The experimental investigation of syllable structure

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This paper is a selective state-of-the-art report on a variety of issues related to the adoption of experimental methods to the study of syllable structure. The rationale for an experimental approach is presented in the first section, followed by a brief section on of some of the main theoretical issues involved. Section three then presents a recap of the most important empirical findings, focusing on the key factors involved, rather than the details of the specific results. Section four then presents an illustrative case where the experimental results seem to conflict, along with discussion of some of the factors that are likely responsible for this. Finally, in the last section, an appeal is made for a deeper theoretical perspective than the one that has guided research in this area heretofore.

Keywords: syllable structure, psycholinguistics, phonology, word segmentation, mora, onset-rime, body-coda, syllabification, ambisyllabic, pause-break task

The syllable is widely recognized as a viable phonological unit in most languages, although its status as an absolute substantive universal has been questioned. Even if present in all languages, its importance or salience seems to vary widely from one language to another. Experimental research has also raised questions about the kind of mental model that is appropriate for syllables. For the most part, however, syllable structure research has proceeded apace, taking the familiar constituent hierarchy ("tree diagram") as the basic working framework.

As with most areas of linguistic inquiry, the great bulk of research on syllables has been purely descriptive or theoretical in nature, focused largely on the details of what have come to be known as the "primary linguistic" or "internal" data, i.e., data about the (spoken) forms of language and their distribution (i.e., the language product). After several decades of the free-wheeling kind of theoretical speculation that this environment has engendered, the result has been a

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vast proliferation of theoretical concepts and representational structures,[1] many of which directly conflict with one another (see, for example, the five models of syllable-internal structure summarized in Blevins' 1995 survey, p. 212), but with no empirical means of deciding between them.[2]

We see this result as a consequence of doing structural analysis in the absence of a clear view of the ontological status of the concepts and structures that emerge from this analysis. Put another way, and despite frequent claims to the contrary, most theoretical linguistic accounts are not truly cognitive in orientation, but rather deal with linguistic units and structures as abstract concepts, treating language as a system that is "out there" somewhere, but whose components are undefined in any kind of accessible empirical space.[3] It is precisely this approach that has led to the repeated dead ends and constant retooling that theoretical linguistics finds itself faced with.

However, if linguistic constructs are to be conceived as something more than vague abstractions, relevant only to those members of the linguistic community who speculate about them, what kind of reality might structural units like the syllable, the segment, the rime, the body, or the mora (to name just a few) actually represent? Since all are linked to the stream of speech in some way, it is tempting to think that such notions might all have definitions in the physical realm; however, all attempts to accomplish this have failed, even in the case of the lowly segment (i.e., speech sound), as noted, for example, by Liberman (1970), who points out that the acoustic information that cues an individual segment is often distributed over a broad range of the stream of speech, or concentrated in a very narrow range for several segments (cf. Mehler et al. 1981: 298). And if not even the segment can be isolated from the stream of speech, what hope do any of the higher-order units have?

The inescapable conclusion that we experimental linguists have drawn is that if linguistic structures have any reality at all, this reality must be psychological in nature.[4] Put another way, linguistic entities such as segments and syllables have

1. As Blevins (1995: 234) aptly notes, models of syllable-internal structure (and the like) "are almost as numerous as the researchers working on these topics."

2. Many attempts have, of course, been made on the basis of various "evaluation metrics" (usually involving some notion of simplicity or generality), but these can readily be seen to be arbitrary rather than empirical in nature.

3. As Watt (1974: 32) confesses, "The truth is that the 'mentalism' of most of us generativists is as irrelevant to our linguistic practice as our taste in movies."

4. This is not at all a novel idea. Consider Saussure (1915 [1959]: 6): "Everything in language is basically psychological, including its material and mechanical manifestations, such as sound changes…."

reality only to the extent that real speakers attribute reality to them. Thus a phonetic segment might be real to a speaker not because the stream of speech actually contains a well-defined discrete unit of this kind (though it does, as already noted, provide complex, discontinuous cues for a hearer to interpret), but rather because the speaker-hearer perceives such a unit to be there. And the same is true, of course, for all higher-order entities such as the syllable, the rime, the mora, and all the rest, right up to the word, phrase, clause, sentence, etc. that morphologists and syntacticians concern themselves with (see Derwing 1973: 305–307, and 2007: 325–328, and Derwing and Almeida 2009: 234–237, for further discussion of this important issue).

From this perspective, therefore, the motivation for an experimental psycholinguistic approach is obvious and double-faceted: As part and parcel of asking whether a particular hypothesized structure is empirically real, experiments can, in principle, (1) determine whether that structure plays any role in the mental activity of real speakers, thereby (2) providing a potential way to sort out those theories that are on the right track (i.e., the ones that actually say something about the knowledge and abilities of human beings) from those which are mere figments of the analysts' lively imaginations. In short, while linguistic theories provide the crucial kind of direction that psycholinguistic experimentation requires in order to proceed efficiently and fruitfully, no degree of linguistic theorizing or primary data sifting can correctly claim to establish psychological reality without firm psychological evidence to back it up.

When we speak in this paper, therefore, about a language "having" some particular linguistic structure of feature, what we mean by this is that we have experimental evidence that real speakers actually recognize or make use of that feature in their internal representation and/or processing of the language involved.

Theoretical Background

No program of experimental research can expect to make much in the way of progress without some kind of antecedent theoretical perspective to guide it, as random "cage rattling" and serendipity can only take a field so far. Significantly, therefore, all of the research summarized in the remainder of this paper was quite explicitly conceived and designed in order to test ideas that were developed by theoretical linguists on the basis of their examination of properties of the language product, except for those cases, as specifically noted, when a new experiment was developed in order to clarify the results of one or more prior ones.

The theoretical notions that experimental research on syllable structure has concerned itself with to date have mainly involved questions about syllable

boundaries (i.e., the demarcation points that separate one syllable from another) and about the internal make-up of syllables (i.e., the kinds of units that have been proposed as syllable-internal constituents and their presumed interrelationships, which, assuming a hierarchical "tree structure" model, have brought such theoretical notions as "branching direction" into the picture as well). This section of the paper will provide a brief overview of some of these fundamental ideas.

The concept of the syllable is taken to be important primarily because of its obvious role as the domain of stress and tone in many languages, not to mention its high level of salience in many languages as a phonological unit in its own right. In Mandarin Chinese, for instance, the syllable is the smallest domain of meaningful representation, as well as serving as the chief unit of representation in the standard orthographic system of that language; and in Korean the syllable is the primary metrical unit that figures in that language's poetic system (called *sico*), just as the mora is in the more widely familiar Japanese *haiku*.[5] And even in a language like English, where the segment would seem to predominate, there is a striking agreement among adults as to the number of syllables a given word contains, while children have revealed an ability to count syllables (but not phonetic segments) in their pre-school years (Lieberman et al. 1974).

Questions about the internal structure of syllables have received a good deal of experimental attention primarily, it would seem, because of the proliferation of theories that have developed about this (see Note 1), combined with claims about universality that have recently been challenged. In particular, while it was long thought by many linguists (e.g., Kaye 1989: 54–58) that a right-branching onset-plus-rime model of the syllable (as shown in Figure 1a below) might be universal, experimental research has indicated that syllables of a left-branching body-plus-coda type (as in Figure 1b) might be the norm for some languages (such as Korean; see especially Yoon & Derwing 2001), and perhaps even syllables with a completely flat structure, with no units intervening between the syllable and the segment levels (as in Figure 1c), which was another possibility that emerged from the research to be briefly summarized and described below.

We will also note that even the utility of the syllable and segment themselves has been questioned for some languages (such as Mandarin Chinese, where the

5. Although often parodied in English using a syllable count, the traditional *haiku* consists of 17 morae, with the mora count based on one for each short syllable, plus an additional one for each long vowel (including diphthongs) or geminate consonant, and another for each syllable-final /n/. Thus the Japanese word *nip.pon* 'Japan' contains 2 syllables, as demarcated by the dot, but four morae. (The so-called *hiragana* and *katakana* "syllabaries" of Japanese also represent moraic units, rather than syllabic ones.)

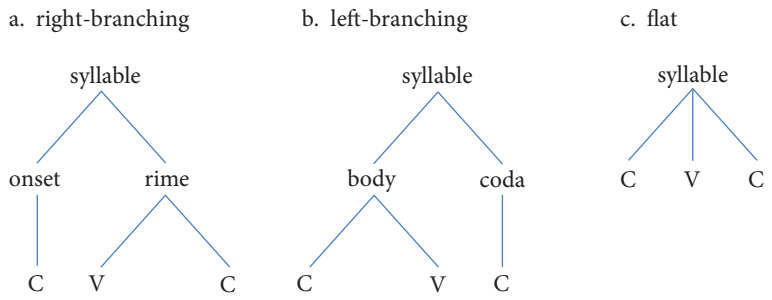

Figure 1. Right-branching (onset-plus-rime; a); left-branching (body-plus-coda; b) and flat (c) models of the syllable structure.

segment is of dubious status, and Japanese, where the mora unit may well supplant both the segment and the syllable[6]).

Another important theoretical notion is sonority (or its correlates, such as "strength"), which has been taken by most theoreticians as the primary concept around which syllables are organized, with vowels as the sonority peaks and surrounding consonants as the lower-sonority margins. Unfortunately, there is much controversy as to how sonority should be defined or measured, although something along the lines of perceptual saliency or perceived loudness (e.g., Parker 2008) seems to be the general intent; at the same time, however, there is widespread agreement about the hierarchy of segment types that are represented on what has come to be known as the "sonority scale", the details of which have changed little from the account presented in Heffner (1949: 74), who ranked the speech sounds as follows (moving from highest to lowest levels): low vowels > mid vowels > high vowels > r > l > nasals > voiced consonants > voiceless consonants.[7] As we shall see, this consensus has been helpful in guiding the experimental research on this factor in the studies reported below.

6. Vance (2008: 124) suggests, however, that the syllable may play a role in the intonation system of Japanese.

7. Using a novel substitution-pattern identification task with English monosyllables, Derwing and Nearey (1991: 211) obtained experimental support for that portion of the hierarchy stretching from (high) glide to obstruent, i.e., glide > r > l > nasal > obstruent.

Experimental Approaches to Syllable Structure

Testing Syllable Boundaries

Methods and Tasks

A number of creative methods have been devised to elicit syllable breaks, which have principally been applied to English, which is a language that manifests quite complex phonotactics and about which there has been much disagreement on how to syllabify words. This contrasts with a language such as Spanish in which syllabification is mostly uncontroversial (Jiménez-González & Ortiz-González 1994; however, see Hualde & Prieto 2002). While, as we shall see, most researchers have worked with adults and written stimuli, Zamuner and Ohala (1999) worked with preliterate English-speaking children and taught them to say words with a pause in the middle. The children were first trained to put a pause between the elements of compound words such as *snowman* and *dumptruck*. In the test phase, the children's task was to insert a pause in words such as *carrot* and *tiger*. Ishikawa (2002) employed this same method with adults.

A similar task with written stimuli has been used in several other studies (Eddington, Treiman, & Elzinga 2013a, b; Redford & Randall 2005; Treiman, Bowey, & Bourassa 2002; Treiman & Danis 1988; Treiman & Zukowski 1990). In these studies, participants chose between different word divisions indicated with a slash or a hyphen. For example, subjects were asked whether they preferred to divide *melon* as *me/lon* or *mel/on*. In a similar manner, Treiman, Gross, and Cwikel-Glavin (1992) presented nonce words auditorily, then had subjects choose between written responses. The application of these experimental designs has not been limited to English. For example, Bertinetto (1999) and McCrary (2004) have examined syllabification in Italian using similar methods, while Schiller, Meyer, and Levelt (1998) did much the same with Dutch.

The written tasks just described require participants to break words into parts and do not allow for ambisyllabic responses, where a unit is placed in both syllables. The reduplication or doubling task allows for this possibility, and it has been used with children (Fallows 1981) and adults (Treiman, Bowey, & Bourassa 2002; Treiman & Zukowski 1990). Fallows trained children to repeat the first or second part of a word. For example, upon hearing *chipmunk*, the children were to respond *chipchipmunk* when the goal was doubling of the initial syllable. A week or more later, the same subjects were retrained to double the second syllable (*chipmunk* > *chipmunkmunk*). Actual test words were not compounds or pseudo-compounds and included items such as *summer* and *baby.* Ambisyllabicity is evident when a subject places a consonant in both the initial and final doublings (e.g. *lemon* > *lemlemon, lemonmon*).

The syllable reversal task (Treiman & Danis 1988) is somewhat similar to the doubling task. Given a word such as *lemon*, the subjects were told to reverse the order of the syllables. This could yield *onlem, monle,* or the ambisyllabic *monlem*. Another method was to ask subjects to produce the first or the last part of a word (Treiman, Bowey, & Bourassa 2002). For example, participants were asked whether the first part of *salad* was *sal-* or *sa-*, and later they were asked whether the last part was *-lad* or *-ad.* An ambisyllabic response was indicated if a participant indicated that the first part of *salad* was *sal* and that the last part was *lad*.

Another approach that allowed for ambisyllabic responses was the "pause break" task, in which participants were trained either to insert pauses into their own word productions (Briere, Campbell, & Saemarmo 1968; Zamuner & Ohala 1999), or else were presented auditorily with various alternative ways of breaking words up with pauses and asked to decide which option sounded the most natural to them (Derwing 1992b).

Even in oral syllabification tasks, however, participants' knowledge of words' spellings may affect their syllabifications. Researchers have dealt in different ways with this possibility. Fallows (1981) did not take spelling into account. Her stimuli included words with single-letter spellings of the medial consonant, such as *lemon*, and words with double-letter spellings of the medial consonant, such as *summer*, but these variations were not considered in analyzing the data. Later researchers have typically distinguished between words with geminate and single-letter spellings of a medial consonant. Some researchers have even taken the trouble to check whether individual participants knew the correct spellings of the orally presented stimuli and have considered this in their analysis of the data (e.g. Treiman, Bowey, & Bourassa 2002; Treiman & Danis 1988).

All of the methods described above are metalinguistic tasks in which the subjects were asked in a number of different ways to divide bisyllabic words into two parts. Generally, the instructions given did not mention the word *syllable* itself. However, while metalinguistic tasks are useful, conscious decisions of this nature may produce different outcomes than unconscious divisions. For this reason, Treiman, Straub, and Lavery (1994) devised a short term memory recall task in which subjects were auditorily presented a list of numbers and nonsense words which they were later asked to recall. Recall errors involving blends of two nonce words revealed implicit syllabifications. For instance, when the nonce words [vərud] and [ʧɪlep] appeared in the list, blends like [vəlep] and [ʧɪrud] pointed to a CV.CVC division, whereas [vərep] and [ʧɪlud] indicated CVC.VC. The main importance of this study was that, as hoped, it revealed the very same trends as the prior metatheoretical studies, indicating that those findings were not artifactually limited to conscious manipulations, but were tapping the same information about syllables as the spontaneous unconscious productions were.

The design of Smith and Pitt (1999) allowed syllable breaks to be tested in an indirect manner as well. The subjects' task was to press a button if they heard a particular sound in a word. All words had a CVCCVC structure and the target sound was always the third segment. In some cases the syllable structure was clearly CVC.CVC (e.g., *mag.net*), which put the target consonant /g/ in the coda, while in others it was CV.CCVC (e.g., *mi.graine*), where the target consonant was in the onset. The researchers varied the proportions of the two kinds of test items. In one condition, 80% of the words had CV.CCVC and only 20% CVC. CVC, while in the other condition, these percentages were reversed. Since the target sound appeared in the same serial position, no reaction time differences would be expected if the syllable distinctions were not relevant. However, reaction times to the target sound were reduced when it appeared in the same syllabic position as the majority of the test stimuli. For example, when 80% of the stimuli had CV.CCVC, the /g/ in *migraine* was responded to more quickly than the /g/ in *magnet*, and such time differences suggested that the syllabic units were involved in the perception of these words.

A method used by Rapp (1992), which was developed by Prinzmetal and Keysar (1989), also avoids metalinguistic judgments. It involves briefly presenting multicolored words to the subjects and then asking them to remember what color a specific letter was. Some of the stimulus words were coded so that the colors of the letters corresponded to the syllables in the word. For example, SIG, the first syllable of SIGMA, was green and MA was yellow. In these cases, when the subjects were asked what color G was, most correctly indicated that it was green. In other cases, the colors and syllables did not correspond, so that SI was green and GMA was yellow. If the subjects were asked to decide what color the letter G was, and GMA was yellow, they would have trouble because G has the color that corresponds to the second syllable, yet G belongs to the first syllable. This mismatch caused many subjects to perceive that G was green even though it was actually yellow. In other words, syllable structure influenced the subjects' color perception.

Factors that Influence Syllabification in English

A great deal of information about the syllabification of English words has resulted from experimental studies of the kinds described above, most of which have been carried out using bisyllabic test words with a single medial consonant. A key finding in this connection was that the preferred break-points between syllables are strongly affected by the interaction of the factors of stress, vowel quality (lax vs. tense), the sonority of the medial consonant, and even by the way that consonant is spelled, as well as by morpheme boundaries.

First of all, experimental evidence from English indicates that stress interacts with vowel quality in determining the syllabification of single medial consonants in bisyllabic words. Consider words like *herald, melon,* and *lemon*, which have stress on their first syllable, as compared to *parade, select*, and *demand*, with stress on the second. In such words (which all have lax vowels in their initial syllables), the stressed syllable seems to attract the medial consonant, which links as either the coda of the first stressed syllable (e.g., *hér.ald, mél.on, lém.on*) or as the onset of the second (e.g., *pa.ráde, se.léct, de.mánd*). This means that the syllabifications *hér.ald* and *pa.ráde* are preferred over *hé.rald* and *par.áde*, etc., as shown in Table 1 below. However, if the vowel in the first syllable is tense as well as stressed, the medial consonant attaches as the onset of the second, unstressed syllable, as can be seen in the comparisons between *h*[ɛ]*r.ald* vs. *d*[au].*ry*, *m*[ɛ]*l.on* vs. *p*[aɪ].*lot*, and *l*[ɛ]*m.on* vs. *m*[ou].*ment*. (For details, see Derwing 1992b; Fallows 1981; Treiman & Danis 1988; Treiman, Gross, & Cwikiel-Glavin 1992; Treiman, Staub, & Lavery 1994; Treiman & Zukowski 1990; Zamuner & Ohala 1999).

In those cases where the first vowel is stressed and lax, the sonority of the medial consonant also plays a role in its syllabification, yielding a gradient effect; specifically, the more sonorous the consonant, the more likely it is to be viewed as the coda of the first syllable. Thus, for example, as can also be seen in Table 1, there is a greater tendency for the syllabification *hér.ald* (with a medial /r/) than for *mél.on* (with a medial /l/) and, in turn, for mél.on than for *lém.on* (with a medial nasal), while the preferred syllabification for *seven* (with an intervocalic obstruent) is *sé.ven*, in which the /v/ has been moved out of the first syllable to become the onset of the second (Derwing 1992b; Eddington, Treiman, & Elzinga 2013a; Ishikawa 2002; Moreton, Feng, & Smith 2008; Treiman & Danis 1988; Treiman, Staub, & Lavery 1994).

Those experimental designs that allowed for ambisyllabic responses showed that the medial consonant could be placed in both syllables under some circumstances. Ambisyllabic responses were somewhat more frequent when the vowel in the first syllable was lax and stressed (Derwing 1992b; Treiman & Danis 1988; Treiman, Gross, & Cwikiel-Glavin 1992) or if the medial consonant was a sonorant (Treiman & Danis 1988). These tendencies are also reflected in Table 1, along with the most prominent one that, even in oral tasks, ambisyllabic responses were much more frequent when the medial consonant was spelled with a geminate than otherwise (Derwing 1992b; Treiman, Bowey, & Bourassa 2002; Treiman & Danis 1988). Whether orthographic geminates affect children's syllabifications is less clear; Zamuner and Ohala (1999) found a positive influence, while Treiman, Bowey, and Bourassa (2002) did not. However, as illustrated by the Amb results for *melon* in Table 1, these studies provide scant evidence to support the linguistic hypothesis

Table 1. English response proportions for stimuli varying in stress, quality of first vowel, and spelling and sonority of medial consonant.

Explanation of symbols: 1Str = stress on first syllable, 2Str = stress on second; Lax = lax vowel in first syllable, Tns = tense vowel; SgSp = medial consonant spelled with a single letter, DbSp = spelling with double letters; S1/Co = coda of first syllable, S2/On = onset of second syllable, Amb = ambisyllabic response. Majority responses for each category are shown in boldface. The numbers in parentheses in this table show the results of the Treiman and Danis (1988) oral task (Expt. 3, syllable inversion; n = 20); if a second number also appears, this is the result from their written task (Expt. 3, slash insertion; n = 24).

Stimulus	Category	Examples	S1/Co	S2/On	Amb
1. /r/					
	1Str, Lax, SgSp	herald	**.75**	.07	.18
	2 Str, Lax, SgSp	parade	.11	**.75**	.15
	1 Str, Tns, SgSp	dowry	.05	**.85**	.10
	1 Str, Lax, DbSp	parrot	.25	.10	**.65**
2. /l/					
	1 Str, Lax, SgSp	melon	**.62** (.40/.55)	.20 (.33)	.18 (.26)
	2 Str, Lax, SgSp	select	.01	**.85**	.14
	1 Str, Tns, SgSp	pilot	.17 (.26/.37)	**.77** (.58)	.07 (.15)
	1 Str, Lax, DbSp	gallon	.20	.12	**.68**
	2 Str, Lax, DbSp	collide	.36	.04	**.60**
3. Nasals					
	1 Str, Lax, SgSp	lemon	**.51** (.46/.64)	.37 (.29)	.12 (.24)
	2 Str, Lax, SgSp	demand	.06	**.86**	.08
	1Str, Tns, SgSp	moment	.13 (.26/.14)	**.82** (.68)	.05 (.06)
	1Str, Lax, DbSp	tennis	.24	.20	**.56**
	2Str, Lax, DbSp	command	.02	.42	**.56**
4. Obstruents					
	1Str, Lax, SgSp	seven	.30 (.27/.44)	**.60** (.58)	.10 (.14)
	2Str, Lax, SgSp	reveal	.02	**.94**	.04
	1Str, Tns, SgSp	crisis	.13 (.17/.13)	**.80** (.79)	.07 (.03)
	1Str, Lax, DbSp	rabbit	.06	**.62**	.32
	2 Str, Lax, DbSp	effect	.05	**.61**	.34

Note: This table is adapted from Derwing (1992b), which, was originally conceived as an informal pilot study (n = 95) to show the efficacy of a new technique that could be used with unwritten languages and with participants of limited education or literacy. The table is used here, therefore, merely as a convenient visual device to illustrate the general patterns of responses that were found in a number of better-controlled earlier and subsequent studies, as noted in the other references provided. Furthermore, the scores indicated do not necessarily reflect the responses for the specific words shown as examples, but may be the means for up to three words with the same essential properties (see Derwing 1992b for details).

that the /l/ in a word like *palace* "properly belongs to both first and second syllables" (Cutler et al. 1986: 387). Eddington and Elzinga (2008) have suggested, in fact, that ambisyllabic responses might represent nothing more than mere uncertainty on the speaker's part about which syllable a particular consonant belongs to.

The majority of the experimental work on English syllabification has dealt with test words containing only one medial consonant, as in all of the studies cited above; however, a few studies have included test items with two or more medial consonants. Some of the findings parallel those discussed above, such as the one that stressed syllables containing lax vowels tend to attract consonants (Treiman & Zukowski 1990). In general, consonant clusters that are illegal word-initially are separated word-internally as well, as are clusters that are illegal word-finally (Eddington, Treiman, & Elzinga 2013a, b; Fallows 1981; Redford & Randall 2005; Smith & Pitt 1999; Treiman & Zukowski 1990). The influence of word-initial phonotactics on syllabification was also found in Dutch (Martens et al. 2002). Berg and Niemi (2000) and Berg (2001) also experimentally explored such global strategies as onset maximization in the syllabification of complex medial consonants in German, Finnish, and Icelandic.

An interesting anomaly arises when legal word-initial clusters are considered. Most clusters that are allowed word-initially would be expected to appear in the onset of the second syllable when word-internally. This is generally the case, with the glaring exception of medial *-sC-* clusters, which are typically syllabified C.C in both real and nonce words (Eddington, Treiman, & Elzinga 2013b; Redford & Randall 2005; Treiman, Gross, & Cwikiel-Glavin 1992; Treiman & Zukowski 1990). One reason for this could be because *s* + stop clusters do not demonstrate an optimal rise in sonority in transitioning to the syllable nucleus. The difficulty with this explanation is that clusters such as *sw* and *sl* do provide the optimal sonority transition, yet even they are generally divided word-internally, as well (Treiman, Gross, & Cwikiel-Glavin 1992). Another explanation that has been put forth is that word-initial *sC-* clusters are exceptional onsets in English (Kaye, Lowenstamm, & Vergnaud 1990). On the other hand, Wright (2004) suggests that /s/ has enough perceptual acoustic cues by itself and thus does not depend on formant transitions in the following vowel in order to be perceived. This allows it to be separated from a vowel by an intervening consonant, yet still be part of the same syllable.

Davidsen-Nielsen (1974) provides spectrographic data from word-internal *s* + stop clusters. His general finding is that stops in this position are not aspirated unless a morpheme boundary intervenes, as in *miscalculate*. This supports the idea that morphology influences syllabification. Since the aspiration of voiceless stops is only thought to occur when the stop is the first element of the onset, this suggests a .CC rather than a C.C syllabification for these clusters. Treiman, Gross,

and Cwikiel-Glavin (1992) argue that rather than take this phonetic study as evidence for a .CC syllabification of *-sC-* clusters, which conflicts with the body of evidence showing that they are C.C, perhaps the difficulty lies in the delineation of the phonetic environments that are currently thought to govern the allophonic distribution of the voiceless stop phonemes. More research is definitely called for in order to clarify these issues.

The most common effect of spelling on syllabification that has been investigated is that of orthographic geminates (Derwing 1992b; Treiman, Bowey, & Bourassa 2002; Treiman & Danis 1988; Zamuner & Ohala 1999), whereby doublets in words such as *rabbit* are more likely to be treated as ambisyllabic than the singleton in *habit*. Eddington, Treiman, and Elzinga (2013a) explored the idea that the influence of orthography may go beyond geminates. They found that even in a syllable division task that did not entail dividing orthographic word representations, English speakers preferred to put consonants in the coda if their spelling was not permissible word-initially, as is the case of *ck* and *ng*, for example. Spelling has also been shown to influence Dutch syllabification (Gillis & Sandra 2000).

The majority of experiments on English syllabification have excluded multimorphemic words in order to control for the influence of morpheme boundaries. However, Derwing (1992b) included some bimorphemic words and noted that subjects typically divided these words at morpheme boundaries. Thus, for example, while nearly two-thirds of the participants preferred breaking the monomorpheme *doily* before the /l/ (i.e., *doi.ly*), a like majority opted instead to place it after the /l/ in the bimorpheme *oily*, (i.e., *oil.y*), thus keeping the root morpheme "oil" intact; and similar results also occurred with examples like *si.nus* vs. *rain.ing* and even *i.ris* vs. *wir.ing* (with a full 89% of the participants opting for the latter syllabification, despite the fact that the "e" of the root "wire" was suppressed in the spelling.) In a much larger study containing many polymorphemic words (Eddington, Treiman, & Elzinga 2013a, b), the effect of morphology was also highly significant, showing that participants tended to break words at morpheme boundaries. This was true for compound words such as *without,* and words with transparent morphology such as *washer*, but it even extended to more opaque morphological relationships, as in *tidings* and *windage*. On the other hand, Smith and Pitt (1999) found no influence of morphology. In their study, words were not divided in order to ascertain syllabifications, but syllabifications were determined indirectly in a phoneme monitoring task (see p. 177 above). This suggests that differing outcomes may be due to the different experimental designs.[8]

8. See also Côté and Kharamov (2011) for a study in Russian where the results varied widely, depending on the particular syllabification task employed.

Many variables that affect syllable division make it appear that people divide words so that the resulting syllables are as word-like as possible (Eddington, Treiman, & Elzinga 2013a, b). In a language such as English, whose morphology is largely whole-word based (rather than attaching affixes to bound stems), respecting morpheme boundaries allows one to parse out the basic word within a word. Even when syllable division does not result in a freestanding word, the resulting syllables tend to respect what segments as well as letters and letter combinations are allowed at the beginning and end of extant English words.

Finally, however, as is readily obvious from the results summarized in Table 1 above, the gradient nature of all of these results should also be noted. As Treiman et al. (1994: 56) expressed, "Although people often favor one syllabification over another, the preferences being influenced by stress pattern, vowel type, and consonant type, the preferences tend to be statistical, rather than absolute." To our minds, this fact seems to argue against the kind of fixed, hard-and-fast boundaries that are implied by constituent analyses for syllables and the corresponding hierarchical tree representations that are used here and which dominate the literature in general, and cries out instead for some alternative theoretical approach in which the breakpoints both between and within syllables are not so well defined or clear cut. (See Derwing & Nearey 1991 for the general outlines of one such alternative approach.)

Testing for Syllable Constituents

Another line of research focuses not on where the boundary between two syllables occurs, but on whether single syllables have internal constituents that are larger than the individual segments involved. If the rime is a significant unit that is comprised of a nucleus and coda, one would expect speakers to avoid separating the coda from the nucleus in language processing. Treiman (1983) tested this by having English-speaking subjects combine two monosyllabic nonce words to form a new monosyllabic word, then observed how the syllables were divided. In other research, Treiman (1985, 1986, 1988) engaged participants in a variety of language games that entailed dividing syllables. In all cases, the elements of the rime tended to be kept together, suggesting that it formed a cohesive unit. Similar findings also resulted from a task in which subjects were trained to substitute syllable parts in test words (Derwing, Dow, & Nearey 1989; Dow & Derwing 1989). Substitution was carried out on segments that belonged to a number of different possible syllable constituents. The most easily substituted elements, though, were onsets and rimes, which supported the view that the English syllable was composed of these two subcomponents.

Just as in the case of boundaries between syllables, however, the intrasyllabic boundaries between syllable constituents also appear to be less than firm, but can vary as a function of the sonority of the segments involved, and with a quite high level of uncertainty from one participant to another. In her study of English final consonant clusters, for example, using a blending technique with nonsense syllables, as well as some novel word games, Treiman (1984) found that the border between the nucleus and coda tended to shift as a function of the sound class of the post-vocalic consonant involved. Specifically, participants tended to break VCC syllables before the first consonant, if that consonant was an obstruent, but after it if the consonant was a liquid (i.e., /l/ or /r/), whereas the two tendencies were about equal if the first consonant was a nasal. To the extent that comparisons can be made, this result parallels that for syllable boundaries, as summarized in the previous section (see Table 1).

Besides such relatively extensive efforts with English, a good deal of experimental work has also been done on the internal syllable structure of a few other languages, though typically using only a single method or a very narrow range methodological approaches. One notable exception to this, however, is Korean, where tasks as diverse as sound similarity judgments, word-blending, concept formation, and nonsense word recall have all conspired to indicate that the onset and the nucleus cluster into a cohesive body unit, yielding a left-branching body-coda structure, in contrast to English, where much the same variety of tasks consistently revealed a right-branching onset-rime configuration instead. (See Derwing 2007 for a convenient summary of the main Korean language research, and Yoon & Derwing 2001 for the methodological details.) Other languages that have received quite heavy experimental attention in this regard include Spanish and Italian, as well as Minnan Chinese, as noted in the next section of this paper.

Bertinetto et al. (1998–1999) studied Spanish syllables with methods similar to those used by Treiman and concluded that the rime is a relevant syllabic unit in this language, although their results could be due to syllable frequency instead (Eddington 2004). In a more complex study, Bertinetto et al. (1994) have also looked at Italian, concluding that this language sometimes gave evidence of a right-branching structure, while at others a completely "flat" structure (see Figure 1c above), with no internal hierarchical elements at all, i.e., of a kind that M. Ohala (1999) tentatively ascribed to Hindi.

When Experimental Results Conflict: The Case of Minnan Chinese

It is both encouraging and comforting when a methodologically diverse body of experiments on a given language conspire to show a converging pattern of results,

as has largely been the case for both English and Korean, though with diametrically opposed results across the two languages, as just noted above. It is not at all uncommon, however, for the results of diverse experiments to conflict, a situation that invariably leads to questions about issues such as faulty assumptions, uncontrolled extraneous variables, and sometimes even critical flaws in the design of the experiments themselves. The history of research on the syllable structure on Minnan Chinese provides a useful object lesson on some of the pitfalls that a well-meaning program of research can sometimes encounter.

Minnan (often previously referred to in the literature as "Taiwanese"[9]) seemed like a fruitful ground to explore in this connection, as there was some striking internal evidence suggesting that this language might be of the same left-branching type as indicated for Korean, in contrast to the widespread traditional assumption that all of the Chinese languages were right-branching, just as Mandarin was assumed to be. Particularly notable was the phenomenon of nasal assimilation within the Minnan syllable, by which the CV portion of a CVC syllable was required to be nasalized either throughout or not at all, while a nasalized (C)V was incompatible with a final nasal C. (Thus [ban] [bat], [ba], and [mã] are all possible syllables, while *[ma], *[bã], and *[mãn] are not.) At the same time, however, it was puzzling to discover (from Chang 1992) that rhyming poetry was attested in Minnan (unlike the Korean case, where, as noted earlier above, a syllable count served as the poetic base) and rimes were also reported by Li (1985) to be the basis of at least some Minnan secret languages or language games.

As reported in more detail in Derwing, Wang, and Tsay (2011), the first experiments to assess the internal constituent structure of the Minnan syllable took place nearly two decades ago, when the two techniques of sound similarity judgments and word-blending (both of which had yielded consistent, albeit opposite, results in the earlier English and Korean studies) were adapted to this language. In the first case, participants were asked to judge which of two words (e.g., *tang* and *pan*[10]) was more similar to a key word (e.g., *tan*), and it was found that body-sharing words like *tan-tang* were judged more similar than rime-sharing words like *tan-pan* by a more than 3:1 margin. On the other hand, however, when these same participants were asked to choose between body-sharing blends like *san* + *tsim* →

9. Though Minnan was previously referred to as "Taiwanese" in many academic as well as informal circles, the latter term is now considered both politically and linguistically incorrect, since the language is neither the only nor the main language spoken in Taiwan, nor is its use restricted to that island. The preferred terms now, therefore, are either "Taiwanese Min" or "Taiwan Southern Min", or, most simply "Minnan". (The "nan" part means "south".)

10. For convenience, tones are omitted in these and some of the other Minnan examples, though they were, of course, not changed within a given test item.

sam and rime-sharing blends like *san* + *tsim* → *sim*, they overwhelmingly chose the latter. (Similarly, as reported in Wang 1996, Minnan participants did better at language games that involved manipulating rime elements, as compared to ones that involved body elements.)

These conflicting experimental results caused us to reflect deeply about what might be different about the Minnan situation, as compared to English and Korean, where variants of both of these same two techniques had yielded consistent results within each of the languages involved. This analysis drew our attention to the following three factors:

1. Unlike either the English or Korean cases, all of the adult Minnan participants were bilingual in two closely related languages (Minnan and Mandarin), having learned either both at home or the former at home and the latter in school, where Mandarin is the language of instruction throughout Taiwan, which is where the research was carried out.
2. In school these participants were also heavily exposed to the traditional "initial vs. final" analysis of the Mandarin syllable, which is equivalent to an onset-rime scheme, as well as to traditional rhyming poetry.[11]
3. To further reinforce this onset-rime bias, these participants had all also been taught a practical writing system (called "Zhuyin Fuhao") that was onset-rime based, which was used in the early grades to indicate the pronunciation of the standard Chinese characters for Mandarin, which were learned at a much slower pace.

These considerations led us to suspect the results of those experiments that involved the overt manipulation of syllable constituents (such as word-blending and other string manipulation techniques) might have been heavily influenced by the participants' knowledge of Mandarin, and by the overt instruction they had received in school about the structure of the Mandarin syllable — and in particular by their knowledge of an explicit supplementary orthographic scheme that specifically exploited the onset-rime principle. It took us some time, however, to devise an experiment that effectively controlled for this knowledge and training.

In the meantime, an application of a global sound similarity judgment task in Minnan led us also to question the basis of the results of our earlier and smaller-scale word-pair comparisons. Specifically, in the global comparison study, all possible comparisons of C1VC2-C1VC2 were performed, with similarities measured on the same 9-point scale. The following shows examples of all of the

11. As schoolchildren, these participants were also exposed (though less intensively) to English, a language with a demonstrably clear onset-rime syllable structure.

comparison types that were involved, and where the subscript numbers show the places of the specific contrasts used:

C_1VC-C_2VC	(e.g., /tan-kan/)
CV_1C-CV_2C	(e.g., /tan-tin/)
CVC_1-CVC_2	(e.g., /tan-tam/)
C_1V_1C-C_2V_2C	(e.g., /tan-kin/)
CV_1C_1-CV_2C_2	(e.g., /tan-tim/)
C_1VC_2-C_2VC_2	(e.g., /tan-kam/)

The results of this study showed not only that C1VC2 words that differed in their rime elements (VC2) were judged to be much more similar than those that differed in their body elements (C1V), but a regression analysis involving only the three individual segments showed that both C1 and V made large and highly significant contribution to similarity scores, while the contribution of C2 was so small as to be only marginally significant (see Derwing, Wang, & Tsay 2011, for details). This finding thus led us to believe that the results of our sound similarity judgment tasks were most likely a consequence of intrinsic differences in salience among the segmental portions of a Minnan word, rather than reflecting differences in some higher-order internal syllable structure of these words.

Finally, when we eventually managed to come up with a practical experiment to avoid the effects of the Zhuyin Fuhao orthography, the phenomenon just noted once again raised its ugly head. The new experiment (which had also been used earlier to differentiate the English and Korean cases) involved learning lists of novel nonsense words by non-literate pre-school children. In the Minnan case, such children were required to recall the same names when embedded in three-item body-sharing lists like GA^{51}-LAM^{55}, GA^{51}-LAN^{55}, and GA^{51}-LANG^{55} as in three-item rime-sharing lists like GA^{51}-LAM^{55}, GA^{51}-KAM^{55}, and GA^{51}-TSAM^{55}). As expected, they did better with the body-sharing lists, but, in retrospect, rather than viewing this as a difference in the recall-enhancing effect of the body vs. rime constituents (which was the idea that the study was predicated upon in the first place), we are now concerned that this result, too, might have been a consequence of differences in salience at the segmental level, enabling the names to be more readily identified and better recalled in the context of other words containing the highly salient C1 and V elements than in one where the V was paired with a C2 of very low salience.

In short, after several years of trying, we still lack a convincing experimental demonstration that the Minnan syllable has a left-branching rather than a

right-branching internal structure, or even that, given its extreme simplicity,[12] it might be best to consider it as an unanalyzable whole, since the number of possible syllable types is only about 800 (ignoring tones), certainly well within the range of memorization by rote. In the process of this frustrating exercise, however, we have learned quite a few important things about some of the methods that were employed and the kinds of factors that can affect the results of experiments, most notably the following:

1. A technique that might be accessing syllable structure in one language may not be doing so in another, where some extraneous factor may be at work instead.
2. In bilingual or multilingual participants, knowledge of one language can influence the results of experiments done in another, especially if the two languages are typologically very similar.
3. Orthographic effects can also carry over from one language to another.
4. Finally, and most importantly, because of considerations like these (and others), we cannot simply keep a stock of "reliable techniques" on hand to throw at each new language as it comes along — at least not if we expect to get anywhere in anything like an efficient manner. Techniques that work well in one language (as far as we know), such as sound-similarity judgments and word-blending in English, may not work at all well in another, such as the same two in Minnan, because of differences in both the linguistic and non-linguistic factors that may be critically involved. Hopefully, as the enterprise expands and more people get involved in experimental work of this kind, a body of expertise will be built up that will at least help to guide researchers in their choice of methods and experimental designs.

The Next Stage: Towards a Deeper Understanding of Syllable-Internal Complexity

So just where does this all leave us? On the one hand, it is encouraging to see an increase in experimental linguistic work these days (which bodes well for the future of the entire discipline), but the mood within our own little domain is not quite as optimistic as it was a few years ago, before the "messy" results started coming in en masse. We now know that we cannot simply grind each new language through

12. If pre- and post-vocalic glides are interpreted as part of the nuclei of Minnan syllables (as in Mandarin), the only canonical patterns the language manifests are V, CV, VC, and CVC, with the coda consonants restricted to three nasals and four voiceless stops.

the same set of routines and expect to get anywhere, at least not anywhere fast. Furthermore, given the difficulties that the enterprise is now poised to face, we can no longer afford to continue to look at syllable structure just because (like the proverbial mountain) it is "there". In short, we need, it seems, some higher-order theoretical considerations that will serve to give both motivation and direction to our efforts. In this connection we were very encouraged to come across a now quite old but seemingly ignored suggestion that strikes us as a highly promising tack to take during the next stage of this research. The original source was a long-buried working paper by Bertinetto, Cioni, and Agonigi (1994: 17), where the following remarks appeared at the conclusion of an experimental study that presented a picture of the Italian syllable as having, at best, a very weak hierarchical structure, and perhaps none at all:

> "[W]hy should Italian have such a weak hierarchical arrangement (or indeed no internal hierarchy at all, according to the flat model hypothesis that we do not dare to reject)? The answer we would like to offer is that Italian is a language with a rather elementary syllable structure, so that it does not need to develop an elaborated processing strategy, which would help the speaker to assemble the speech chain into chunks of segments conforming to the phonotactics of the language, and ultimately guiding her/him in the process of lexical recognition. In contrast, a language like English, which exhibits a much more complicated syllabic structure, might be in need of establishing precisely this sort of mechanism, based on a rigid internal hierarchy. According to this view, the internal hierarchy of the English syllable would be a consequence of the more complicated phonotactics of the language."

What an interesting idea! Clearly, what is being suggested provides a processing motive as to why some languages may have more complex syllable-internal structures than others, giving us a much larger perspective within which to view syllable structure research. Moreover, if true, it also leads to the expectation that a link should exist between the specific phonotactic complexities that occur at the segmental level in a language and the relative intrasyllabic complexity that the language presents, viewed in terms of a hierarchy of elements that mediate the relationship between syllables and segments. And this, in turn, raises the very question that the authors themselves ask near the end of this discussion on p. 17: "If this hypothesis is correct, why should languages like Korean and Taiwanese [i.e., Minnan], with a very simple syllable structure, present a hierarchical arrangement, while Italian does not?" Why, indeed.

To illustrate this point concretely, we could scarcely find a better example than Mandarin Chinese, which can be quite accurately characterized as a syllable-based language par excellence. We have already noted that the syllable is the

smallest meaning-carrying unit in the language, with a likely consequence that the syllable is its smallest significant phonological unit, as well.[13] Moreover, as Myers (2010: 421–422) points out, "The [Mandarin] Chinese lexicon is characterized by its typologically unique one-to-one mapping of morphemes, syllables, and orthographic characters." Even more striking, though, is the fact that there is "no cross-syllable tone spreading, vowel harmony, consonant assimilation, or resyllabification", with each utterance pronounced as a sequence of "neatly separated syllables." The phonotactics of the language are also extremely simple, with consonant-glide onsets as the "closest it comes to consonant clusters", and where "even these are analyzable as single segments with secondary articulation", or else treated as part of the syllable nucleus, rather than the onset (Wang & Chang 2001), and with the inventory of coda consonants limited to the two nasals /n/ and /ŋ/.

Putting this all together, it would thus seem that Mandarin is a language almost perfectly designed for the easy and efficient lexical (= syllabic) parsing of phonological strings. Given a string that might be canonically represented as CVCCVC, for example, the syllabification CVC.CVC is inevitable, since no syllable can either begin or end with a consonant cluster; what's more, since the nasals /n/ and /ŋ/ are the only possible codas, even strings like CVCVC (with single intervocalic consonants) must generally be parsed as CV.CVC, except in the single circumstance when the medial C is /n/. (This is because /m/ occurs only syllable-initially and /ŋ/ only finally, leaving /n/ as the only segment that is ambiguous between onset and coda.) In any event, viewed in the context of Bertinetto's[14] string-parsing hypothesis, there is certainly no need for anything like the traditional onset-rime structure in order to carry such a parsing process out, and this, in turn, makes us wonder whether the Mandarin syllable may have been overanalyzed in its traditional conception.

By the same token, as already noted in the preceding section of this paper, we are, in fact, now coming around to the idea that the Minnan syllable has a much simpler structure that the early experiments seemed to suggest that it had, as well (see Derwing, Wang, & Tsay 2011), an idea that is also bolstered by the Bertinetto hypothesis. At first glance, the syllable-parsing problem might seem to be rather more formidable in the Minnan case, since it adds the four voiceless stops /p, t, k, ʔ/ to the nasals (in this case, three, viz., /m, n, ŋ/) as possible codas.

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13. See Derwing (1992a: 206, fn. 11) on some of the difficulties that native speakers of this language have in identifying and manipulating individual segments, even after considerable exposure to English and its segment-based orthography.

14. Although the working paper cited was co-authored, we assume that this particular idea was Bertinetto's, since it re-appeared without acknowledgment in the single-authored published version of this study (Bertinetto 1999).

but in reality there is actually no major new complication involved. This is because, as Cheng (1973) points out, whenever the stops are involved, one or the other of two unique "entering tones" is attached to the syllable which signals that fact — and the parsing advantage perhaps explains this redundancy. In reality, therefore, the parsing problem in Minnan is essentially the same as in Mandarin, except for the only slightly increased ambiguity introduced by the possibility of one more nasal in the coda position. This reinforces our conviction that the same "whole syllable" treatment that seems appropriate for Mandarin is likely also true for Minnan.

The Korean case is somewhat more complicated, and there is no space to develop it here, but it is probably worth pointing out that (1) as with both Mandarin and Minnan, the syllable-internal phonotactics of the language are again very simple, with (2) the number and variety of possible onset consonants again greatly exceeding those that may appear in the coda, a disparity that also seems to be well motivated from the standpoint of Bertinetto's theory. We are therefore encouraged to go back and look at the Korean case further, to see if our earlier experiments may have caused us to overanalyze the Korean syllable, as well.

Unfortunately, there is a problem with the idea of a universal syllable-based parser, as Bertinetto himself noted in the published version (1999) of the working paper cited above, and this is the finding by Cutler et al. (1986) that the syllable did not seem to play any role at all in the segmentation of English, although it did do so in French (Mehler et al. 1981). The suggestion that Cutler and company offer for this difference also makes very good sense, namely, that "the lack of clear syllable boundaries" in English — a phenomenon well documented in the kind of findings summarized in Table 1 above — make the syllable an impractical vehicle to use as part of a segmentation strategy in this particular language.

However, if we have learned anything from research in this area over the past few years, it is the danger of jumping to conclusions on the basis of the results of one single study, using a single experimental technique, and it would be imprudent to generalize very far with the findings of Cutler et al. (1986), as well, given the limited range of syllable types and languages that were actually dealt with.[15] Is the lack of clear syllable boundaries, for example, a peculiarity of English alone, or do many or all languages with complex phonotactics reveal the same kind of uncertainties? This question in itself now becomes a motivation for a future line of research. But even if the string-parsing role of the syllable is limited in its application to languages that lend themselves to relatively easy and consistent syllabification, it behooves us to discover precisely which languages those are,

15. Note, too, the seemingly conflicting findings of Smith and Pitt (1999), as related on p. 177 above.

and how complex their phonotactics have to be before a syllable-internal hierarchy becomes necessary. Moreover, whatever the value of his general hypothesis, Bertinetto has identified an intriguing relationship between phonotactic complexity and the complexity of syllable internal structure that seems to be working out in our research, as well, and it will likely prove fruitful to follow this line of inquiry further, whatever its ultimate source or explanation.

In a nutshell, what such ideas provide us with is not simply a reason to continue to pursue this line of research, but also to direct us to those places where the problems may most likely lie — which in this case puts languages with widely disparate phonotactic systems directly under the spotlight.

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