An Experimental Approach to Ambisyllabicity in English

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Abstract

The factors that influence native English speakers to make a consonant ambisyllabic is explored in 627 bisyllabic words. The /b/ in habit, for example, was considered ambisyllabic when a participant chose hab as the first part of the word, and later in the experiment, bit as the second. About 20% of the responses were ambisyllabic. For words such as rabbit with a single intervocalic consonant, a strong effect of geminate spelling was found to interact with social variables such that older participants, and those with a college degree made the consonant ambisyllabic more often than younger ones and those without a college degree. The idea that a stressed lax vowel in the first syllable conditions both the ambisyllabicity of the consonant and its geminate spelling is not supported since the two only coincide in 75% of the cases. Ambisyllabicity also occurred more often when the vowel preceding the single medial-consonant was lax, or stressed, or when the medial-consonant was a sonorant rather than an obstruent. The influence of word-level phonotactics on syllabification was clearly evident in responses to words with two medial-consonants. A consonant such as the medial /d/ in standard is attested as the second consonant in the coda of many English words (e.g. lard), as well as in the single-consonant onset of many others; for this reason it is a prime candidate for ambisyllabicity. This contrasts with the /n/ in standard, which is never the first consonant in word-initial cluster (e.g. *ndorf) and therefore, not made ambisyllabic by the participants.

1. Introduction

The idea that a consonant can belong to two syllables at the same time was suggested in the early 20th century (Hermann 1923). On the one hand, the implementation of this notion has been hailed as a formal device that helps account for a number of sticky allophonic variations in English (e.g. Kahn 1976); on the other hand, the very existence of the phenomenon has been flatly denied (Goldsmith 1999, Picard 1984). Rather than explore ambisyllabicity as a universal linguistic strategy, we limit ourselves to testing its role in the English language where a good deal of the literature on the topic has
been focused. There are two questions we address in the present paper: What evidence is there for
ambisyllabicity in English? What factors condition a consonant or consonant cluster to belong to two
syllables at the same time? We first review the formal and experimental literature on the subject. These
suggest a number of conditioning factors for ambisyllabicity which we test by means of an online
experiment. Our method allows us to determine what factors contribute to the ambisyllabicity of a
consonant or consonant cluster, as well as to measure how influential each factor is.

2.0. Ambisyllabicity in the Formal Literature on English

There are essentially three formal arguments for ambisyllabicity in English: (1) ambisyllabicity
is used as a way to resolve conflicting requirements on syllable structure; (2) statements of the
distribution of phones are simpler if ambisyllabicity is assumed; (3) the facts of allophony demand an
ambisyllabic representation. We address each of these arguments in turn.

2.1. Conflicting Syllable Structure Requirements

Giegerich (1992) defends ambisyllabicity on the grounds that it resolves the tension between the
requirement that stressed syllables containing a lax vowel be closed by a coda consonant and the
universal requirement that syllables have onsets when possible. He asserts that ambisyllabicity only
occurs in a particular context: “A consonant is ambisyllabic if it is (part of) a permissible onset (cluster)
and it immediately follows a stressed lax vowel” (172).

2.2. Phonotactics

Arguments for ambisyllabicity arising from the distribution of consonants assume that the same
phonotactic requirements that govern word-initial and word-final clusters also operate in word-medial
explicitly: “We claim that medial clusters are combinations of clusters that can be final in
monosyllables and clusters that can be initial. This is plausible only if we permit overlap: i.e. there is not a proper bracketing.” The claim that word-initial/word-final phonotactics hold in word-medial position is not universally accepted, however. For instance, Harris and Gussmann (2002) explicitly reject this position. As part of a more general program to demonstrate the autonomy of syllable structure from the segmental string, they “relinquish the assumption that onsets and codas slavishly mimic word edges” (2).

2.3. Allophony

Many of the arguments for ambisyllabicity center around /t/ and its allophones in English, particularly [tʰ] and [ɾ]. Kahn (1976) argues that [tʰ] occurs as an allophone of /t/ when it is syllable-initial and not syllable-final (this formulation rules out an ambisyllabic environment). Glottalized [ʔt] occurs when it is syllable-final and not syllable-initial. Flapped or tapped [ɾ] occurs when it is part of both an onset and the preceding coda; that is, when it is ambisyllabic. In this way, Kahn is able to describe the allophony of /t/ using distinct environments for all three allophones. Gussenhoven (1986) refines Kahn’s original analysis for American English and extends it to British English. In like manner, Anderson and Jones (1974) and Anderson and Ewen (1987) use /t/ allophony in their defense of what they refer to as overlapping structure: “A medial sequence like [tr] in petrol has ‘syllable-initial and syllable-final characteristics’. In particular, the [ɾ] is voiceless as in initial [tɾ] clusters, but there is also glottal reinforcement of the [t], as in final position” (Anderson & Jones 1974:8). This means that /t/ is affiliated with both the initial and final syllables simultaneously: (pe(t),rol)².

Hammond (1999) uses allophony and stress placement to determine syllabification generally. Under Hammond’s analysis, syllables containing a non-reduced vowel must be bimoraic. This bimoraic requirement can be satisfied if the syllable contains a tense vowel or diphthong or is closed by a consonant. In addition, voiceless stops are aspirated when they are initial in a stressed syllable.
Therefore, a word like *raccoon* \([\texttt{ək\textsuperscript{h}ùn}]\) must have an ambisyllabic /k/; this consonant serves as the coda of the first syllable to make it bimoraic, and since it is aspirated it must be in the onset of the second syllable: \([(_{1}\texttt{æ}(k^{b})_{1}\texttt{ùn})_{2}]\).

Kiparsky (1979) rejects an ambisyllabic analysis for English flapping. Instead, he analyzes flapping as occurring foot-medially. The consonant /t/ undergoes laxing when it follows a vowel in the same foot. If it is itself followed by a vowel, it then undergoes flapping. If not, it may undergo glottalization. However, this analysis is not incompatible with ambisyllabicity; one might restrict ambisyllabicity to foot-medial position, as Anderson and Ewen (1987) suggest: “Within the foot, ambisyllabicity is preferred, whereas foot boundaries inhibit it: specifically, the salient initial syllable of the foot resists sharing of consonants with the final syllable of the preceding foot” (64).

Selkirk (1982) also rejects Kahn’s ambisyllabic account for flapping as ad hoc. In her alternative account, both glottalization and flapping occur when /t/ is in the coda. The difference between flapping and glottalization is the specification of /t/ as [+release] or [–release], respectively. If /t/ is [+release] and in the coda, it is flapped. If it is [–release] and in the coda, it is glottalized. Selkirk assumes that the default specification for consonants is [+release]; the correct environment changing this specification to [–release] needs to be established. In the examples given by Selkirk, it is clear that [–release] is assigned to /t/ whenever it cannot form a licit onset with a following consonant. Selkirk’s rejection of ambisyllabicity seems to stem from a general discomfort with improper bracketing, since the analysis is no less ad hoc than that of Kahn (1976).

2.4. Objections to Ambisyllabicity

The syllable, and therefore ambisyllabicity, is something that lacks consistent correlates in the speech signal. For this reason, Picard (1984) argues that ambisyllabicity is a vacuous formal device. While we agree the syllable cannot be studied as a phonetic phenomenon, some evidence exists that it is a psychological phenomenon. People appear to group sounds into syllabic units as a number of
online and metalinguistic studies attest (see section 3 below). For example, Stemberger (1983) examined interchanges between phonemes in speech errors. In general, he observed that errors involve exchanges between phonemes in the same syllabic position (e.g. onset interchange: big and fat > fig and bat). However, consonants that are thought to be ambisyllabic because they are preceded by a stressed syllable and followed by a stressless syllable (see Kahn 1976) are often exchanged into either the onset or the coda (e.g. ambisyllabic to coda exchange: effort to make > ekkort to mafe).

Another charge against formal notions of ambisyllabicity is that they are based on the researchers' own intuitions rather than less subjective data. Personal introspections are highly suspect because they allow a theoretician to assert, either consciously or subconsciously, syllable boundaries in a way that best supports his/her own theoretical bent. In some cases, researchers intuitions differ widely. Consider the case of flapping in American English. Kenstowicz (1994), Selkirk (1982), and Wells (1990) 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 (1976) and Gussenhoven (1986) flaps are always ambisyllabic. Who is right? Formalists generally rely on theory-internal arguments to resolve such issues, while psycholinguists insist that evidence must be sought that moves beyond researchers' intuitions, issues of distribution, and theoretical elegance.

This was the motive behind Eddington and Elzinga (2008) whose experiment was devised to resolve the debated issue of where flaps, and other allophones of /t/, appear in the syllable. They found a statistically significant preference for [tʰ] in the onset and [ɻ] in the coda, but American English speakers, it appears, have no consensus about where [ɻ] belongs. They placed it in the onset and coda, and made it ambisyllabic as well. This led Eddington and Elzinga to suggest that ambisyllabicity may be “considered uncertainty on the part of the speakers as to which syllable the consonant belongs” (258). Others have expressed similar sentiments in terms of syllable boundaries not needing to be precisely defined (Kahn 1976), having fuzzy transitions (Kreidler 1989), or varying widely depending on register and dialect (Bailey 1980).
3.0. Ambisyllabicity in the Experimental Literature on English

In an effort to move beyond personal introspection, psycholinguists have utilized a number of innovative techniques to test for ambisyllabicity and to determine what governs it. In the pause-break task (Derwing 1992) participants say words with a pause between the syllables. Producing lemon as lem (pause) mon is evidence that /m/ is ambisyllabic. Using this method, Briere, Campbell, and Saemarmo (1968) report that 22.8% of syllables in the English words they tested were ambisyllabic. Participants in the syllable reversal task (Treiman & Danis 1988) were taught to switch the syllables in bisyllabic words such as lemon. Outcomes such as monlem indicate an ambisyllabic /m/, while monle and onlem do not. In syllable doubling (Fallows 1981), participants repeat the first syllable twice, then at a later date repeat the last syllable twice. Doubling the first syllable of lemon could yield lelemon or lemlemon. Doubling the second syllable could produce lemonmon or lemonmon. The consonant /m/ belongs to both syllables when a particular participant gives lemlemon and lemonmon. Ambisyllabic responses occurred in about 22% of Fallows' responses. A variant of doubling (Eddington & Elzinga 2008, Treiman et al. 2002) is to ask what the first part of lemon is (le or lem) on one occasion and what the second part of lemon is on another occasion (mon or on). Ambisyllabicity of /m/ is observed when the two parts identified are lem and mon.

3.1. Results from the Experimental Literature

The above methods have been applied in a number of studies which have shown that certain phonetic, phonological, and social factors influence ambisyllabicity. For example, ambisyllabicity is found more often when the preceding vowel is lax versus tense (balance vs. valence; Derwing 1992, Treiman & Danis 1988, Treiman et al. 1992, Treiman & Zukowski 1990), as well as when the preceding syllable is stressed versus unstressed (happy vs. appear; Treiman & Danis 1988, Treiman & Zukowski 1990). The nature of the consonant is also relevant; liquids and nasals tend to be ambisyllabic more than obstruents (camel vs. chapel; Treiman & Danis 1988). Ambisyllabicity is also
favored when a consonant is spelled with a geminate (*rabbit* vs. *habit*; Derwing 1992, Treiman & Danis 1988, Treiman et al. 2002, Zamuner & Ohala 1999). However, this effect may be mitigated by age. In one study (Treiman et al. 2002) older children and adults were more likely to make an orthographic geminate ambisyllabic because of their more advanced knowledge of words' spellings. In contrast, Zamuner and Ohala (1999) observed that children who have not yet learned to read tend to make consonants ambisyllabic that are written with geminates. This could mean that the children were influenced by a phonetic correlate that is also responsible for geminate spellings, namely a preceding stressed lax vowel.

4.0. The Word Division Experiment

Previous experimental studies of syllable structure have shed a great deal of light on what influences a consonant to be ambisyllabic in English, but there are limitations to these studies. For instance, with few exceptions (Fallows 1981, Treiman & Zukowski 1990, Treiman et al. 1992), the majority of experiments focus on words with a single medial consonant, while much less is known about what consonant or consonants are ambisyllabic in words such as *abridge* and *metric*. Furthermore, the role that phonotactics plays in the syllabification of consonant clusters is highlighted in some theoretical proposals, but has not been sufficiently tested, nor have possible interactions among the predictor variables.

All previous studies have also been factorial in nature. They involved matching words on all characteristics except the one or two that are thought to influence ambisyllabicitity. For example, the influence of geminate spellings were investigated by observing syllabification differences between words such as *habit* and *rabbit*. One result of this methodology is that it severely limits the number of words that can be used as test items to those that can be easily contrasted. It also limits the number of predictor variables that may be tested in one experiment. In a factorial experiment it is difficult to determine the degree to which different predictor variables affect ambisyllabicitity.
The present study is designed to address these limitations. It contrasts with previous factorial experiments in that it includes a large number of test items that have not been matched or grouped according to predictor variables. Instead, the influence of the predictor variables is determined statistically after the experimental data have been gathered, rather than by matching test items in advance. This requires a large number of test participants, each of whom as a practical matter, respond to only a subset of all test items. Logistic regression is an ideal statistical test for these kinds of data because it allows one to determine whether a predictor variable contributes to ambisyllabicity to a statistically significant degree once the influence of the other variables has been taken into account. In addition, it provides log odds values that allow the relative influence of each value of a predictor variable to be compared to each other.

Previous studies found a number of linguistic variables that influence ambisyllabicity. For this reason the following predictor variables were examined in the present study: (1) the quality of the vowel in the first syllable, (2) the medial consonant, (3) stress, (4) whether the word has an orthographic, word-medial geminate, and (5) whether a word-medial consonant cluster or the consonants it is comprised of are attested word-finally or word-initially. Social information about the participants were also included, namely: 6) gender, 7) age, and 8) level of education. In addition, following Sigley (2003), all two-variable combinations of variables were tested for significant interactions.

4.1. Participants

280 native English speakers responded to the questionnaire. Of these, 73 were male and 207 female. 278 were from the US, one from Canada, and one from the UK. In response to the question “What state feels most like home to you?”. The 278 US participants indicated 35 different states, with some people responding that they had moved so much that no state felt like home. The majority of respondents (74%) indicated having some college education, 23% were college graduates, and 3% had
only a high school education.

4.2. Test Items

Responses were gathered to 627 bisyllabic test words. Of these, 384 contained a single word-medial consonant (e.g. *valid*), 216 had two medial consonants (e.g. *window*), and 27 had three medial consonants (e.g. *destroy*). Given the strong influence of morpheme boundaries on syllabification (Eddington et al. 2011), only monomorphemic words were included as test items. For words with one medial consonant, only those consonants that are attested both word-initially and word-finally were included. For words with more than one medial consonant, the influence of the existence of consonant clusters word-initially and finally in English words was included as a predictor variable. With the exception of geminate graphemes such as *<bb>*, whose influence was assessed in words with a single medial consonant, grapheme combinations such as *<ck>* and *<ng>* that are not licit in both word-initial and word-final position did not appear word-medially in the test items. This was done to control for orthographic influence (see Eddington et al. 2011).

4.3. Design and Procedure

The questionnaire was carried out online using Qualtrics. The authors invited friends and acquaintances to circulate a request to participate in a study to their acquaintances via e-mail, Facebook, and other social media. A link to the questionnaire was included in the electronic request. As an enticement to complete the survey, participants were entered into a drawing for a gift card to a national restaurant chain. Participants were able to complete the questionnaire at their leisure, and no time constraint was imposed.

Upon logging into the questionnaire, participants were asked to read and agree to an informed consent form, and answer a number of biographical questions about their native language, gender, age, region of origin, and education. At that point, native English speakers were assigned to respond to a
subset of the test words. The 627 test words had been randomly divided into 14 test sets containing 44 or 45 test words each, and with each set containing words with one, two, and three medial consonants. The experimental method of the questionnaire was essentially a written version of the verbal experiment paradigm of Treiman et al. (2002). The questionnaire consisted of three parts. In the first, participants were asked to click on a button that identified either the first or last part of all of the 44-45 test words assigned to them. Whether they were asked for the first or the last part of the words in this section was randomized. The order of presentation of the questions in each set was also randomized. Questions that asked for the first part of the word appeared in this format:

What is the first part of *standard*?

- sta
- stan
- stand

Questions that asked for the second part of the word appeared in this format:

What is the last part of *standard*?

- ndard
- dard
- ard

Words with geminate spellings appeared in this format:

What is the first part of *rabbit*?

- ra
- rab (or rabb)

The second section of the questionnaire was designed to distract the participants by focusing them on a different task, namely, determining the number of syllables in 30 unrelated words. In the last section of the questionnaire, the participants determined the first or last part of the words that they were presented in the first section of the survey.
Ambisyllabic responses are those in which a participant placed a consonant in both the first and last part of the word. For example, the <d> in standard is considered ambisyllabic when a participant chose stand as the first part and dard as the second: (stan(d)ard). Ambisyllabicity for words with geminate spellings (e.g. rabbit) were determined in the same way; <b> is ambisyllabic if the first part was rab or rabb and the second part bit or bbit. Although no response graphically divides the geminate consonant, this method still allowed participants to make that consonant ambisyllabic.

4.4 Results and Discussion for Words with One Medial Consonant

Of the 7,649 responses to test items with a single medial consonant, 21.4% placed the consonant in both the onset and the coda. In order to determine what predictor variables condition ambisyllabicity in English, and the relative strength of each variable, mixed effects logistic regression was applied to the task using Rbrul (Johnson 2009), an interface to the R environment statistical software (R Development Core Team 2011). In this and all analyses reported in this paper, participants and test items were included as random effect variables. This helps control for variation in individual participants and test items that is not generalizable to the effects of the predictor variables; it assures that the effect of the predictor variables is significant above and beyond any differences between particular test items or particular participants.

Interactions between variables were tested following Sigley (2003). All combinations of two predictor variables were crossed and the model containing each new interaction variable was compared to the model without any interaction variables. Log likelihood ratio tests were used to determine if a model with an interaction factor provided a significantly better fit than the model without. This procedure produced two significant interactions: geminate spelling by age and geminate spelling by educational level. Because it is not statistically sound to include two interaction variables containing the same variable--geminate spelling in this case--in the same model, two separate analyses were performed. Analysis 1 includes the education by geminate interaction factor, and Analysis 2 the age by
geminate interaction.

The results of the two analyses appear in Table 1. Predictor variables are ordered according to their level of statistical significance. Therefore, age by geminate spelling is the most significant predictor with a \( p \) value so small that it is given in scientific notation (8.18 with the decimal place moved 101 places to the left). The log odds is given for each value of a variable. Log odds close to zero indicate that that value neither favors nor disfavors ambisyllabicity. The larger a positive log odds, the more that value favors ambisyllabicity. The smaller a negative log odds, on the other hand, the less that value favors ambisyllabicity. The raw percentage of ambisyllabic responses appears in the last column, but it is important to note that log odds are calculated by taking all other predictor variables and their effect on ambisyllabicity into account at the same time. One variable may influence responses toward ambisyllabicity, while another variables may exert opposing pressures. Percentages are not an accurate representation of the pull one variable has when the pulls of the other variables are factored out.

**Table 1:** Logistic regression analysis of predictor variables that that favor ambisyllabic responses (over all other types of responses combined) for words with one medial consonant.

<table>
<thead>
<tr>
<th>Age by Geminate Spelling (( p = 8.18 ) e-101)</th>
<th>Analysis 1</th>
<th>Analysis 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Log odds</td>
<td>Log odds</td>
<td>% Ambisyllabic</td>
</tr>
<tr>
<td>----------</td>
<td>----------</td>
<td>----------------</td>
</tr>
<tr>
<td>50+ and Geminate</td>
<td>--</td>
<td>2.76</td>
</tr>
<tr>
<td>40s and Geminate</td>
<td>--</td>
<td>1.45</td>
</tr>
<tr>
<td>30s and Geminate</td>
<td>--</td>
<td>0.88</td>
</tr>
<tr>
<td>20s and Geminate</td>
<td>--</td>
<td>0.32</td>
</tr>
<tr>
<td>40s and Non-geminate</td>
<td>--</td>
<td>-1.26</td>
</tr>
<tr>
<td>20s and Non-geminate</td>
<td>--</td>
<td>-1.27</td>
</tr>
<tr>
<td>50+ and Non-geminate</td>
<td>--</td>
<td>-1.29</td>
</tr>
<tr>
<td>30s and Non-Geminate</td>
<td>--</td>
<td>-1.58</td>
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### Education by Geminate Spelling \((p = 1.55 \times 10^{-79})\)

<table>
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<tr>
<th></th>
<th></th>
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<th>48</th>
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<tbody>
<tr>
<td>College Degree and Geminate</td>
<td>1.56</td>
<td>--</td>
<td></td>
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<tr>
<td>No College Degree and Geminate</td>
<td>0.62</td>
<td>--</td>
<td>32</td>
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<td>12</td>
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<tr>
<td>No College Degree and Non-geminate</td>
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<td>--</td>
<td>9</td>
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### Consonant \((A_1 p = 3.74 \times 10^{-09}, \ A_2 p = 1.47 \times 10^{-09})\)

<table>
<thead>
<tr>
<th>Consonant</th>
<th>Initial</th>
<th>Final</th>
<th>(A_1 p)</th>
<th>(A_2 p)</th>
</tr>
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<tbody>
<tr>
<td>(\tilde{f})</td>
<td>0.69</td>
<td>0.69</td>
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<tr>
<td>(\tilde{a})</td>
<td>0.62</td>
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<td>(\theta)</td>
<td>0.41</td>
<td>0.33</td>
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<tr>
<td>(n)</td>
<td>0.31</td>
<td>0.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(l)</td>
<td>0.26</td>
<td>0.28</td>
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<td></td>
</tr>
<tr>
<td>(m)</td>
<td>0.20</td>
<td>0.18</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(v)</td>
<td>0.05</td>
<td>0.01</td>
<td></td>
<td></td>
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<td>(f)</td>
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<td>0.01</td>
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<td></td>
</tr>
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<td>(g)</td>
<td>-0.05</td>
<td>0.01</td>
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<td>(z)</td>
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</tr>
<tr>
<td>(s)</td>
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<td>-0.09</td>
<td></td>
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<td>(p)</td>
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<td>-0.21</td>
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<td>(d)</td>
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<td>(b)</td>
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<tr>
<td>(t)</td>
<td>-0.41</td>
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</tr>
<tr>
<td>(\delta)</td>
<td>-0.90</td>
<td>-0.98</td>
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### Stress \((A_1 p = 3.47 \times 10^{-06}, \ A_2 p = 1.23 \times 10^{-06})\)

<table>
<thead>
<tr>
<th>Stress</th>
<th>Initial</th>
<th>Final</th>
<th>(A_1 p)</th>
<th>(A_2 p)</th>
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<td></td>
<td>0.27</td>
<td>0.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-0.27</td>
<td>-0.28</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Vowel in First Syllable \((A_1 p = 0.000752, \ A_2 p = 0.000465)\)

<table>
<thead>
<tr>
<th>Vowel in First Syllable</th>
<th>Lax</th>
<th>Tense</th>
<th>(A_1 p)</th>
<th>(A_2 p)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lax</td>
<td>0.18</td>
<td>0.19</td>
<td></td>
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</tr>
<tr>
<td>Tense</td>
<td>-0.18</td>
<td>-0.19</td>
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</tbody>
</table>

### Gender (not significant in either analysis)
The relationship between ambisyllabicity and geminate spelling has been attested in previous studies (Derwing 1992, Treiman & Danis 1988). However, most studies of ambisyllabicity (with the notable exception of Fallows 1981, Treiman et al. 2002 and Zamuner & Ohala 1999) focus strictly on linguistic variables, which is why it is so surprising that extralinguistic variables such as age and education exert such an extremely robust influence here. For words with geminate spellings, older participants were more likely to place the consonant in both syllables. In like manner, participants with college degrees are more apt to make a geminate ambisyllabic that those without a degree. As the log odds indicate, large differences based on age and education do not occur with non-geminates. This corroborates the findings of Treiman et al. (2002) whose six and seven-year-old participants did not give more ambisyllabic responses to words with geminates than to words without geminates. This contrasts with the 11-year-olds and adults who did make consonants written with a geminate ambisyllabic more often than words without geminates (see also Fallows 1981). When taken together, this suggests that people with more experience with English favor an ambisyllabic interpretation of geminates. What this is due to is debatable. One possibility is that older and more educated speakers are more likely to have learned a rule to the effect that orthographic geminates must be separated. Another is that more language experience means having read more, and therefore having seen more words divided with hyphens between their orthographic geminates when they occur across line breaks in written materials.

One question that has been raised is whether geminate spelling either reflects or coincides with some phonetic property of the words, and that it is that property, rather than or in addition to spelling, that is responsible for the higher numbers of ambisyllabic responses. The combination of initial stress and vowel quality could be this phonetic trait. Treiman et al. (2002) searched a dictionary and observed that 66% of bisyllabic English words with one medial consonant that contain a stressed lax vowel in the first syllable are written with a geminate (e.g. rabbit, grammar). In contrast, no words with an initially stressed tense vowel are followed by a geminate (e.g. photo, demon).
Some evidence for this phonetic property comes from Zamuner and Ohala (1999) who trained preliterate children to say words and insert pauses into them. Responses such as \textit{sal [pause] lad} for \textit{salad} counted as ambisyllabic. Even though these children could not read, and should therefore be immune from the influence of written geminate spellings, they tended to make words with geminate spellings ambisyllabic more than those with singleton spellings, suggesting that some phonetic correlate is responsible. However, this positive evidence is contradicted by Treiman et al. (2002) whose six- and seven-years-old participants did not give more ambisyllabic responses to words with geminate spellings than to non-geminates.

Therefore, the question that presents itself is whether gemination and its phonetic correlate (stress and vowel quality) are one and the same. The results of the present study indicate that both stress and vowel quality exert an influence above and beyond the geminate interactions, and are therefore separate influences. As previous research has shown (Derwing 1992, Treiman & Danis 1988, Treiman et al. 2002), lax vowels that precede the medial consonant favor more ambisyllabicity while tense vowels disfavor it. In like manner, a stressed initial syllable favors ambisyllabicity while an unstressed initial syllable disfavors it. Once again, this was presaged in earlier work (Hooper 1978, Kahn 1976).

Could the phonetic correlate be an interaction between the vowel quality and stress of the first syllable? This is not likely either. When these two predictor variables were crossed, the resulting interaction variable did not significantly add to the prediction of ambisyllabicity, nor did it improve the fit of the model. In fact, the interaction variable did not help predict ambisyllabicity to a statistically significant level, while stress and vowel quality by themselves were very significant predictors (see Table 1). In addition, the overlap between ambisyllabic responses to words containing geminates and words containing initial stressed lax vowels is not large. Of the 1211 responses to test items with geminates, 913 (75.4%) also have stressed lax vowels in the first syllable. Both of these variables favor ambisyllabicity, but they are not as mutually inclusive as one would expect if they were instantiations
of the same influence.

The medial consonant also affected ambisyllabicity. In a previous study (Treiman & Danis 1988), liquids and nasals were more often ambisyllabic than obstruents. In the present study, liquids and nasals did favor ambisyllabicity more than most obstruents. However, the fricatives /ʃ/ and /θ/ also favor it. Further research is needed to determine if this finding can be replicated, and if so, explain why these fricatives pattern with sonorants in favoring ambisyllabicity.

4.5. Results and Discussion for Words with Two Medial Consonants

The presence of two medial-consonants implies three different outcomes: only the first consonant of the cluster may be ambisyllabic, only the second, or both. Of the 4,209 responses, 6.8% placed the first consonant in both syllables, 9% made the second consonant ambisyllabic, and a miniscule 0.6% placed both consonants in both syllables. The environment for ambisyllabicity may differ in each case which requires three separate analyses. As in the earlier analysis, the quality of the first vowel, primary stress placement, and the age, education, and gender of the participant were included as predictor variables, while participants and test items were random effect variables. The only test items with geminate spellings were approve and suppress, so including a gemination variable would not be very telling.

A new way of encoding the consonants was necessary. Separate variables for each of the two consonants is problematic since they are often interdependent. For example, /s/ is often followed by p, t, k/, but only occasionally by /ʃ/ in English. Previous studies (Eddington et al. 2011, Fallows 1981, Treiman & Zukowski 1990) indicate that word-level phonotactics influence syllabification. Anderson and Jones (1974) and Jones (1976) specifically claim that a consonant that can appear in both the onset and coda of a syllable must be ambisyllabic. For this reason, the presence of a consonant in a cluster that is attested in word-initial or word-final position was included as a variable.
4.5.1. Factors that Influence the Ambisyllabicity of the First Consonant in a Two-consonant Cluster

Consider the /b/ in *abridge*. It is attested at the end of words such as *lob* and *rib* and therefore, could be placed into the coda. At the same time, many words begin with /b/ followed by another consonant (e.g. *black, brown*) so it could also appear in the onset. The fact that the /b/ in *abridge* is attested in both positions makes it a likely candidate for ambisyllabicity. This contrasts with the /m/ in *bamboo* that is only possible word-finally; no English words begin with /mb/ or /mC/ so /m/ cannot be part of the onset in that cluster which make may it less likely to be ambisyllabic. This information was included as a predictor variable. Clusters whose first consonant is attested both word-finally and in word-initial clusters were coded as such (e.g. *abridge, astute*) in contrast to those that are not attested in both positions (e.g. *bamboo, dogma*).

Initial analysis indicates an extremely high degree of interaction between the first consonant of the cluster and whether that consonant is attested in a word-initial cluster. Including both as variables confounds the statistical outcome which should not be surprising given that clusters beginning with /p, t, k, b, d, g, f, s/ are attested word-initially, while clusters beginning with /m, n, r, l/ are not. In order to eliminate the lack of independence between these variables, the first consonant variable was excluded from the analysis. Once this was done, the only predictor variable that favored the ambisyllabicity of the first consonant of the cluster was the word-level phonotactics (see Table 2). Consider the /n/ in *standard* which was not favored to be ambisyllabic. While /n/ is attested in word final position, there are no words that begin with /nd/ clusters. This contrasts with the /s/ in *pastor* that is more likely to be ambisyllabic; it is attested both word-finally in a simple coda and word-initially in a two-consonant onset.

The lack of effect of stress and vowel quality contradicts Treiman and Zukowski (1990). They contrasted /st/ clusters (as an example of /sC/ clusters) with other non-s clusters that are attested word-initially. The first consonant in either type of cluster was ambisyllabic more often when it was preceded by a stressed lax vowel (e.g. *metric, master*) than a stressed tense vowel (e.g. *cloister, apron*).
However, non-s clusters produced significantly more ambisyllabicity when preceded by a syllable with a stressed lax vowel (e.g. *metric*) than when followed by a stressed syllable (e.g. *Madrid*). The same was not found for /st/ clusters (e.g. *master vs. estate*). In the present study, only 15 of the 594 responses to /sC/ clusters have ambisyllabic initial consonants. In like manner, only 10 of the 503 responses to other non-s clusters that are attested word-initially were ambisyllabic. Unfortunately, this paucity of ambisyllabic responses does not allow the influence of stress to be contrasted between /sC/ and non-s clusters with the present data.

**Table 2**: Logistic regression analysis of predictor variables that favor ambisyllabic responses (over all other types of responses combined) of the first consonant of words with two medial consonants.

<table>
<thead>
<tr>
<th>Word-level Phonotactics (p = 1.77 e−23)</th>
<th>Log odds</th>
<th>% Ambisyllabic</th>
</tr>
</thead>
<tbody>
<tr>
<td>First consonant attested word-finally and in word-initial clusters</td>
<td>1.29</td>
<td>17</td>
</tr>
<tr>
<td>First consonant only attested word-finally</td>
<td>-1.29</td>
<td>3</td>
</tr>
<tr>
<td><strong>All Other Variables</strong> (not significant)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.5.2. Factors that Influence the Ambisyllabicity of the Second Consonant in a Two-consonant Cluster

Consider a word such as *vintage* in which /nt/ is attested word-finally and /t/ word-initially. This opens up the possibility of an ambisyllabic syllabification of the second consonant of the cluster: (vin(t)age). In the test items, all of the second consonants in the clusters are attested word-initially in English so the real question is whether the entire cluster is attested word-finally (e.g. /nt/ vs. /nv/). For this reason, whether consonant clusters are attested word-finally was included as a variable in this analysis along with stress, vowel quality, age, gender, and education.

The results of the analysis appear in Table 3. The strongest influence on the ambisyllabicity of
the second consonant is whether it is attested in a two-consonant cluster in English words. The /b/ in harbor fits this criterion. Many English words end in /rb/ and many begin with /b/ which makes /b/ likely to be ambisyllabic. Apart from phonotactic considerations, the second consonant is favored to be ambisyllabic in words that have initial stress. This supports Treiman and Zukowski (1990) who found more ambisyllabicity of the second consonant of a cluster when it appeared following a stressed syllable. For example, the second medial consonant in words such as pontoon was less likely to be ambisyllabic than the second medial consonant in words with initial stress such as pontiff (see also Hooper 1978).

Table 3: Logistic regression analysis of predictor variables that favor ambisyllabic responses (over all other types of responses combined) of the second consonant of words with two medial consonants.

<table>
<thead>
<tr>
<th></th>
<th>Log odds</th>
<th>% Ambisyllabic</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Word-level Phonotactics (p = 9.36 e-07)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cluster is attested word-finally</td>
<td>0.48</td>
<td>11</td>
</tr>
<tr>
<td>Cluster is not attested word-finally</td>
<td>-0.48</td>
<td>5</td>
</tr>
<tr>
<td><strong>Stress (p = 9.06 e-06)</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>0.41</td>
<td>11</td>
</tr>
<tr>
<td>Final</td>
<td>-0.41</td>
<td>5</td>
</tr>
<tr>
<td><strong>All Other Variables (not significant)</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.5.3. Factors that Influence the Ambisyllabicity of the Both Consonants in a Two-consonant Cluster

Only 41 responses places both consonants in both syllables. This small number makes it impossible to investigate the influence of the predictor variables statistically. Nevertheless, a few tendencies are apparent. Lax vowels precede 38 of the 41 instances of ambisyllabic consonant clusters, while 25 of them have final stress. Only 14 of the 41 cases involve clusters, such as /st/, that are
attested in both word-final and word-initial position.

4.6. Results for Words with Three Medial Consonants

Ambisyllabic responses are rare for words of this sort. The 15% of responses that put one or more of the three consonants into both syllables are spread among six categories containing from one to 42 ambisyllabic responses. The first, second, or third consonant is ambisyllabic in 4%, 7%, and 1% of the cases, respectively. The last two consonants are ambisyllabic in 3% of the cases, while in less that 1% of the cases are the first two consonants or all three given ambisyllabic responses. This dilutes the data to the point that most of the values of a predictor variable do not co-occur with those of another, which renders a logistic regression analysis impossible. However, as far as the ambisyllabicity of the second consonant is concerned, there are 42 instances which allows for some tendencies to be mentioned. In 35 of the cases, the second consonant appears in attested word-final clusters (e.g. /p/ in /mp/ as in *impress*) as well in attested word-initial clusters (e.g. /p/ in /pr/ as in *impress*). In addition, 30 of 42 have initial stress.

5. Conclusions

In the present study, 19.6% of the responses were ambisyllabic, which compares favorably with the 22% rate of Fallows (1981) and the 22.8% rate of Briere et al. (1968). Although there have been a number of experimental investigations into ambisyllabicity, most involved small numbers of test items and participants, focused principally on words with one medial consonant, generally did not include social information about the participants as variables, and did not exhaustively test interactions between predictor variables. Furthermore, the factorial nature of the studies did not allow them to include a large number of variables and measure the degree to which each affects ambisyllabic responses. The present experiment was designed to address these issues and thereby shed more light on ambisyllabicity in English.
The most novel findings of the present study have to do with how orthographic geminates affect ambisyllabicity. A significant interaction between variables involving orthographic geminates, age, and level of education was observed to the effect that older participants and those with a college degree make words with geminates ambisyllabic more often than younger participants and those without a college degree. This agrees with Treiman et al. (2002) and Fallows (1981), who both observed a similar interaction for younger children when compared to older children and adults. Since the participants in the present study were all 18 or over, these results extend those of previous experiments and suggest that syllabification strategies are not fossilized at a particular stage of life. We hypothesize that older and more educated speakers may perceive geminates differently, either because they are more likely to have learned a spelling rule to the effect that geminates should be split among syllables, or because their greater experience with the written language means they have had more exposure to written materials that hyphenate between geminate consonants.

Zamuner and Ohala (1999), on the other hand, argue that knowledge of geminate spelling is not relevant, since they found that preliterate children tend to make consonants ambisyllabic that are written with geminates. They propose that that the children were influenced by a phonetic correlate--preceding stressed lax vowels--that is associated with both ambisyllabic consonants as well as geminate spellings. However, in the present study, we registered only a 75% overlap between ambisyllabic responses to words with geminates and those with initial stressed lax vowels. This lack of near-total overlap suggests that orthographic geminates and the presence of preceding stressed lax vowels are distinct phenomena.

The data resulting from the experiment also relates to competing notions about what conditions ambisyllabicity. Some researchers (Anderson and Jones 1974, Jones 1976, and Kahn 1976) assume that word-level phonotactics influence word-internal syllabification, while Harris and Gussmann (2002) deny any relationship between the two. The present study supports the former; the influence of phonotactics was clearly found in responses to words with two medial consonants since a consonant...
that is attested in a particular position both word-initially and word-finally is more likely to be viewed as ambisyllabic. For example, the /t/ in *astute* is often made ambisyllabic. This is due to the fact that many words have /st/ in the onset (e.g. *stare*), and many others have /st/ in the coda (e.g. *past*). On the other hand, the /m/ in *dogma* is not ambisyllabic since, while orthographic <gm> is attested word-finally (e.g., *phlegm*), there are no English words such as *[gmir]*.

Is ambisyllabicity a vacuous formal device? One outcome that must be highlighted is that placing a consonant into two syllables is not a highly common strategy. A number of formal analyses of English assume that ambisyllabicity conditions allophony, but without explicitly examining whether English speakers make a particular consonant in a particular word ambisyllabic or not. If this were done, and only about 20% of the responses to a consonant in a particular position were ambisyllabic, how would that fare for a theory that holds that a particular allophone appears because it is ambisyllabic? The relationship between ambisyllabicity as a formalism and ambisyllabicity as a syllabification strategy of English was not addressed in the present study, but future research needs to compare individual speaker's pronunciations with their syllabification intuitions in order to determine whether a correlation between the two exists. At present, few studies (e.g. Eddington & Elzinga 2008) have empirically tested formal claims about ambisyllabicity and allomorphy in English. Whether demonstrable ambisyllabic and formal proposals about it coincide must be determined experimentally in order to avoid charges that it is an empirically meaningless formal mechanism.
References


Harris, John & Edmund Gussmann. 2002 Word-final Onsets. *University College of London Working


1 We are grateful to Bruce Derwing for his comments and feedback on this paper.
2 We use round brackets to delimit syllables. Matching subscripts are given to opening and closing
brackets. This should not be taken, however, for a proposal concerning the structure of syllables beyond
an indication of the syllabic affiliation of the phones of a word.
3 www.qualtrics.com