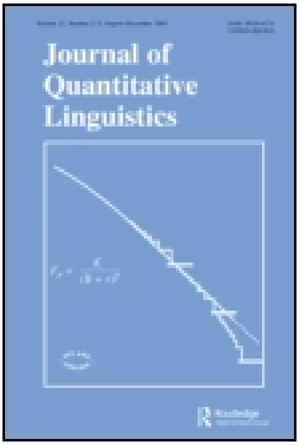

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Syllabification of American English: Evidence from a Large-scale Experiment. Part I*

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Syllabification of American English: Evidence from a Large-scale Experiment. Part I*†

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ABSTRACT

4990 bi-syllabic English words were syllabified by about 22 native speakers who choose between different slash divisions (e.g. *photon:* FOW/TAHN, FOWT/AHN). Results of the regression analyses of the items with one medial consonant are discussed. Consistent with previous studies, consonants were drawn to stressed syllables, and more sonorant consonants were more often placed in the coda. A model in which syllables are made to be as word-like as possible is supported; syllables were often created that begin and end in the same phonemes that are legal word-initially and finally, and syllabifications tended to follow morphological boundaries. Orthographic conventions, such as not placing *ck* or *ll* syllable-initially were also followed.

1. INTRODUCTION

The role of syllables in language processing has been the subject of much attention. For English, however, there is often a lack of consensus about where syllable boundaries fall. Pronunciation dictionaries do not always agree with one another on the location of syllable boundaries. For example, the online Cambridge dictionary[1] gives *bal.ance*, which contrasts with

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[1]dictionary.cambridge.org

Merriam-Webster's[2] *ba.lance*; Cambridge gives *bur.y*, while Merriam-Webster recognizes both *bur.y* and *bu.ry* (a full stop is used to indicate the location of a syllable break). One comparison of syllabifications in two different dictionaries reports different syllabifications in about 25% of the entries (Marchand et al., 2009). Despite the large degree of variability that is sometimes seen (Titone & Connine, 1997, p. 251), the bulk of linguistic research points to the existence of general patterns. Exactly what factors influence syllabification in English and how strongly they influence it is the topic of our study.

Côté and Kharlamov (2011, p. 291) point out two ways in which syllabification may be conceptualized. At one end, the phonological syllable can be seen as a purely abstract constituent upon which experimental results have little bearing. At the other end, syllabification may be considered as a meta-linguistic procedure which results from a complex interplay of phonetic, phonological and morphological factors, including segmental regularities. Phonological processes would then operate independently from syllabification and syllable well-formed-ness.

Analyses that depend on abstract syllabic constituents include those that postulate syllable boundaries based primarily on things such as allophonic distribution. For example, [t^h] is the allophone of /t/ that appears in the onset and glottal stop in the coda. One thing that points to the abstract nature of the syllable in such models is that the relationship between the flap allophone and the syllable varies from one theoretician to the next. For example, Kenstowicz (1994), Selkirk (1982), and Wells (1982) assert that flapping occurs in syllable-final position. Giegerich (1992) on the other hand, contends that the context for flapping is syllable initial position, while according to Kahn (1980) and Gussenhoven (1986) flaps are always ambi-syllabic. It appears that theory-internal arguments (as opposed to empirical evidence) have not been able to resolve the matter. (However, see Eddington and Elzinga (2008) for an experimental approach to this issue.) Relying on internal evidence such as allophonic distribution is problematic in another way. We are fortunate that there are a number of allophones of /t/ in English that may aid in determining syllable boundaries for words containing /t/. However, only a very few English consonants give clues in the distribution of their allophones as to what part of the syllable they belong in. It is for these reasons that we chose to examine syllabification as a meta-linguistic task rather than as an abstract phonological entity.

[2]www.merriam-webster.com

In the present work, we went beyond our own introspections by obtaining data from a large number of native speakers of English. Specifically, we carried out an Internet-based study in which 4990 bisyllabic English words were syllabified by an average of 22 people each. The questionnaire presented words in standard spelling along with a quasi-phonemic transcription of the syllabification options (e.g. *photon*: FOW/TAHN, FOWT/AHN). Test items included words with one to four medial consonants (e.g. *lemon*, *absent*, *central*, *subscribe*), many of them morphologically complex. We analysed the data by means of mixed effects logistic regression, allowing us to examine the relative influence of many different variables.

The organization of the remainder of this paper is as follows. In Section 2, we review previous studies on English syllabification. In Section 3, we introduce our study. Section 4 presents our findings for words with a single medial consonant, and Section 5 is a general discussion of the results.

2. PREVIOUS STUDIES ON ENGLISH SYLLABIFICATION

Several principles governing syllable division have been proposed in previous studies: onset maximization, sonority, phonological legality, stress, morphology and spelling. We review these principles here and discuss the evidence for each.

It is commonly assumed that every syllable has at its core a vowel or syllabic consonant that forms its peak. A principle that figures prominently in many linguists' accounts of syllabification is that a consonant belongs to the same syllable as the following peak (Pulgram, 1970; Hoard, 1971; Hooper, 1972; Kahn, 1980; Selkirk, 1982; Bailey, 1987), This means that the [b] in *debut* is placed with the following vowel rather than the preceding one: *de.but*. Closely related to this is the principle of onset maximization, which states that clusters of consonants between vowels should be syllabified with the following peak, but following the constraints in the language on what constitute legal onsets.

Sonority is also frequently invoked in discussions of syllabification (e.g. Vennemann, 1972, 1988; Murray & Vennemann, 1983). When a syllable consists of several sounds, the most sonorous one is the peak. Sonority is defined according to a scale whose precise formulation differs from researcher to researcher. A typical sonority scale runs as follows: low vowels > high vowels > glides > liquids > nasals > voiced fricatives >

voiceless fricatives > voiced stops > voiceless stops (Giegerich, 1992, p. 133; Blevins, 1995, p. 211), where low vowels are the most sonorous and voiceless stops are the least sonorous. Other versions of the sonority scale combine categories together into single steps in the scale (e.g. Clements, 1990a, 1990b). But all versions of the sonority scale have in common that vowels are more sonorous than sonorants, which are in turn more sonorous than obstruents (Jespersen, 1904; Foley, 1972; Vennemann, 1988; Clements, 1990a, 1990b; Giegerich, 1992; Blevins, 1995; Zec, 1995).

The sonority sequencing principle (Clements, 1990b, p. 285) states that consonants in an onset should rise in sonority and that segments of the rhyme should fall in sonority, though typically not as sharply as they rise in the onset. The ideal sonority profile for the syllable is thus low at the margins and high at the peak. This observation applies not only to individual syllables within a polysyllabic word but also, with a few well-defined exceptions, to words consisting of a single syllable. Thus, individual syllables of polysyllabic words tend to resemble whole (monosyllabic) words.

Experimental studies have shown that VC.V syllabifications are more likely with sonorants than with obstruents (e.g. *cam.el* versus *he.ckle*; Treiman & Danis, 1988; Derwing & Neary, 1991; Treiman et al., 1992; Treiman et al., 1994; Zamuner & Ohala, 1999; Ishikawa, 2002; Moreton et al., 2008). With regard to subdividing sonorants, Derwing (1992) found that [ɹ] was more likely to appear in the coda than [l], which in turn was more likely to appear in the coda than nasals. These results support a role for sonority in syllabification, such that more sonorant consonants are attracted to the coda more than less sonorant consonants.

Principles of phonological legality have also been proposed by several researchers (Anderson & Jones, 1974; Steriade, 1999; Wells, 1990; Martens et al., 2002). A consonant or group of consonants that is prohibited at the beginning (or end) of a word is also prohibited at the beginning (or end) of a word-internal syllable. For example, words in English never begin with [ŋ], so word-internal syllables should not either. In this view, words are syllabified by comparing medial consonant clusters with the clusters that are found word-initially and word-finally and then creating syllables that have the phonotactics of words. Accordingly, the cluster [pɹ] in *approve* will not be divided [pɹ.] since English words do not end in [pɹ]. Syllabifying the cluster as [p.ɹ] or [.pɹ] is legal since word-final [p] and word-initial [pɹ] are widely attested.

Legality may also manifest itself in a prohibition on open syllables containing certain vowels (Hammond, 1997). Because words in English do not end in lax vowels other than [ə], word-medial syllables should not either. Not all linguists agree that legality plays a role in English syllabification, however. Kaye et al. (1990) and Harris (1994) maintain that there is no necessary connection between word margins and word-internal syllabification, since the phonotactics of word-internal clusters differ from those of clusters at word margins. For example, *desks*, *strengths* and *sixths* end with clusters that do not appear word-medially.

Several experiments have tested the role of phonological legality by comparing two-consonant clusters that are legal word-initially, word-finally or neither. In general, clusters that are illegal word-initially appear to be separated word-internally (Smith & Pitt, 1999; Redford & Randall, 2005). The effect of the legality of word-final clusters was tested by Fallows (1981) and Treiman & Zukowski (1990). They found that, *contra* cluster legality, people preferred C.C syllabifications for clusters such as the *nt* of *pontoon* even though *nt* is a legal word-final cluster in English. Clusters that are legal word-initially should appear in the onset of a syllable word-internally if word phonotactics are relevant to syllabification. This is generally the case, except that [s]C clusters are often syllabified C.C (Treiman & Zukowski, 1990; Treiman et al., 1992; Redford & Randall, 2005). For [s]C clusters, this may occur because the clusters do not have an optimal rise in sonority to the syllable nucleus. Clusters such as *sw* and *sl* do provide the optimal sonority transition, yet they too give rise to many C.C syllabifications (Treiman et al., 1992; Redford & Randall, 2005). The experimental results thus suggest three types of clusters. Clusters such as *nt* that are illegal word-initially are usually broken up by a syllable boundary when they appear word-internally. Legal word-initial clusters such as *bl* generally form the onset of a syllable within a word. Finally, [s]C clusters are intermediate between the two: They are legal word-initially, but are often broken up word-medially.

We now turn to the role of stress. It has been claimed that a stressed vowel attracts consonants into its syllable. For some linguists this is a general property of syllabification (Hoard, 1971; Bailey, 1978; Wells, 1990); for others the effect is limited to stressed, lax vowels (Pulgram, 1970). A good deal of experimental work demonstrates that stressed vowels tend to attract medial consonants (e.g. *ér.ie* versus *e.ráse*; Fallows, 1981; Treiman & Zukowski, 1990; Derwing, 1992).

Some linguists have argued that the morphological structure of a word affects its division into syllables (Selkirk, 1982; Borowsky, 1986; Wells, 1990; Derwing, 1992), while Pulgram (1970) argues that it does not. Is [ŋk] more likely to be put in the coda in *blinking* than in *monkey* due the morphological boundary in *blink* + *ing?* Little experimental data is available on the syllabification of morphologically complex words, since most experiments have included only or mainly monomorphemic words. However, Derwing's (1992) subjects often syllabified bimorphemic words along morpheme boundaries. Derwing examined only a small number of bimorphemic words, though, all of which had single medial consonants. He did not compare words with different types of morpheme boundaries, such as compounds and affixed words or words with more and less transparent boundaries. Although Derwing's results suggest that morphology influences syllabification, Smith and Pitt's (1999) results suggest that it may not. The conflicting findings may have to do with the different experimental methods used. In many cases, syllabifying along morpheme boundaries isolates a complete word (e.g. *edit* + *or*) which may indicate a strategy of identifying word-like syllables when possible. The idea that syllable boundaries are made to coincide with morphological boundaries merits further investigation.

Linguists say little, if anything, about the role of spelling in oral syllabification (or phonology, more generally). Because the primary object of linguistic study for the past 100 years or so has been spoken language, orthography is relegated to a supporting role, if mentioned at all. However, experimental studies suggest that spelling affects syllabification even in oral tasks. Specifically, ambisyllabic responses (those that place a consonant in two different syllables) are more frequent for the [b] of a word like *rabbit*, which is represented by an orthographic geminate, than the [b] of a word like *habit*, which is represented by an orthographic singleton (Treiman & Danis, 1988; Derwing, 1992; Treiman et al., 2002). The possible influence of the spelling legality of other letter clusters, such as *ck* of *packet*, has not been considered. Because *ck* does not appear at the beginnings of words, people might avoid placing it at the beginnings of syllables in order to make the resulting syllables look like English words. This aspect of word-likeness was tested in the present study.

Not all of the principles of syllable division can be satisfied simultaneously in all words. For example, in a word like *habit*, onset maximization conflicts with the principle of stress attraction. Onset maximization requires a syllable to have an onset, so *habit* should be syllabified as *ha.bit*. However, stress attraction requires the *b* to be in the coda of the initial syllable, favoring *hab.it*. Some linguists have suggested that ambisyllabicity accounts for this, that is, that the *b* belongs to both syllables simultaneously: (*ha*(*b*)*it*) (Hockett, 1955; Anderson & Jones, 1974; Jones, 1976; Kahn, 1980; Giegerich, 1992).

3. THE BYU SYLLABIFICATION SURVEY

Almost all of the previous experimental work on syllabification has used factorial designs. In such designs, researchers select stimuli that belong to specified categories and compare the results across categories. Typically, each experiment examines one or two factors. A study in which the stimuli varied on a single factor is that of Treiman et al. (2002; Experiment 1). The words in this study were all stressed on the first syllable; of interest was the medial consonant, which was spelled with a single letter, as in *habit*, or a double letter, as in *rabbit*. Experiment 3 of Treiman and Danis (1988) exemplifies a study in which the stimuli varied on two factors. The words all had primary stress on the first syllable and a single-letter spelling of the medial consonant. They varied on whether the first vowel was tense or lax and whether the medial consonant was a liquid, a nasal, or an obstruent. Analyses of variance are well suited for analyzing the results of factorial studies such as these and indicating which factor or combination of factors influences subjects' syllabifications. In Experiment 3 of Treiman and Danis, for example, the analyses used the factors of vowel quality (which had two levels: tense versus lax) and consonant sonority (which had three levels: liquid, nasal or obstruent).

Although factorial experiments have yielded valuable findings, problems can arise when investigators do not report statistical analyses or when there are few words per factor or combination of factors. Factorial studies have some intrinsic limitations as well. One issue is that researchers must equate the items in the different categories for variables other than the one(s) of interest. If spelling is to be a factor, for example, researchers must choose words that differ in their spellings but that are alike in all other respects. Without knowing in advance all the variables that may influence syllabification, this is difficult to do. Results may be misleading if some variable is confounded with the one(s) the researchers have varied. Also, when a number of stimuli potentially fit the parameters of an experiment, researchers may unconsciously select those items that seem better suited for demonstrating the pattern of results that they hypothesize (Forster 2000). Finally, the conclusions that can be drawn from factorial studies are limited by the categories that were chosen in advance.

In response to such issues, researchers in some areas have begun to complement factorial studies with mega-studies. A mega-study includes a large number of items, sometimes even all words of a certain type in a language. The items are not chosen in advance to fit particular cells of a design. If the number of items is very large, it may not be practical for each participant to respond to each one. If so, researchers attempt to ensure that comparable subgroups of participants receive each item. Mega-studies have been used in recent years in research on reading, where researchers are interested in the factors that make some printed words easier to recognize and pronounce than others (e.g. Treiman et al., 1995; Balota et al., in press; Balota et al., 2004, 2007; Kessler et al., 2007; Macizo & Van Petten, 2007; Keuleers et al., 2011). The results from mega-studies complement and extend results from studies using factorial designs.

Logistic regression is particularly useful in analysing the results of large studies with many independent variables in which the dependent variable is nominal (e.g. obstruent, liquid or vowel) rather than numeric (e.g. duration, F1 frequency, amplitude). Logistic regression may be carried out even when not all subjects have responded to the same items, which is the case in the present study. The effects of other variables are controlled for statistically after the experiment is complete rather than by matching test items on all characteristics except one prior to administering the experiment. Researchers can determine which variables contribute most to explaining the data.

In sociolinguistics, for example, logistic regression is used to determine how linguistic and social variables such as phone type, phonetic context, age, social class and gender influence pronunciation or grammatical usage. In particular, does each predictor variable make a significant contribution to the prediction of the dependent variable once the influences of other predictors have been taken into account? If so, logistic regression provides numeric values that allow the relative influence of each variable to be compared. In addition, a measure of the relative influence of the individual values of a variable is calculated. In the present study, we use a mega-study to investigate syllabification, a topic that has not previously been investigated using this method, and we analyse the results using mixed effects logistic regression where subject and word are random factors.

3.1 Participants

The majority of the participants were students at Brigham Young University, although colleagues at several other US institutions also encouraged their students to participate.[3] Announcements encouraging students to participate were sent to all faculty members in BYU's College of Humanities and to specific faculty members in other colleges at BYU. Some faculty

[3]IRB approval was granted from the BYU Office of Research and Creative Activities.

members gave their students extra credit as an incentive for participation and others did not. Of the 942 completed surveys, 66 were discarded because the subjects indicated that they were not native speakers of American English. Once these were eliminated, 816 native English speakers took one subset of the survey, 15 took two subsets, and 10 took three subsets (see Section 3.3). In total there were 841 participants, of whom 523 were females and 318 were males. Of these, 81 were 18 years old or under, 707 were 19 to 28 years old, 26 were between 29 and 38, 15 were between 39 and 48, and 12 were 48 or older.

3.2 Experimental Items

The survey included 5000 bisyllabic English words taken from an expanded version of the Hoosier Mental Lexicon (Pisoni et al., 1985). We chose words that ranged from highly frequent (*about*, *never*) to infrequent (*deaden*, *hallow*) and we included both morphologically simple and complex words. Each word contained between one and four medial consonants. We avoided bi-syllabic words such as *eon* and *chaos* that have no medial consonant. Decisions about the number of medial consonants were usually straightforward. However, two sonorants made the process more difficult. One is the glide [j] as in *value* [vælju]. The conflict was, is it an onset consonant, part of the nucleus (see Davis & Hammond, 1995), or both? We considered it to be a consonant. A second issue involved the encoding of the pronunciation of the first syllable rime in words such as *hermit*. Is it an r-coloured vowel [hɝmət], is it a syllabic consonant [hɹmət], is it a vowel followed by [ɹ] [həɹmət], or is it an r-coloured vowel followed by [ɹ] [hɝɹmət]? We used the latter in coding words such as hermit.

3.3 Experimental Design

The 5000 words were pseudo-randomized into 40 subsets of 125 each such that each subset contained items from across the frequency spectrum. Within each subset, the test items were pseudo-randomized so that they did not appear in alphabetical order or in order of frequency. Subjects saw a word in standard spelling and chose which word division option seemed best. The term *syllable* did not appear in the instructions. The response options used a quasi-phonemic transcription, a modified version of the ARPAbet phonetic alphabet (Shoup, 1980). For example, *value* appeared as VALYOO and *boatswain* as BOWSUHN. A forward slash indicated the syllable boundary in each option. For example, *victim* appeared as:

victim

- □ VI/KTUHM
- □ VIK/TUHM
- □ VIKT/UHM
- □ I'm not sure

We chose this method on the expectation that it would promote attention to the spoken forms of words when deciding on their syllabifications and eliminate problems with written letters that are not pronounced (e.g. *castle*, *brightly*). It is possible that the odd spellings of this quasi-phonemic representation may have influenced syllabifications to some degree. However, we trust that viewing a word only once in this form is much less likely to influence responses than the lifetime experience of producing and hearing a word and seeing it in its standard orthography.

Subjects indicated their preference by clicking on the button that appeared next to each option. The options were displayed in a fixed order. The syllable boundary marker appeared before all medial consonants in the first option and moved progressively to the right. The option immediately preceding the *I'm not sure* response had the slash to the right of all medial consonants. For words with more than one possible stress pattern or pronunciation, the transcriptions sufficed to indicate the intended pronunciation. The results for individual words are available online.[4]

Although mega-studies have a number of advantages, as previously discussed, there are also some limitations. For example, it is not practical to obtain detailed information from a large number of subjects, nor is it practical have them return for further testing. One effect of these limitations on our study is that we did not test for ambisyllabicity. Some previous experiments that tested for ambisyllabicity, involved recording the subjects' responses to the same words on two different occasions, with a lapse of several days between the two test sessions. Others provided response options that tested ambisyllabicity (e.g. *habit:* h/abit, hab/bit, hab/it). However, written options for ambisyllabic responses would have been unwieldy and somewhat strange when more than one medial consonant is involved. For example, if ambisyllabicity were included, the responses for *victim* would have been VI/KTUHM, VIK/KTUHM, VIK/TUHM, VIKT/

[4]linguistics.byu.edu/faculty/eddingtond/BYU Syllabification Survey.xls

TUHM, VIKT/UHM. The number of responses for words with three and four medial consonants would have been even larger. Not only would including ambisyllabic responses result in an overly large number of responses to choose from, it would make the statistical analysis unwieldy and less powerful as well. Another limitation of our method is that it does not allow the influence of phonetic characteristics such as aspiration and phone length to be tested. It was not feasible to record each participant's pronunciation of each word given the nature of the presentation and the large number of participants and items.

3.4 Procedure

Because of the large size of our experiment, the study was conducted via the Internet rather than in a laboratory. Subjects could log on at their convenience from any computer connected to the Internet and no time constraints were imposed, although an informal poll of a number of subjects indicated that the experiment took between 10 and 15 minutes. The presentation program assigned each subject one 125-item subset to syllabify in a quasi-random manner. Subjects indicated their age and sex and whether they were native speakers of American English. This method of administration lacks the tight controls of a laboratory, and it is possible that some subjects consulted a dictionary or other people while taking the survey. However, subjects may intentionally give wrong answers or attempt to sabotage an experiment even under the watchful eye of an experimenter in a lab. We trust that the responses of the other 840 subjects would wash out those of a subject or two who may have resorted to consulting other sources or intentionally giving odd answers.

Upon examining the results of the experiment, we discovered that ten of the test items had been presented with an incorrect transcription. We dropped the responses to those items, reducing the number of test words to 4990. After elimination of responses by non-native speakers, the average number of responses to each word was 22.

3.5 Variables

One factor that appears to affect syllabification, as mentioned in Section 1, is the sonority of the medial consonant. Specifically, sonorants in VCV sequences seem to appear more often in the coda of the preceding syllable, whereas obstruents are parsed into the following syllable. In his study of English syllabification, Derwing (1992) further suggested that [ɹ] is more strongly drawn to the preceding vowel than [l] is. We therefore coded the medial consonant as either an obstruent,[5] lateral, rhotic, glide or nasal.

A number of variables were included to assess the role of word-likeness in syllabification. Word-likeness involves whether syllabification parses out an actual English word or results in a syllable that is a plausible English word. One of these variables is phonological legality. It distinguishes consonants that are legal on word edges, that is, those that are legal only word-initially (e.g. [h]), consonants that are legal both word-initially and word-finally (e.g. [s], [b]) and consonants that are only legal word-finally (e.g. [ʒ], [ŋ]). If word-likeness is important in syllabification, consonants that are legal word-initially will be drawn to the onset of the second syllable and those that are legal word-finally will appear more often in the coda.

Previous experiments tested the influence of lax versus tense vowels in the first syllable. Since lax vowels (with the exception of schwa) do not occur word-finally, this appears to be another possible link between syllabification and word-likeness. As a result we modified the lax/tense distinction into a legality variable. Like consonant legality, vowel legality divides vowels such as tense vowels, schwa, and r-coloured vowels, which are attested word-finally, from other lax vowels that do not appear word-finally in American English. For example, the syllabification of *finish* as *fin.ish* may be preferred since it does not place the first [ɪ] in an open syllable, thus making the syllable more wordlike. If vowel legality is a factor, it would alternately allow the [i] in *phoenix* to end the syllable ([fi.nɪks]) given the existence of words such as *Hailey* that end in [i].

We used a similar approach to examine factors related to the conventional spelling of the word, or orthotactic legality. A letter sequence such as *ck* may occur at the ends of words but not at the beginnings, and people may be reluctant to place a [k] in the second syllable when they know that it is spelled *ck*. Consonants with geminate spellings such as *ll* and *gg* may be drawn to the first syllable for the same reason. We counted these geminates as legal in final but not initial position, even though some of them very occasionally occur initially (e.g. *llama*) and not all of them are common word-finally. This coding decision was based on the fact that most geminate consonant spellings that occur in English are acceptable at the ends of words but not at the beginnings. In contrast, spellings such as *wh*

[5]Logistic regression requires at least one instance of every combination of variables. Subdividing obstruents into fricatives, stops or affricates created empty cells, which would make the statistical analysis difficult.

may appear at the beginning of a word but not the end. Sequences such as *th* and single letters such as *b* are acceptable in either position. A few words in the study, such as *cupboard*, have medial consonant spellings that may not appear in either the initial or the final position of a word. The values for this variable were legal word-initially only, legal word-finally only, legal in both positions and legal in neither position.

As discussed earlier, most previous experimental studies of syllabification have included exclusively or primarily monomorphemic words. On the other hand, the present study includes many multimorphemic words. For example, 23% of the test items with a single medial consonant were bimorphemic, allowing us to ask detailed questions about the effects of morphology on syllabification. For some words, such as *alike*, a morpheme boundary appears before the medial consonant (*a* + *like*) and so morphological factors may pull the consonant toward the second syllable. For other words, such as *plating* (*plat* + *ing*), morphological considerations may pull the consonant to the first syllable. There were a small number of bimorphemic words in which the medial consonant belongs to both morphemes, as with the [l] of *woolly* (*wool* + *ly*). Such cases were marked as ambimorphemic and excluded from the statistical analyses.

If morphological effects are found, are they larger for compound words than for other morphologically complex words? Do boundaries that are more transparent affect syllabification more than opaque boundaries? We classified a word as morphologically transparent if it consists of a base and affix such that the affixed word bears a positive semantic relationship to the base and the base does not change phonologically when the affix is added. Words such as *washer* and *remount* fit these criteria. Words with opaque morphology appear to be morphologically complex but the affixed form either has no synchronic semantic relationship to the base, as in *tidings* (from *tide*), or there are phonological differences between the base and affixed form, as in *right/righteous*.

To address the issue of morphological influence, we included the following values in a variable that encodes both the place and type of morphological boundary: morphologically simple (e.g. *debut*); compound words with boundary before C (e.g. *playmate*); compound words with boundary after C (e.g. *without*); words with transparent morphology and a boundary before C (e.g. *prewar*); words with transparent morphology and a boundary after C (e.g. *running*); words with opaque morphology and a boundary before C (e.g. *knowledge*); words with opaque morphology and a boundary after C (e.g. *zealous*). Test words with more than one medial consonant were coded in a similar manner.

The final two variables considered were primary stress and the quality of the vowel in the second syllable. Research discussed in Section 1 suggests that consonants are attracted to vowels with primary stress. The quality of the nucleus of the second syllable is a variable that has not been examined in previous research. For this variable, vowels were divided into tense and lax. The dependent variable in each analysis was the syllable boundary given by each subject to each word.

3.6 Logistic Regression Analysis

We used mixed effects logistic regression to determine which independent variables (stress, morpheme boundary, and so on) influence the nominal dependent variable (place of syllabification in our analyses) and the degree of influence of each independent variable. Subjects and test items were included as random variables. Stepping up and down analyses were carried out using the Rbrul interface (Johnson, 2009) to R (R Development Core Team, 2011).

One requirement imposed by logistic regression is that the independent variables be orthogonal. That is, one variable must not be a subset or superset of another, and each must act independently of the other. Two variables are completely orthogonal when all of the values of one may co-occur with all of the values of the other. Orthogonality also entails that, when considered together, the influence of two independent variables on the dependent variable must be different than the influence predicted by each variable alone. Unreliable statistical results occur when variables are not independent, meaning that lack of independence between variables must be eliminated or minimized (Sankoff, 1978; Guy, 1988; Paolillo, 2002). We achieved this in a number of ways, and the particular method that was used is indicated in each case in the analyses reported below.

In one case, excluding a small amount of data was necessary to make variables independent. This relates to the fact that only 20 test words contained medial glides (e.g. *Maya, reward*) and that many variables did not co-occur with a glide. For example, no test word with a glide is a compound word with a morpheme boundary that follows the glide. Removing these words from the analysis resolved the lack of independence, yet still left us with data from a sizable number of test words.

Combining the values within a single variable is also a way of assuring that variables are independent of each other (Paolillo, 2002; Tagliamonte, 2006). For example, when necessary we recoded the variable that specifies what type of consonant appears word medially (obstruent, nasal, lateral or rhotic) into two values: obstruent versus sonorant. At times, it was impossible to eliminate a lack of independence between two variables by combining or recoding. For instance, in some analyses, phonological and orthographic legality are not independent. Therefore, two separate analyses are needed, one that includes phonological legality and the other, orthographic legality.

In the section that follows, we report the results of the statistical analyses. The degree of influence is indicated by the log odds of the values of each variable. Positive log odds indicate that a variable value favours the syllabification in question, while negative log odds indicate that a value disfavours the syllabification. The further the log odds are from zero, the stronger the influence of the particular value is. The log odds are calculated by taking the influence of all other variables into consideration. A measure of how strongly a variable is associated with the syllabification analysed is the level of significance for each independent variable, which is why exact *p* values are given.

4. RESULTS AND DISCUSSION OF WORDS WITH A SINGLE MEDIAL CONSONANT

Roughly 111,000 lines of data resulted from the study. In order to constrain the length of the present paper we present our findings concerning the syllabification of words with a single medial consonant below. The syllabification results of words with two, three, and four-medial consonants will be presented in a subsequent issue of this journal where the final conclusions will be discussed.

There were 56,385 total responses to the 2546 words with a single medial consonant. We eliminated the 438 responses to the 19 words containing medial [w] and one word containing medial [j] (see Section 3.6), as well as the 419 *I'm not sure* responses. We also deleted the 348 responses to the 16 words that have an ambimorphemic consonant (e.g. *oneness*, *woolly*) which left 55,180 responses. In 73% of these responses the medial consonant was placed in the second syllable, a .C response. In 26%, the consonant was placed in the first syllable, a C. response. Words varied greatly in the responses they elicited. For example, *forearm*, gave rise to only C. responses; other words, such as *hotel*, elicited only .C responses; and many other words, such as *vigil* and *muffin*, elicited both types of responses. As a rough estimate of how much people agreed on their syllabifications, we calculated how many of the 2546 words were syllabified in the same way by 80% or more of the subjects. Half of the words reached this criterion.

We performed three logistic regression analyses in order to examine the linguistic features that are associated with the variations in syllabification across words. Due to the high degree of interrelatedness between phonological legality, orthographic legality, and morpheme boundaries, these variables were included in separate analyses. Table 1 summarizes the results of the first analysis which includes morpheme boundary. The sonority of the consonant was strongly associated with syllabification. For example, words with medial obstruents favour .C syllabification as indicated by a log odds of 1.12. The raw percentage is also telling; 80% of the 37,389 responses to words with a medial obstruent were given .C syllabifications. Nasals also favor being placed into the onset, but to a lesser degree. On the other hand, the low log odds of −1.45 indicates that rhotics disfavour being placed in the onset, meaning that they favour appearing in the coda. Rhotics behave differently than [l] in that [l] appears in the onset more often. This latter result is consistent with proposals that rank [ɹ] higher than [l] on the sonority scale (Jespersen, 1904; Vennemann, 1988; Giegerich, 1992). It also confirms Derwing's (1992) report that [ɹ] was more likely to appear in the coda than [l], which in turn was more likely to appear in the coda than nasals.

Vowel legality also influenced syllabification to a highly significant degree. When the first vowel is illegal word-finally, C. syllabifications are strongly favoured. Vowels that are attested word-finally, on the other hand, favour .C syllabifications. Subjects appear to have applied this word-level phonotactic constraint so that individual syllables obey it as well.

Close inspection of the morphological variable reveals that the existence of any morpheme boundary before the medial consonant favours .C syllabification, while a boundary after the consonant favours C. syllabification. Compound and transparent boundaries are more influential than opaque boundaries since their log odds fall farther from zero. The log odds of 0.05 for morphologically simple words indicates a near lack of preference for either syllabification. The results thus suggest that people tend to make syllable breaks that separate words and morphemes found within a test word, such as *fill* in *filling* and *with* in *without*. This occurs even when the relationship between the base and the derived form is phonologically or semantically opaque, as when *write* is seen in *written* or *foot* in *footage*. In other words, the subjects made divisions that resulted in word-like syllables.

Table 1. Logistic regression analysis of factors that influence the syllabification of words with one medial consonant as .C. Phonological and orthographic legality factors not included.

	Log odds	#	%
Type of medial consonant (p = 5.69e-219)			
Obstruent	1.12	37389	80
Nasal	0.35	7122	70
Lateral	−0.03	5582	67
Rhotic	−1.45	5087	43
Legality of first vowel (p = 2.04e-137)			
Legal	0.60	30572	82
Illegal	−0.60	24608	64
Type of morphological boundary by boundary placement (p = 1.41e-105)			
Compound boundary before consonant	1.88	935	94
Transparent boundary before consonant	1.32	1949	95
Opaque boundary before consonant	0.84	135	90
Morphologically simple	0.05	43024	75
Opaque boundary after consonant	−0.30	1355	69
Transparent boundary after consonant	−0.77	7111	63
Compound boundary after consonant	−3.03	671	26
Stress (p = 2.31e-57)			
Final	0.51	12314	87
Initial	−0.51	42866	70
Quality of second vowel (p = 4.25e-16)			
Tense	0.21	18049	79
Lax	−0.21	37131	71

Notes: #, number of words in a category; %, percent of those words with .C syllabification.

The effect of primary stress syllabification is consistent with the idea that consonants are drawn into stressed syllables. Stressed initial syllables favour C. while stressed final syllables favour .C. Finally, although previous research into syllabification has not looked at the tenseness of the nucleus of the second syllable, we found a significant effect. A tense vowel in the second syllable tends to draw the medial consonant into its onset.

Table 2. Logistic regression analysis of factors that influence the syllabification of words with one medial consonant as .C. Phonological legality included. Morphology and orthographic legality are not.

	Log odds	#	%
Legality of first vowel word-finally (p = 3.35e-106)			
Legal	0.64	30572	82
Illegal	−0.64	24608	64
Type of medial consonant (p = 4.17e-95)			
Obstruent	0.70	37389	80
Sonorant	−0.70	17791	62
Stress (p = 2.28e-92)			
Final	0.64	12314	87
Initial	−0.64	42866	70
Phonological legality of medial consonant word-initially (p = 3.98e-10)			
Legal word-initially only	1.98	393	98
Legal in both positions	−0.50	54353	74
Legal word-finally only	−1.48	434	54
Quality of second vowel (p = 4.29e-09)			
Tense	0.18	18049	79
Lax	−0.18	37131	71

Notes: #, number of words in a category; %, percent of those words with .C syllabification.

Two additional analyses were carried out to evaluate the role of phonological and orthographic legality on syllabification. These variables could not be included in the same analysis because they are not independent of each other or of the morphological variable. As Tables 2 and 3 indicate, the influences of the medial consonant[6], stress, first vowel legality, and second vowel quality differ little from those of the first analysis. However, phonological legality is also a significant factor when it is included (Table 2). Consonants that are legal exclusively in word-initial position strongly favour being placed in the onset of the second syllable. In contrast, consonants that are only legal word-finally tend to be placed in the coda of the first syllable. In like manner, orthographic legality also influences syllabification when it is included in the analysis (Table 3).

[6]The type of medial consonant was merged into sonorant versus obstruent in order to avoid lack of independence between variables in these analyses.

Table 3. Logistic regression analysis of factors that influence the syllabification of words with one medial consonant as .C. Orthographic legality is included. Morphology and phonological legality are not.

	Log odds	#	%
Legality of first vowel word-finally (p = 7.54e-101)			
Legal	0.40	30572	82
Illegal	−0.40	24608	64
Type of medial consonant (p = 3.18e-92)			
Obstruent	0.53	37389	80
Sonorant	−0.53	17791	62
Stress (p = 1.54e-89)			
Final	0.46	12314	87
Initial	−0.46	42866	70
Orthographic legality of medial consonant word-initially (p = 9.24e-35)			
Legal word-initially only	0.81	463	92
Legal in both positions	0.03	36131	79
Legal in neither position	−0.27	3453	72
Legal word-finally only	−0.53	15133	61
Quality of second vowel (p = 4.32e-12)			
Tense	0.20	18049	79
Lax	−0.20	37131	71

Notes: #, number of words in a category; %, percent of those words with .C syllabification.

Spellings that are orthotactically licit word-initially favour placement of the medial consonant in the onset. Conversely, there is a tendency to place the consonant associated with a spelling that is legal word-finally only in the coda. Spellings that are legal in either both positions or neither position have log odds that fall much closer to zero.

Although some of our findings are unique, others confirm those of previous research. Specifically, stressed syllables were found to attract consonants (Hoard, 1971; Bailey, 1978; Fallows, 1981; Treiman and Zukowski, 1990; Wells, 1990; Derwing, 1992). With the exception of schwa, lax vowels are not attested word-finally and as a result tend to attract consonants into their coda (Hammond, 1997) resulting in word-like syllables. Sonorants are also attracted to the coda of the first syllable more than are obstruents (e.g. Derwing & Neary, 1991; Treiman et al., 1992; Zamuner and Ohala, 1999). Previous studies suggested that orthography plays a role in syllabification (e.g. Treiman and Danis, 1988; Derwing, 1992; Treiman et al., 2002), a hypothesis that our data support. Our findings are also relevant to some competing proposals. The hypothesis that word-level phonotactics affect syllable-level phonotactics (e.g. Steriade, 1999; Martens et al., 2002; Redford & Randall, 2005) is supported, *contra* Kaye et al. (1990) and Harris (1994). In like manner, those who suggest that syllable and morpheme boundaries coincide (e.g. Selkirk, 1982; Borowsky, 1986; Wells, 1990; Derwing, 1992) find supporting evidence in our study, while the opposite proposal (e.g. Pulgram, 1970) does not. A new finding is that the tenseness of the nucleus of the second syllable is also influential.

It is heartening to see that the results of the present study support those of so many previous experiments on English even though the methodologies used often differ. This contrasts with Côté and Kharlamov (2011), who found widely differing results from a number of metalinguistic syllabification tasks that each employed a different experimental method. Their findings may contrast with our own for a number of reasons. First, their subjects syllabified nonce words, while ours syllabified real words. Second, their test language was Russian, while ours was English. These reasons point to the fact that investigation into syllabification strategies in different languages, using different methodologies, and different kinds of test items is clearly called for in future studies.

In any event, many of the results of the present study suggest that speakers of English syllabify in order to make syllables as word-like as possible. Syllabifications that yield real words appear to be favoured, as shown by the tendency to divide words at morpheme boundaries especially when the word is a compound. When the syllables are not real words, the results suggest they are divided in order to yield phonotactically or orthotactically plausible words. Thus, because certain vowels are illegal word-finally, a consonant is often placed in the coda of syllables headed by such vowels word-internally which yields word-like syllables. Words also tend to be syllabified in accordance with English orthotactic constraints.

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