

WEAK SYLLABLES IN A PRIMITIVE READING-MACHINE ALGORITHM¹

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Weak syllables are not simply the lowest level of stress, the bottom of the prominence heap, in this version of mechanical American English. Weak syllables are, rather, a distinct syllable-type, even though that type is metaphorically a minus paralleling the plus of stressable syllables and the interlying zero of plain syllables. The machine works with *syllable-types* rather than *levels of stress*. Or, to put it yet another way, syllable-types are used to implement what is to be heard as English stress and its various kinds of absence.

In particular, syllable-types are used in two compartments (or stages) of the machine: the pronouncing dictionary and the phonological string assembled from it. The syllable-types are slightly different in each. Syllable-types are illustrated in the first section of this paper and examples of weak-syllable transfers from dictionary to phonological string are presented.

The phonological string of the machine is a hierarchical structure of segmentals, syllables, phonological-words and phonological-phrases (Cf Pike, 1943, 1967²). In the second section, examples will be given of how weakened syllables help to shape the phonological-word and set off its boundaries.

Between the two sections a brief interlude will characterize the machine itself of which dictionary and phonological string are parts.

Section I

Weak syllables start out as one kind of syllable in a pronouncing dictionary of print-words. For example, the last syllable of the pronunciations of the following print-words are *weak*: "soda, city, window, Hindu, beater, beetle, bottom, cotton, rotting".

There are two other kinds of syllable in the dictionary *stressable* and *plain*. For example, the first syllable of all the print-words just cited above are stressable. Some print-words include two or more stressable syllables in their pronunciations, e.g., both syllables of "sardine, pastel" and the first and third syllables of "intonation, California". Examples of *plain* syllables, the middle level, are the first syllable of "ideal" and of "psychology" and the last syllable of the verb (but not the noun) "veto" and of "telephone". Plain syllables in the machine are, so to speak, those which merely hold their own. They do not take stress, much less accent, nor do they submit to gradation or neutralization. Finally, plain syllables do not set off the (different) contextual length changes that weak and stressable syllables may

When pronunciations from the dictionary are assembled into a phonological string, syllable types may change. This is shown schematically in Figure 1. All stressable syllables may be realized as stressed or as plain. And a very few stressable syllables may be realized as weakened. All weak syllables may be realized as weakened, some as plain. None will be stressed. Plain syllables are realized only as plain.³

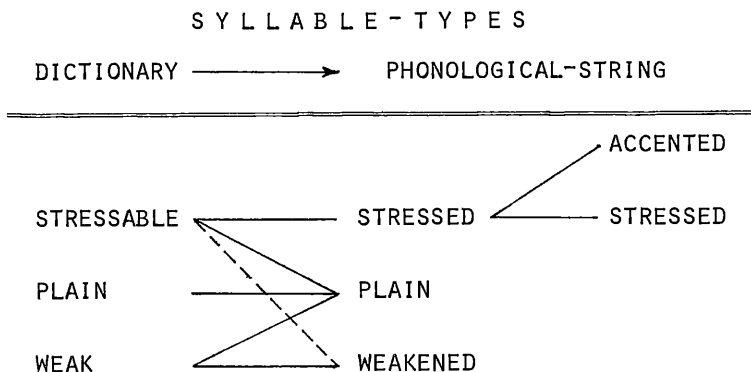


Figure 1

The dashed line from stressable to weakened, which breaks a certain symmetry, represents the operation of often called gradation, as it applies to certain mono-syllabic structural words, e g , "of, at, do" ⁴

For ease of exposition it will be useful to have a cover term for non-weak or non-weakened syllables *Full-syllable* will be the label that includes either stressable and plain or stressed and plain

Weakening operations carry dictionary syllables into weakened syllables of the phonological string Typically, consonant segmentals that come together in clusters at print-word boundaries are smoothed out This may be by reduction (i e , dropping) or by altering component features. For example, the print-word "miss" is stored with the citation pronunciation ['mɪs] and the print-word "you" with ['juː] Yet the print-word sequence "miss you", particularly in a larger context such as "I'm going to miss you a lot", will give the phonological string fragment 'mɪʃw This assembled fragment is quite similar to the dictionary representation of the single print-words "tissue" and "issue"

Weakening operations that touch dictionary vowels (syllabics) often result in mergers (neutralization) For example, the syllable-centers of the dictionary weak-syllables of "windows" and "Hindus" merge into a single tamber when those weak syllabics turn up in various non-final contexts, such as

All the windows are here 'ɔlðə'wɪndwzr'hɪr//

All the Hindus are here 'ɔlðə'hɪndwzr'hɪr//

Whereas in various final contexts, the syllabics of these print-words are quite distinct (and in the example below the dictionary weak syllables have been assembled as *plain* syllables)

Here are all the windows 'hɪrɪ'ɔlðə'wɪn,dəwz//

Here are all the Hindus 'hɪrɪ'ɔlðə'hɪn,dʊwz//

In natural speech the merged syllabic w would have a tamber-range overlapping part of full-syllable u , u^{w} and perhaps o^{w} .⁵

Similar contexts cue the merger of dictionary vowels Δ and i . For example, the print-words "him" and "them" are indistinct in:

I can see him now

'a^vk_o's_iv_m'na^w//

I can see 'em now

and are distinct in

Now I can see him

'na^w, a^vk_o's_iv, i_m//

Now I can see 'em

'na^w, a^vk_o's_iv, Δ_m//

In the end, the list of weakened syllabics (vowels) in non-final position in the assembled phonological string is $\text{ə} \text{v} \text{w} \text{r} \text{l} \text{m} \text{n} \text{ŋ}$. For this and other reasons it has from time to time been proposed that weak syllable-centers are best taken as forming a separate system apart from the larger, main system of full-syllable vowels (e g, Hultzén, 1961, Bolinger, 1963), or that they are positional variants of the sonorant consonants (e g, Householder, 1957). In the reading-machine, however, it proves useful to have just one set of syllabics (vowels) and to have the syllable as a whole marked for its type.⁶

Machine Interlude

With this much of a sketch of weak syllables and weak syllable operations, the reading-machine itself can be characterized in general terms. It is an *algorithm* and a *machine* in the sense that it is a series of computer programs. It *reads* in the sense that it, together with the hardware attached to it, converts strings of print representations into an acoustic signal that is a simulation of speech. Finally, it is *primitive* in that a human editor is asked to intervene at one point to add information that is not available automatically.⁷

Schematically, the machine moves from print-text to synthetic speech in two large steps, as shown in Figure 2. First, the print-text is turned into a phonological string, then the phonological string is converted into parameter-frames that drive an electronic synthesizer, the output of which is an audio signal that can be heard as speech.

The first step converts the print-text into a phonological string. This involves chunking the print-text up into print-words, then replacing the print-words by their dictionary pronunciations, and then re-assembling the text. At the end of this first step, the text appears in a phonetic notation where originally it stood in ordinary English spelling.

Re-assembling the text after the dictionary look-up is a procedure of some complication. The vowel mergers and consonantal simplifications suggested in Section I above are an important part of re-assembly. The dictionary look-up, by contrast, is quite simple. The dictionary is presented with an orthography, such as "cat", whereupon it returns ['kæt] plus the tag for open-class words. In this way the dictionary provides the segmental phonemes and the basic syllable structure of the phonological string. The rest is up to the editor. He marks for phonological-words and -phrases, and, since these carry the intonation, the intonation. The editor is thus standing in for what appears to be a syntactic, semantic analysis of the print-text. He is also carrying out certain independent phonological decisions.

Section II

This section outlines an operation called compression, full-syllable compression, and it is an adjustment of durations. The units to be adjusted are full-syllables, both stressed and unstressed, and the essential context for the adjustment is provided by weak-syllables and phonological-word boundaries.⁸

Other things being equal, the most powerful of the interdependent cues for prominence is generally taken to be literal length—duration in time (Fry, 1970).

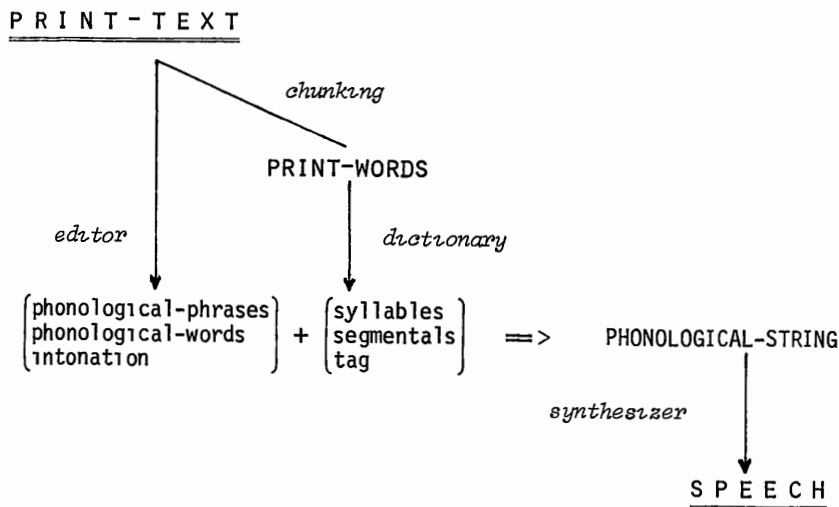


Figure 2

Compression has the curious effect of making a full-syllable salient by shortening its duration. The most complete description of this effect has been given by Bolinger (1963, 1965).

Consider a phrase consisting entirely of full syllables, that is, devoid of weakened syllables

'YOU ,MAKE 'BILL ,LOOK 'GOOD //

It is generally possible to insert a weakened syllable into such a phrase with absolutely no increase in overall phrase duration. In fact the new phrase is just as long as the original. The definite article "the" will do for insertion. It gives:

'YOU ,MAKE THE 'BILL ,LOOK 'GOOD //

The indefinite article and certain possessives, all as weakened syllables, do the same

'YOU ,MAKE A 'BILL ,LOOK 'GOOD //
HER

Inserting a full-syllable rather than a weak-syllable does not give the same result. The phrase becomes not only longer in segmentals and syllables, it also becomes longer in total duration. The demonstrative "that" will do for full-syllable insertion. It gives

,YOU 'MAKE ,THAT 'BILL ,LOOK 'GOOD //

When a weak-syllable is inserted, something in the original phrase is compressed to make room for it. When a full-syllable is inserted, this compression does not occur. What gets compressed when a weak-syllable is inserted is the full-syllable to the *left* of the weak-syllable. In these examples, this is the print-word "make" - it is compressed in the fragments "make the bill, make 'er bill, make a bill", "make" stands at its normal length in the fragments "make bill, make that"

Bolinger is at pains to point out that compression or its absence is independent of I(mmediate) C(onstituent)-cuts. The articles, demonstrative and possessives go syntactically with the next item to the *right*, the print-word "bill" - "a bill, the bill, that bill, her bill". As weak (and then weakened) syllables, they nonetheless compress the syllable to the *left*, "make". In short, compression is determined phonologically rather than syntactically.

Compression is obligatory in the sense that failure to compress a full-syllable in this context tends to give a stage (stereotyped) Scandinavian accent, and pronunciation guides intended for Scandinavian learners of English often explicitly point out this potential stumbling-point (e.g., Lewis, 1969 50-51). Full-syllable compression is obviously no language universal, and this suggests that it is not even a universal for

languages that have stressed syllables, as do the Scandinavian.

By way of parentheses, it is worth noting a possible articulatory explanation for full-syllable compression Ladefoged (1962), attempting to correlate intercostal muscle activity with Stetson's chest-pulses, noted that certain syllable sequences may be articulated on a single burst of intercostal activity, even though the usual pairing is one chest-pulse/one syllable. He cites the word "pity" as an example, and the word "doddered" in his Figure 3 appears to have been articulated this same way.

To put it metaphorically, a full-syllable in English attempts to include an immediately following weak-syllable, include it in the same production gesture. There is, perhaps, a parallel with syllable-closing consonants which are also not in their most natural place at the end of a syllable. Consonants naturally begin syllables. In this sense, both syllable-final consonants and included weak syllables would be unnatural phonological structures, and of course both shorten the segmental substance that precedes 'in the same syllable'.

What is the magnitude of compression? Lehiste (1971) has published measurements in phrase-final position, i e , where compression is combined with phrase-final length adjustments (and those of intonation as well). She compared pairs such as "stead", a full-syllable, with "steady", full-plus-weak. In this position, with such pairs, the single syllable actually averages out longer in duration than the whole compressed sequence. Not all components were equally compressible. The full vowel is most amenable to compression. Differences between regular and compressed vowel lengths are somewhat greater than two to one. The leading consonants are most resilient, though nonetheless affected. Every element in the compressed syllable is compressed to some degree.

Bolinger maintained that compression is independent of IC-cuts, i e , independent of the syntax. In a British tradition, compression is treated as a

correlation between the lexicon and the phonology Abercrombie (1964) has given an exposition from this point of view In the Received Pronunciation of British English, he notes (or perhaps declares -- see Uldall, 1966, 1971) that the spacings between stressed-syllable onsets are "of (approximately) even length" RP stresses are isochronous Yet given the roughly constant durations between stressed onsets, the included segmental material may be divided over the available time in different ways Here he gives the classic contrast:

take Grey__to London vs take Greater__London

In the phrase on the left, Abercrombie stated that the relative lengths of the syllables "Grey" and "to" are on the order of two to one, whereas in the single word "greater" the relative syllable lengths are on the order of one to one For a comparable contrast with the segmentals of American English, there is

the rush__and turmoil vs the Russian__turmoil

In sum, full-syllable compression on the left-hand side of these contrasting pairs has been blocked by an immediately following word-boundary So an effective cue for the presence of this word-boundary would be the sequence full- plus weak-syllable with an uncompressed full-syllable

Abercrombie wanted to relate (what I call) compression to the lexical composition of the phrase Certain structural words (proclitics in the examples above "to, and") are not independent words at all they merge phonologically into their neighbors But this way of looking at things as lexically determined, apparently leads to overlooking yet a third possible way of distributing the same segmental material between two stressed onsets, to wit with no included phonological word-boundary at all

The contrast of presence vs absence of phonological word-boundary between two stressed onsets is demonstrated by Pike (1945 37 and 1967 385) with two versions of the print-phrase "a book of stories"

a book_of stories vs a book of stories

Since Pike actually recorded these examples when the earlier book appeared, it is possible to measure his segmental durations. The difference in compression is as clear to the tape measure as it is to the ear. The full-vowel of "book" followed by the boundary is about twice as long as the same full-vowel followed immediately by the weak-syllable "of". But the up-shot of this, is that the absolute durations between stressed onsets in these two versions of "a book of stories" are distinctly different. At this level of detail, at least, English is *not* literally isochronous. In fact, a phonological word-boundary gives what Householder (1957) calls "a significant rhythm break" and if that is so, we would expect the different overall durations we do indeed find.

So a third version of the Abercrombie and American examples is possible, this time without any included phonological word-boundary, and it will be not only shorter in total duration, but lexically ambiguous as well.

take Grey to London = take Greater London
 'teʷk'greʷtə'lʌndŋ// = ,teʷk'greʷtə'lʌndŋ//

and

the rush and turmoil = the Russian turmoil
 ðə'rʌʃŋ'tɜ,moʷl// = ðə'rʌʃŋ'tɜ,moʷl//

I suspect this is the usual way of saying these phrases when the print-words "greater" and "Russian" are used, despite the ambiguity.

Now to these versions, let me immediately add yet a fourth in which the weak-syllable previously included is left out. Over the fragment of interest, we will now have stressed-plus-stressed, where before we had stressed-plus-weakened-plus-stressed. Some of these truncations will be nonsense sequences, but no matter

take Grey__London
the rush__turmoil
a book__stories

The uncompressed syllables "Grey, rush, book" followed by phonological word-boundary here are quite comparable in length to their other occurrence followed by phonological word-boundary:

take Grey__ to London
the rush__and turmoil
a book__ of stories

To put it another way, when compression is blocked by a phonological word-boundary, the on-going calculations for segmental durations would be caught up to that point. There do not seem to be durational dependencies of this kind running over the phonological-word boundary.⁹

Summary

Pronunciations from a dictionary look-up on a print-text are reassembled into a phonological string which is then converted into synthetic speech. The phonological string is a hierarchical structure based on segmental phonemes which are grouped into syllables, phonological-words and phonological-phrases by boundary marks inserted among the segmentals. Full-syllables are marked where they begin, words and phrases, where they end. Weak-syllables are taken to have no inherent boundaries at all. They may be 'included' in adjacent full syllables by effects of compression and neutralization which simultaneously give the including phonological-word characteristic features of its prominence silhouette.

NOTES

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² What are called *phonological-words* here are called *total contours* in Pike (1943) and *stress groups* in Pike (1967) What are called *phonological-phrases* here are called *rhythm units* in Pike (1943) and *pause groups* in Pike (1967). What are called *weakened syllables* here are tentatively called *ballistic syllable types* in Pike (1967 368-369).

³ The three syllable-types in the dictionary correspond to the three stress levels posited by Newman (1946) if one moves Newman's *sonorous weak* in *pre-heavy* position to reading-machine *plain*. Component features that would define the four types in the phonological string could correspond with the first three suprasegmental features of Vanderslice and Ladefoged (1972) plus or minus *heavy, accent, intonation* Correspondences can be made with other three- and four-way systems

⁴ See, for instance, Kenyon (1950 104-114) and Gimson (1964 239-243)

⁵ See, for instance, Kingdon (1969 10) and Bolinger (1963 22)

⁶ The notational convention is that full-syllables are marked where they begin, while phonological-words and -phrases are marked where they end. (Weak and weakened syllables are not considered to have boundaries of their own at all) By this means all distinctions of the kind "gray day" vs "grade A" and "a nice .." vs "an ice " are automatically assembled. See Jones (1931, 1956), Lehiste (1960), Hoard (1966), Lee (1970)

However, this style of marking also requires that the syllable-centers of "hot" and "heart" be written with different symbols. This is because the full-vowel of "hot" may, in the assembled string, be followed by r and then a weakened syllable It must still remain

distinct from the full-vowel of "heart" plus r plus weakened syllable A test-pair would be

bas__relief vs bar__a leaf

which I just pronounced with phonological word-boundary When the boundary is omitted (with concomitant full-syllable compression to the left, see Section II below), the phrases are still distinct

bas-relief ≠ bar a leaf
'barə'lɪv f// ≠ 'barə'lɪv f//

Similarly

paw repair ≠ pour a pair
'pɔrə,pɛr// ≠ 'pɔrə,pɛr//

It is nonetheless possible to write the syllable-center of "bird" either as a unit or as a sequence of wedge (or shwa) plus r Full-syllable wedge will never be followed by r in this kind of American English, but weakened syllable shwa plus r may occur at print-word joints When it does, it will not contrast with syllabic r in a weakened syllable A test-pair, with phonological-word boundary included, would be

rows__are applied vs Rosa__replied

When the boundary is omitted, the two print-word sequences are indistinct.

'roʷzrə'plavd// = 'roʷzərə'plavd//

Other sequences of weakened shwa plus sonorant are taken as equivalent to the syllabic sonorant alone

⁷ This characterization of the machine is not only general, it is idealized In particular the introduction of the *editor* can be taken as an expository device

⁸ What are called *phonological-word boundaries* here are called *intonation breaks* in Pike (1945) See also

the discussion of Solutions A, B, and C in Pike (1967 405-409).

⁹ Phonological-word boundaries are independent of lexical word-boundaries, though they frequently coincide. It is to be noted that a phonological-word boundary may appear in the middle of a single lexical item, provided the item is realized with two stressed syllables. Any multistressable word will lend itself to this kind of realization and no more so than in ultra-careful citation form: Thus we have double-stressed versions, with included phonological-word boundary, of "sardine" and "absolutely"

'sar_ 'dɪʒn//

'æbsə_ 'luwtly//

Double-stressed versions without phonological-word boundary.

'sar'dɪʒn//

'æbsə'luwtly//

The most usual versions retain only the last dictionary stress

,sar'dɪʒn//

,æbsə'luwtly//

(See Pike, 1945 77.)

Berger (1955) notes several examples, particularly from advertising and comic strips, where this incipient ambiguity among print-words and print-phrases has been exploited. "Chip 'n Dale, Etta Kett, K-9 Corps", etc. A phonological-word boundary is presumably more likely than not to correspond to a lexical boundary, just as a consonant is more likely to begin a syllable than is a vowel. Absolutely, however, the occurrence of a consonant does not establish a syllable-boundary and the occurrence of a phonological-word boundary does not establish lexical boundary. In this sense the phonology is independent of the lexicon, though closely related to it.

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