Weak Syllables in a Primitive Reading-Machine Algorithm

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ABSTRACT

Weak syllables are syllable types in the pronouncing dictionary of the reading machine. Weakened syllables, in the output string of the machine, come either from weak dictionary syllables or from full dictionary syllables that have been subjected to gradation. In either case, weakened syllables are further subject to certain mergers and may exhibit special segmental allophones. Weakened syllables of all kinds may also condition shortening of the full syllables they immediately follow. This compression seems to come from a kind of inclusion of the weak syllable by the full syllable. It does not occur across phonological word boundaries and by this fact helps to identify phonological word boundaries in the output.

Weak syllables, in this version of mechanical American English, are a special syllable-type which, among other things, typically comes to carry the lowest level of stress and so ends up at the bottom of the prominence heap. But weak and weakened syllables are also terms involved in a number of key operations, among which are gradation, certain neutralizations, and the selection of special segmental allophones. Finally, weak syllables condition a noticeable compression of full syllables they immediately follow. The absence of such compression, when a phonological word boundary intervenes, is a strong cue for the presence of the word boundary.¹

In Section I of this paper syllable-types in the machine will be outlined and the operations of gradation, neutralization, and allophone selection will be identified. In Section II the shortening effect of weak syllables on full syllables will be explored. Between the two sections a brief interlude will characterize the machine itself including the pronouncing dictionary and phonological string, of which weak and weakened syllable-types are parts.

¹The phonological string of the machine is a hierarchical structure of segmentals, syllables, phonological words, and phonological phrases (cf. Pike, 1945, 1967). What are called phonological words here are called total contours in Pike (1945) and stress groups in Pike (1967). What are called phonological phrases here are called rhythm units in Pike (1945) and pause groups in Pike (1967). What are called weakened syllables here are among those tentatively called ballistic syllable-types in Pike (1967:368–369).
SECTION I

Syllable Types

In the pronouncing dictionary of the machine, phonetic entries are made up of combinations of three types of syllables. Weak, as a syllable-type in the dictionary, is illustrated by the last syllable of the following print-words: "soda, city, window, Hindu, beater, beetle, bottom, cotton, rotting." The other two types of syllable in the dictionary are stressable and plain. Stressable syllables are illustrated by the first syllable of the print-words in the list just given. Plain syllables are those which never take stress (much less pitch-accent), on the one hand, and, on the other, are not subject to mergers (neutralization); nor do they condition full syllable shortening. Illustrations of plain syllables are the first syllables of "ideal" and of "psychology" and the last syllables of the verb "veto" (but not the noun) and of "telephone." In sum, plain syllables—"ideal, telephone"—will never be stressed in any text occurrence; neither will they be degraded, that is, replaced by schwa or a weak syllabic sonorant.

It is to be noted that each print-word pronunciation in the dictionary contains at least one stressable syllable and that some pronunciations contain two or more stressable syllables. Examples of multistressable print words are "sardine(s)" and "pastel(s)" (both syllables) and "intonation" and "California" (first and third syllables). In citation pronunciation, because it means end-of-phrase, the last stressable syllable in a multistressable word would normally be stressed (and get the pitch accent): "(can of) sardines," "(box of) pastels," "intonation," "California." Within a phrase, an earlier stressable syllable may be stressed: "sardine sandwich," "pastel picture," "intonation contour," "California sunshine." The number of weak or plain syllables in a dictionary pronunciation has no upper or lower limits.

The distinction between stressable and stressed is thus one between dictionary pronunciation—stressable—and phonological string pronunciation—stressed. In the dictionary, stress is a potential of certain syllables; the stressable, a potential which may or may not be realized in some occurrence in a phonological string. A similar distinction applies to weak syllables in the dictionary and actually weakened syllables in the phonological string. By contrast, plain syllables in the dictionary carry over only into plain syllables in the phonological stress string. Figure 1 shows the possibilities.2

Gradation

The dashed line from stressable to weakened, which breaks a certain symmetry in Figure 1, represents the working of the operation called gradation.

2 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.
Gradable syllables in the dictionary may be realized as stressed, plain, or weakened in the phonological string. By contrast, most stressable syllables may be realized only as stressed or plain. Gradation applies to a small number of monosyllabic structural words, such as "of," "at," "do." Only some four dozen dictionary words are subject to gradation, but they are all very frequent text words. When a gradable syllable does appear in weakened form, it behaves like weakened syllables which come in the usual way from dictionary weak syllables: a syllable weakened by gradation is just like any other weakened syllable.\(^3\)

For ease of exposition, it is useful to have a cover term for nonweak or nonweakened syllables. Full syllable will be the label that includes stressable and plain, or stressed and plain syllables.

**Allophone Selection**

When print words are strung together, consonant segmentals may come together at print-word boundaries. These consonant clusters may be smoothed out by reduction (dropping) or by altering component features when the syllable-type sequence over the print-word boundary is full-plus-weak. For example, the print word "miss" is stored in the dictionary with the citation pronunciation ['mɪs] and the (gradable) print word "you" with ['yu\(^]\). Yet the print-word sequence "miss you," particularly in a larger context, such as "I'm going to miss

\(^3\)See, for instance, Kenyon (1950:104-114) and Gimson (1964:239-243).
you a lot," will give the phonological string fragment ['mɪʃw]. This assembled fragment is quite similar to the string representation of the single print word "issue" ['ɪʃw] in the same context: "I'm going to issue a lot." It will be seen that the print-word boundary in the vicinity of the (de)graded and weakened syllables of structural words may be heavily camouflaged.

A number of single consonants have special allophones in the position between full and weak syllabics ("intervocalic position"); for example, [t, d] are flapped and [g] appears as a fricative. The special allophone is selected regardless of where the print-word (lexical) boundary falls. For instance, the fragment [meʊdŋ] can represent the first two words of "made in France," with print-word boundary on the right-hand side of the [d], or it can represent the entire word "maiden" with no print-word boundary at all abutting the [d]. Similarly, the fragment [biʊkn] could represent all the print-word sequences, "beacon," "bee can," "beak and," embedded in some larger context. (This is not to say that the print-word sequences cannot be distinguished, but rather that they may not be.)

Neutralization

Syllables may also be weakened—carried into the phonological string as weakened syllables—by neutralization or merger of syllable-center tambers. For example, the syllable centers of the dictionary weak syllabics of "windows" and "Hindus" merge into a single tamber when those weak syllabics turn up in various nonfinal contexts, such as:

All the windows are here. 'ɔləʊ'wɪndwɜːr'hr//
All the Hindus are here. 'ɔləʊ'hɪndwɜːr'hr//

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. 'hrr'ɔləʊ'wɪn,dəz//
Here are all the Hindus. 'hrr'ɔləʊ'hɪn,dəz//

In natural speech, the merged syllable [ʊ] would have a tamber range overlapping part of full syllable [u, u*] and perhaps [ow]. In sum, the allophone range of certain weakened syllabics differs from the corresponding full vowel range.

Similar contexts cue the merger of dictionary vowels [ʌ] and [ɜ]. For example, the print words "him" and "them" are indistinct in:

I can see him now. 'aʊkn'siʌm'naʊ//
I can see 'em now. əm'naʊ//

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4 A small circle below a letter has been used to indicate a weakened-syllable center: [ə y w r ɪ m n ʊ]. Alternatively (and equivalently), the same weakened-syllable centers could be written schwa or schwa plus sonorant consonant: [ə oy aw ar al am an ag].

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

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and are distinct in:

Now I can see him. 'na"a,avkn'si,y,rm//
Now I can see 'em. 'na"a,avkn'si,y,am//

In the end, the list of weakened syllabics (vowels) in nonfinal position in the assembled phonological string is ə ə ə ə ə ə ə. 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., Hultzen, 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

6 The notation convention for marking syllable types 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" versus "grade A" and "a nice ..." versus "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 can be held separate when pronounced with phonological word boundary at the points shown. 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'i⁶'f// # 'barə'i⁶'f//

Similarly, with phonological word boundary omitted:

Ma renewed # mar a nude
'marə'nu⁷'d// # 'marə'nu⁷'d//

and also:

paw repair # pour a pair
'poɾə,peɾ// # 'poɾə,peɾ//

It is nonetheless possible to write the syllable center of "bird" either as a unit—[ə]—or as a sequence of wedge plus [r]—[ər]—with no contrastive difference. Full-syllable wedge will never otherwise be followed by [r] in
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 the sense that a human editor is asked to intervene at one point to add information that is not available automatically.  

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 reassembling the text. At the end of this first step, the text appears in a phonetic notation where originally it stood in ordinary English spelling.

Reassembling 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 reassembly. 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.

This kind of American English. Schwa plus [r] may occur in weakened syllable at print-word boundary joints. When this happens, schwa plus [r] 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 phrases fall together and are indistinct:

'r0wzɔrˠə'plaɪd//' = 'r0wzɔrˠə'plaɪd//'  

and in other such instances, sequences of weakened schwa plus sonorant are taken as equivalent to the syllabic sonorant alone.

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.
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 interdepending cues for prominence is generally taken to be literal length: duration in time (Fry, 1970). 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:

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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).
'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 parenthesis, it is worth noting a possible articulatory explanation for full-syllable compression. Ladefoged (1962), attempting to correlate intercostal muscle activity with Stetson's (1951) 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, that is, 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 (1963) maintained that compression is independent of IC-cuts, independent of the syntax. In a British tradition, compression is treated as a correlation between the lexicon and the phonology. Abercrombie (1965) has given an exposition from this point of view. In the R(ceived) P(ronunciation) 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 classical 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 is here called) 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 versus absence of phonological word boundary between two stressed onsets is demonstrated by Pike (1945:37, 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 upshot 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:

\[
\begin{align*}
\text{take Grey to London} & = \text{take Greater London} \\
'te\,k\,g\,r\,e\,y\,t\,o\,l\,a\,n\,d\,n// & = ,t,e\,k\,g\,r\,e\,y\,t\,o\,l\,a\,n\,d\,n// \\
\end{align*}
\]

and

\[
\begin{align*}
\text{the rush and turmoil} & = \text{the Russian turmoil} \\
\delta\alpha'r\,a\,f\,n\,t\,o\,m\,v\,l// & = \delta\alpha'r\,a\,f\,n\,t\,o\,m\,v\,l// \\
\end{align*}
\]

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 can be immediately added 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:

\[
\begin{align*}
\text{take Grey London} \\
\text{the rush turmoil} \\
\text{a book stories} \\
\end{align*}
\]

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:

\[
\begin{align*}
\text{take Grey to London} \\
\text{the rush and turmoil} \\
\text{a book of stories} \\
\end{align*}
\]

To put it another way, when compression is blocked by a phonological-word boundary, the ongoing 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.  

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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
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.

REFERENCES


is realized with two stressed syllables. Any multistressable word will lend itself to this kind of realization and no more so than in ultracareful citation form. Thus we have double-stressed versions, with included phonological-word boundary, of "sardine" and "absolutely":

'sar-di\n // 'æbs\l\u\'t\l\i\n
and double-stressed versions without phonological-word boundary:

'sar-di\n // 'æbs\l\u\'t\l\i\n
The most usual versions retain only the last dictionary stress:

'sar-di\n // 'æbs\l\u\'t\l\i\n
(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.