		1		1		1			1		2		3	1
Phrase 2												the	belt	for his	big	pants
Cycle 3		1		1		1		1			2		3		4	1
Phrase 3										He	bought	the	belt	for his	big	pants
Cycle 4		1		1		1		2			3		4		5	1
Phrase 4									Dick	should	have	bought	the	belt	for his	big	pants
Cycle 5		1		1		2		3			4		5		6	1
Phrase 5					He	thought	that	Dick	should	have	bought	the	belt	for his	big	pants
Cycle 6		1		2		3		4			5		6		7	1
Phrase 6				The	cop	thought	that	Dick	should	have	bought	the	belt	for his	big	pants
Cycle 7		2		3		4		5			6		7		8	1
Phrase 7 = Sentence A	He	kicked	the	cop	who	thought	that	Dick	should	have	bought	the	belt	for his	big	pants

Fig. 1. Speech material used in this study presented in terms of its derivation. Sentence *A* and the phrases 1-7 are positioned so that the stress level, numerals represent both a step in the cyclical derivation of the stress contour of sentence *A* and the final stress contours of phrases 1-7 which were used as test utterances.

the final stress contours of the test utterances. Mingograms were made of recordings of five readings of this material and fundamental frequency and intensity was measured.

3. RESULTS

Figure 2 is a summary of the average F_0 contours for all the test phrases considering only the stressed words. There seems to be no linear correlation here between the output of the NSR and the F_0 parameter in the speech wave. Chomsky and Halle's (1968) use of the numbers which represent stress level would indicate a greater degree of perceptual prominence in connection with higher level of stress. It is clear from Figure 2 that when we consider the NSR, prominence does not bear a 1-1 relation with F_0.

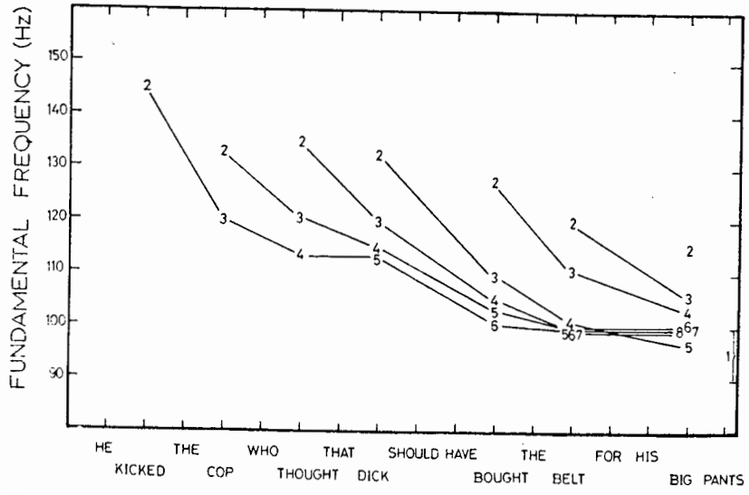

Fig. 2. Summary of the F_0 contours for all the test phrases with F_0 plotted as a function of the stressed words in the phrase.

Figure 3 shows a summary of the intensity contours considering only the stressed words. It is obvious that these curves are similar in some important ways to the F_0 data. As was the case for the F_0 curves in Figure 2 it appears difficult to discover meaningful correlation between the intensity patterns and the stress level contours which are the outputs of the NSR.

4. DISCUSSION

These data would be adequate motivation for us to systematically evaluate the NSR as a means of predicting acoustic parameters in the speech wave. In this evaluation,

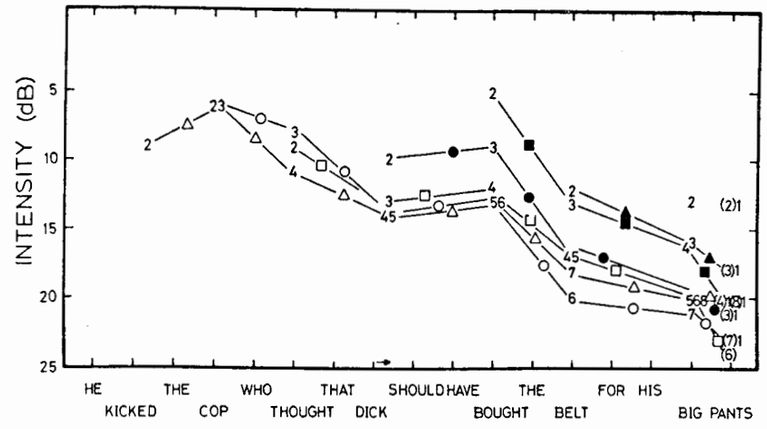

Fig. 3. Summary of the intensity contours for all the test phrases with the intensity values plotted as a function of the stressed words in all the phrases.

an NSR-based model for the prediction of the F_0 and intensity parameters in this study will be compared to an alternative model based on the number of stresses in a phrase and position of words in the phrase. In an NSR-based model, we must make use primarily of numerical outputs of this rule as a basis for predictions. A reasonable demand that may be placed on this rule is that it, through its stress contour outputs, show a correlation between the syntax (information the rule makes use of in its operation) and phonetic reality by predicting the parameters we have discussed in this paper. The capacity of the NSR to do so for the F_0 parameter is illustrated in Figure 4. This is a summary of observed F_0 values for each stress level including data for all the stressed words isolated and in context. It is immediately apparent that at least two problems are associated with the NSR-based model. First, there is no linear correlation between descending F_0 or intensity values and descending stress levels. The second problem apparent here is the spread of the data. The NSR-based model not only does not account for the spread, but perhaps more important, does not account for the obvious regularities in this spread. These two problems are also apparent in Figure 5, which shows the same type of summary for intensity as the previous one for F_0. Use of an NSR- based model for the F_0 and intensity patterns in this study would require considerable adjustments of the NSR outputs. These adjustments would be based on some of the same factors which an alternative model would make use of for prediction of F_0 and intensity such as the number of stresses and their position in the utterance.

Examination of the figure material presented in this study leads to the conclusion that it is possible to formulate rules that have quite different characteristics than the NSR. Instead of the syntactic information used by the NSR, it is possible to derive the F_0 and intensity values for the words in the test phrases by considering (1) the length of the phrase and (2) the position of the individual word in the phrase.

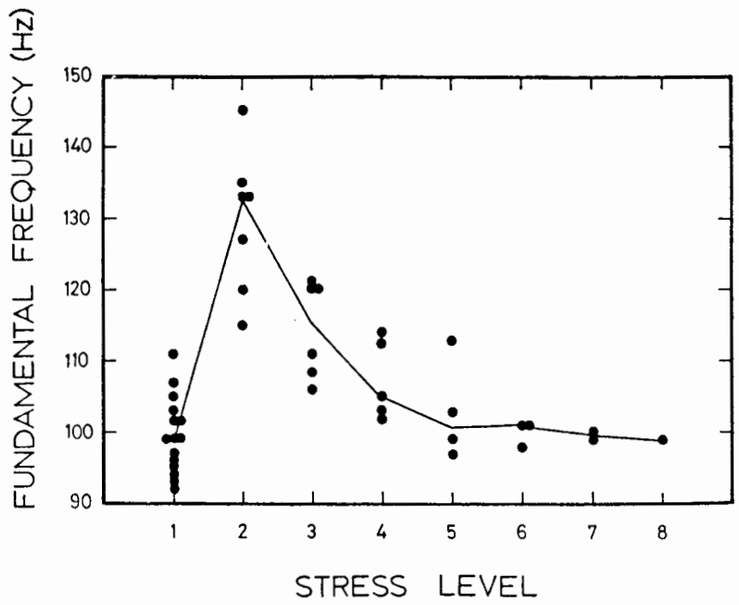

Fig. 4. A Summary of observed F_0 values for each stress level including data for all the stressed words isolated and in context. The line connects the median values for each stress level.

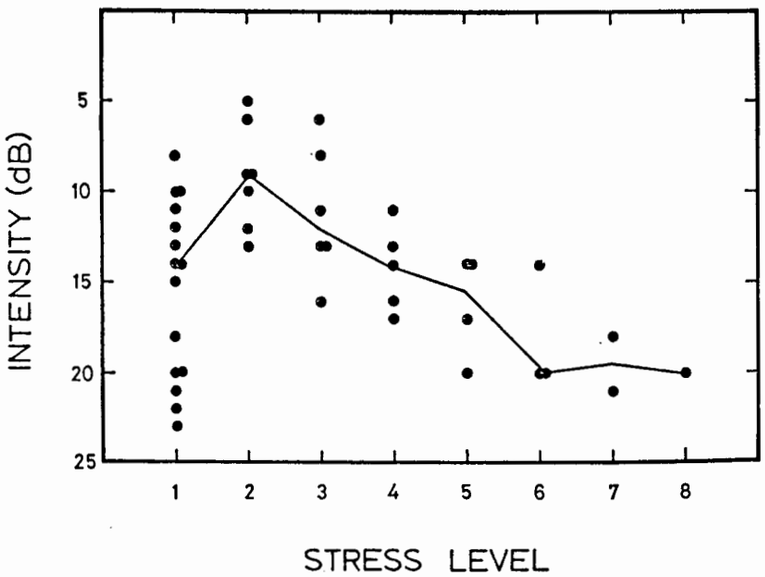

Fig. 5. A summary of observed intensity values for each stress level including data for all the stressed words isolated and in context. The line connects the median values for each stress level.

In Figure 6, observed values for F_0 have been plotted as a function of values predicted with formulas which utilize the number of stresses in the phrase and position of stress as variables. Figure 7 shows the same plot for the intensity parameter. It appears that these formulas display a reasonable degree of adequacy in prediction these parameters for the phrases in this study. The fact that these predictions can be made with only two variables, position and number of stresses, which in any case would have to be incorporated into the adjustments of NSR outputs to obtain equally satisfactory predictory capacity leads us to the conclusion that the NSR is, in fact, of no use in these predictions.

5. CONCLUSION

The preceding evaluation of the NSR raises the question of Chomsky and Halle's view of stress and the role of the phonetic representation expressed in *The Sound Pattern of English*. If the phonetic representation can be viewed as a set of commands

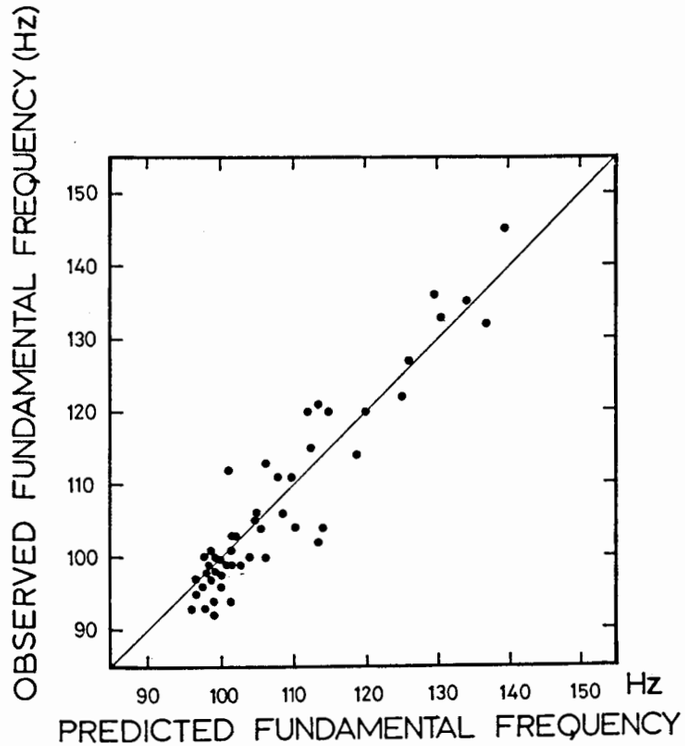

Fig. 6. Observed values for F_0 plotted as a function of values predicted with formulas utilizing number of stresses and position.

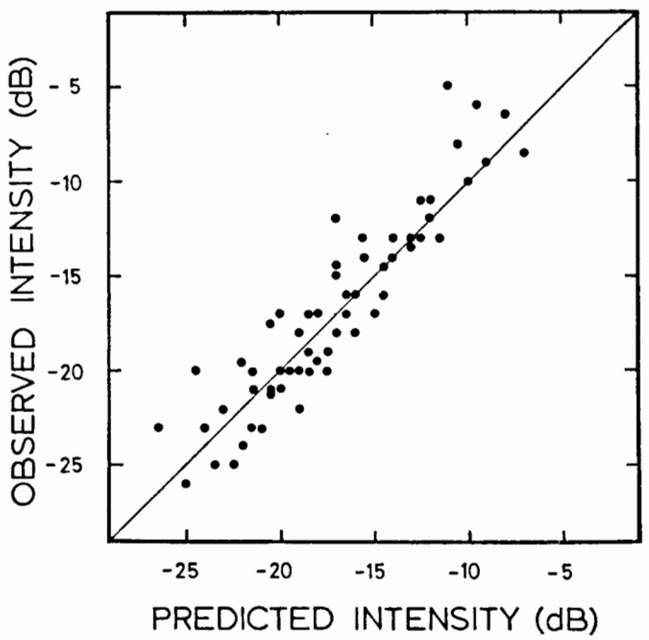

Fig. 7. Observed intensity values plotted as a function of values predicted with the formulas utilizing number of stresses and position.

to the speech mechanisms about the speech signal that is to be produced, and if rules, in this case the Nuclear Stress Rule, have outputs which are part of a phonetic representation which shows little correlation to the speech wave produced, we must, conclude that the demands of the phonetic representation must be better defined and that rules which give rise to this phonetic representation be accordingly formulated.

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REFERENCES

Chomsky, N. and M. Halle
1968 *The Sound Pattern of English* (New York, Harper and Row).
McAllister, R.
1971 "Predicting Physical Aspects of English Stress", *TL-QPSR* 1 (Stockholm).

DISCUSSION

WODE (Kiel)
Does McAllister's approach allow the specification of F_0 etc. for any morpho-syntactic string whatever, or is it limited to the set of examples contained in the

experiments? Furthermore, which information is used for assigning the F_0 peaks etc. correctly to the respective underlying morpho-syntactic material?

MCALLISTER
The answer to your first question is simply that we do not know yet. As regards the assignment of F_0 values, McAllister's rules presuppose information on the degree of stress, (stressed, unstressed) position of stress and the number of stresses per utterance.

COLLIER (Michelen, Belgium)
I would like to know whether the F_0-values are relative or absolute ones. It seems as if they are absolute. If that is the case, I would think it is quite unusual for absolute F_0 to be a good measure for the degree of stress.

MCALLISTER
The F_0 values are absolute. The reason for this is that the paper is based on material from one speaker. I think it is reasonable to suspect, however, that the overall F_0 and intensity patterns discussed in the paper have some generality since the utterances used seem to be regarded by native speakers as fully acceptable and prosodically neutral. If this is so, the absolute values could easily be replaced by constants in the formulas so that the same general contours can be predicted.

As to the question concerning absolute F_0 as a measure of degrees of stress I am not sure I understand the question. It was not my purpose to show that, say, 140 Hz should be considered stress level 2 and 90 Hz level 8. To argue that such an assignment of F_0 value to stress level would show any relevant linguistic generality would be unusual indeed. As a general rule of English, the NSR should be applicable to one speaker. The discussion here concerns the investigation of what relation the numerical outputs of the NSR have to the F_0 contours (expressed in absolute values) of this speaker.