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An experimental approach to ambisyllabicity in English

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Abstract
The factors that influence English speakers to classify a consonant as ambisyllabic are explored in 581 bisyllabic words. The /b/ in *habit,* for example, was considered ambisyllabic when a participant chose *hab* as the first part of the word and *bit* as the second. Geminate spelling was found to interact with social variables; older participants and more educated speakers provided more ambisyllabic responses. The influence of word-level phonotactics on syllabification was also evident. 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 such consonants were often made ambisyllabic. This contrasts with the /n/ in *standard*, which is never the first consonant in a word-initial cluster (e.g. **ndorf*) and, therefore, rarely made ambisyllabic in the experiment. Ambisyllabicity was also found 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 idea that a stressed lax vowel in the first syllable conditions both the ambisyllabicity of the consonant and its geminate spelling is not supported.

Keywords
Ambisyllabicity, English, experimental approach, syllabification.

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 idea that a consonant may belong to two syllables at the same time has been hailed as a formal device that helps account for a number of allophonic variations in English, such as flapping (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 process, we limit ourselves to testing its role in the English language, where a good deal of the literature on the topic has been focused. We address a number of questions in the present paper: what empirical evidence is there for ambisyllabicity in English? What factors condition a consonant or consonant cluster to belong to two syllables at the same time? Are there any other factors that condition amibsyllabicity that have not been found in previous studies? We first review the formal and experimental literature on the subject. These suggest a number of conditioning factors for ambisyllabicity which we test experimentally. 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.

1.0. 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.

1.1. 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).

1.2. 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 position (Anderson and Jones, 1974; Jones, 1976; Kahn, 1976). Anderson and Jones (1974, p.4) state this 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) reject this idea. Working within the framework of Government Phonology (Charette, 1990; Harris, 1994; Kaye, 1990; Kaye, Lowenstamm, and Vergnaud, 1990; Scheer 2004), they "relinquish the assumption that onsets and codas slavishly mimic word edges" (2). Thus, in their model the argument for ambisyllabicity from the coincidence of word-edge and word-medial phonotactic requirements is not available.

Another problem for ambisyllabicity within the Government Phonology framework is that ambisyllabicity crucially depends on improper bracketing. Since Government Phonology rejects improper bracketing, ambisyllabicity is not a possible structural configuration (Harris, 1994). While it may be possible to treat ambisyllabicity as a special case of gemination (Borowsky, Itô, and Mester, 1984), phenomena that others use to argue for ambisyllabicity receive alternate explanations in the most extensive treatment of English within Government Phonology, (Harris, 1994, pp. 198-202).

1.3. Allophony

Many of the arguments for ambisyllabicity centre 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 enviroment). 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 defence 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 [r] is voiceless, as in initial [tr] clusters, but there is also glottal reinforcement of the [t], as in final position" (Anderson and Jones, 1974, p.8). This means that /t/ is affiliated with both the initial and final syllables simultaneously: $(_1\text{pe}(_2\text{t})_1\text{rol})_2$.[1]

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* [ɹækʰún] 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: $[(_1\text{ɹæ}(_2\text{kʰ})_1\text{ún})_2]$.

Kiparsky (1979) rejects an ambisyllabic analysis for English flapping. Instead, he analyses flapping as occurring foot-medially. The consonant /t/ undergoes laxing when it follows a vowel in the same foot. If it is followed by a vowel itself, it undergoes flapping. If not, it may undergo

[1] 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.

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 her analysis is no less ad hoc than that of Kahn (1976).

1.4. Objections to ambisyllabicity

Syllable boundaries, and therefore ambisyllabicity, lack consistent correlates in the speech signal. For this reason, Picard (1984) argues that ambisyllabicity is a vacuous formal device. While we agree that exactly where syllable boundaries fall is difficult to study 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 when /t/ is 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 [t^h] in the onset and [ʔ] in the coda, but American English speakers, it appears, have no consensus about where [ɾ] belongs. They placed it in the onset and coda, and made it ambisyllabic as well. This led them 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).

2.0. Ambisyllabicity in the experimental literature on English

In an effort to move beyond personal introspection and theory-internal arguments, psycholinguists have utilized a number of innovative techniques to test for ambisyllabicity and to determine what governs it. For example, in the pause-break task (Derwing, 1992; Ishikawa, 2002) 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 and 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 *lemonon*. The consonant /m/ belongs to both syllables when a particular participant gives *lemlemon* and *lemonmon*. Ambisyllabic responses occurred in about 22% of Fallows's responses. A variant of doubling (Eddington and 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*.

2.1. 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 and Danis, 1988; Treiman et al., 1992; Treiman and Zukowski, 1990), as well as when the preceding syllable is stressed versus unstressed (*happy* vs. *appear*; Treiman and Danis, 1988; Treiman and Zukowski, 1990). Ishikawa (2002) reported an interaction between vowel quality and stress such that ambisyllabicity occurred more often when the first syllable contained a stressed lax vowel. The nature of the consonant is also relevant; liquids and nasals tend to be ambisyllabic more than obstruents (*camel* vs. *chapel*; Treiman and Danis, 1988). Ambisyllabicity is also favoured when a consonant is spelled with a geminate (*rabbit* vs. *habit*; Derwing, 1992; Treiman and Danis, 1988; Treiman et al., 2002; Zamuner and 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 possibly 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.

3.0. 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 and 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 ambisyllabicity. For example, the influence of geminate spellings was 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 ambisyllabicity.

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 odds ratio 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 quality medial consonant; (3) stress; (4) whether the word has an orthographic, word-medial geminate; (5) whether a word-medial consonant cluster, or the consonants it is comprised of, are attested word-finally or word-initially; and (6) the log frequency of the word (Balota et al., 2007). Social information about the participants was also included, namely: 7) gender; 8) age; and 9) level of education. All two-variable combinations of variables were tested for significant interactions as well.

3.1. 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.

3.2. Test items

Responses were gathered to 581 bisyllabic test words. Words were chosen from the English Lexicon Project (Balota et al., 2007) which were sufficiently frequent that they would be familiar to the participants. Their log frequencies ranged from 0 to 13.57. Words were chosen with a variety of word-medial consonants. Of these test items, 355 contained a single word-medial consonant (e.g. *valid*), 199 had two medial consonants (e.g. *window*), and 27 had three medial consonants (e.g. *destroy*). Given the possible influence of morpheme boundaries on syllabification, 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. Words with clusters such as -stl- in *castle*, in which there is a grapheme that is unpronounced, were not included as test items either.

3.3. Design and procedure

The questionnaire was carried out online using Qualtrics.[2] 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 draw 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 581 test words had been randomly divided into 14 test sets of roughly the same size, 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 words in the test set 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:

[2] www.qualtrics.com

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 orthographic geminate spellings appeared in this format:

What is the first part of *rabbit*?

- ra
- rab (or rabb)

Words with other digraphs appeared in this format:

What is the first part of *purchase*?

- pu
- pur
- purch

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 orthographic geminate consonant, this method still allowed participants to make that consonant ambisyllabic.

3.4 Results and discussion for words with one medial consonant

Of the 7,069 responses to test items with a single medial consonant, 21.6% 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. In this analysis, participants were allowed random slopes over the geminate spelling status of the test word and over the quality of the medial consonant. This accounts for the fact that the responses to different kinds of test items by a participant may be correlated. It also helps control for variation in individual participants that is not generalizable to the effects of the predictor variables and assures that the effect of the predictor variables is significant above and beyond any differences between particular participants. We also fit models with random intercepts for individual test words and random slopes for participant over word stress type and the quality of the vowel in the first syllable, but the amount of variation in those cases was not significant, so they were not included as random factors in the final analysis.

Interactions between variables were tested following Sigley (2003). All combinations of two categorical 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 model correctly predicted 87.8% of the responses in Analysis 1, which is 21.7% better than the by-chance accuracy rate of 66.1%.[3] In Analysis 2 the model correctly predicted 87.7% of the items. The results of the two analyses appear in Table 1. The odds ratio is given for each value of a variable. The raw percentage of ambisyllabic responses appears in the last column, but it is important to note that odds ratios are calculated by taking all other predictor variables and their effect on ambisyllabicity

[3] Proportion of ambisyllabic responses (1529/7069) squared plus the proportion of other responses (5540/7069) squared.

into account at the same time. One variable may influence responses toward ambisyllabicity, while another variable may exert opposing pressures. Percentages are not an accurate representation of the pull one variable has when the pulls of the other variables are taken into consideration as well.

	Analysis 1	**Analysis 2**	
	Odds Ratio	Odds Ratio	% Ambisyllabic
Age by Geminate Spelling ($p < .0005$)			
50+ and Geminate	48.66*	--	70
40s and Geminate	16.15*	--	51
30s and Geminate	8.79*	--	41
20s and Geminate	5.04*	--	30
50+ and Non-geminate	1.30	--	11
40s and Non-geminate	Ref. Value	--	8
30 and Non-geminate	1.25	--	10
20s and Non-geminate	1.25	--	10
Education by Geminate Spelling ($p < .0005$)			
College Degree and Geminate	--	13.05*	50
No College Degree and Geminate	--	5.06*	32
College Degree and Non-geminate	--	1.33	12
No College Degree and Non-geminate	--	Ref. Value	10
Consonant (A_1 $p < .0005$, A_2 $p < .0005$)			
Sonorant	1.76*	1.76*	27
Obstruent	Ref. Value	Ref. Value	18
Stress (A_1 $p < .0005$, A_2 $p < .0005$)			
Initial	1.75*	1.72*	23
Final	Ref. Value	Ref. Value	17
Vowel in First Syllable (A_1 $p < .0005$, A_2 $p < .0005$)			
Lax	1.52*	1.50*	25
Tense	Ref. Value	Ref. Value	13
Gender (A_1 $p = .750$, A_2 $p = .851$)			
Female	0.94	1.04	23
Male	Ref. Value	Ref. Value	21
Log Frequency (A_1 $p = .047$, A_2 $p = .038$)	1.04*	1.04*	--

*Significant at $p < .05$

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

For the age by geminate spelling interaction, the reference value was the responses given by 40-year-olds to words without a geminate spelling. None of the other age groups departed significantly from this group as far as words without a geminate spelling is concerned. However, the odds that a word with a geminate spelling (e.g. *letter, lesson, guppy*) would be perceived to have an ambisyllabic medial consonant was significantly larger than the reference group. For instance, the odds of ambisyllabicity are 48 times greater for the 50-year-olds when responding to words with a geminate consonant spelling. What is more, it appears that the older the participant is, the more likely he/she was to give ambisyllabic status to the medial consonant to words with geminates (see Figure 1). On the other hand, no influence of the participant's age was found for words with singleton spellings (e.g. *forest, cootie, copy*).

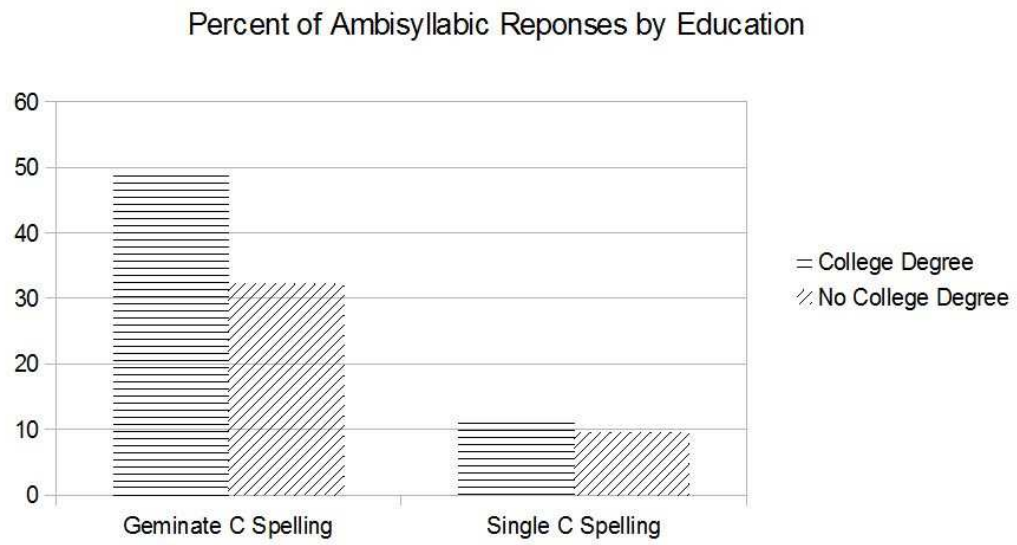

Figure 1: Percent of ambisyllabic responses to words containing a singleton or geminate spelling by the age of the participant.

Another interesting finding is the relationship between educational attainment and geminate spelling. No significant difference was found between the ambisyllabicity rates of words with singleton spellings when syllabified by participants, regardless of whether they had or did not have a college degree. However, the odds that a college graduate would make a word with a geminate consonant ambisyllabic was 13 times greater than a participant without a college degree when syllabifying words with a singleton spelling. The odds are only five times greater for participants without a college degree. This is evidenced most clearly in Figure 2.

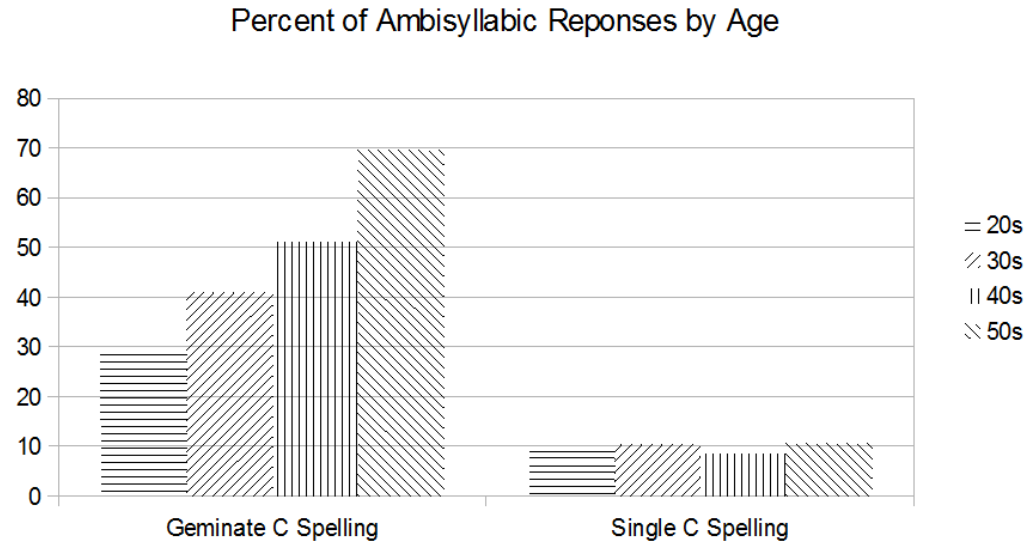

Figure 2: Percent of ambisyllabic responses to words containing a singleton or geminate spelling by the education level of the participant.

The relationship between ambisyllabicity and geminate spelling has been attested in previous studies (Derwing, 1992; Treiman and Danis, 1988). However, most studies of

ambisyllabicity (with the notable exception of Fallows, 1981; Treiman et al., 2002 and Zamuner and 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 than those without a degree. As the odds ratios indicate, 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 orthographic 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 favour an ambisyllabic interpretation of orthographic 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 when hyphenating. Another possible explanation 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 that have one medial consonant and that also 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 a corresponding phonetic property comes from Zamuner and Ohala (1999). These researchers trained preliterate children to say words and insert pauses into them. Responses such as *sal* [pause] *lad* for *salad* counted as ambisyllabic. Even though these children could not read, and should therefore have been 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 orthographic gemination and its possible 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 that of orthographic geminates and are therefore separate influences. As previous research has shown (Derwing, 1992; Treiman and Danis, 1988; Treiman et al., 2002), lax vowels that precede the medial consonant favour more ambisyllabicity while tense vowels disfavour it. In like manner, a stressed initial syllable favours ambisyllabicity, while an unstressed initial syllable disfavours 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? Our results suggest that 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 (contra Ishikawa, 2002). In fact, the interaction variable did not help predict ambisyllabicity to a statistically significant level, while stress and vowel quality by themselves were significant predictors (see Table 1). Again, if a geminate spelling is a graphic representation of a preceding stressed lax vowel, the relationship between gemination and stressed lax vowels would surely be closer to 100% rather than hover around the 66% rate reported by Treiman et al. (2002).

In addition to the influence of the predictor variables already discussed, we observed that the medial consonant also affected ambisyllabicity. In a previous study (Treiman and Danis, 1988), liquids and nasals were more often ambisyllabic than obstruents. In

the present study, sonorants favoured ambisyllabicity more than most obstruents. The effect of word frequency is also a novel finding as far as we are aware. When log frequency increases by one unit, the odds of a word being given an ambisyllabic response increase by 4%.

One concern about carrying out the present experiment in a written rather than oral or auditory format is that the participants may only have been attending to factors present in the written form of the test words. However, we believe this concern is unfounded. Stress, for instance, is not apparent in the written form of English words, nor is vowel quality. For example, <a> and <e> may both represent either a tense or a lax vowel. However, stress and vowel quality significantly influenced the participants' syllabification preferences. This is evidence that these purely phonetic factors, along with the orthographic ones, played a part in the experimental task.

3.5. 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 (e.g. [*sta(n)dard]*), only the second (e.g. *[stan(d)ard]*), or both (e.g *[sta(nd)ard]*). The environment for ambisyllabicity may differ in each case which requires three separate analyses. Of the 3,994 responses, 3.7% placed the first consonant in both syllables, 4.8% made the second consonant ambisyllabic, and a miniscule 0.4% placed both consonants in both syllables. As in the earlier analysis, the quality of the first vowel, primary stress placement, log frequency, and the age, education, and gender of the participant were included as predictor variables. The only test items with geminate spellings were *approve* and *suppress,* so including a gemination variable would not be very telling.

The effect of stress and vowel quality on ambisyllabicity was observed by 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-sC 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 a handful of responses to /sC/ clusters and non-sC clusters were made ambisyllabic by the participants, which does not allow the influence of stress to be contrasted between /sC/ and non-sC clusters in the present study.

Coding both of the consonants in the medial cluster proved challenging. Separate variables for each of the two consonants are problematic since they are often interdependent. For example, /s/ is often followed by p, t, k/, but only occasionally by /f/, in English, and never by /ʒ/. Rather than consider each consonant in isolation, we looked to previous studies (Fallows, 1981; Treiman and Zukowski, 1990) which indicate that it is the word-level phonotactics associated with the consonant clusters that 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 also included as a variable.

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 may make 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*).

3.5.1. Factors that influence the ambisyllabicity of the first consonant in a two-consonant cluster

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 unfortunate outcome was that none of the variables were significant predictors of the ambisyllabicity of the first consonant in a two-consonant cluster. There are too few cases of ambisyllabicity to allow us to carry out a reliable statistical test. One thing to note is that 74% of the cases of ambisyllabic first consonants involve a cluster that is legal word-initially (e.g. *gr, st, fl*). This means that the first member of the cluster is legal both word-finally as well as in a word-initial cluster (e.g. g in *egg, great*). In addition, 61% have initial stress and 95% have an initial lax vowel.

3.5.2. 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. There was significant variability among participants which was accounted for by including a random intercept by participant in the model.

The results of the analysis appear in Table 2. Whether the consonant is attested in a two-consonant cluster in English words influences ambisyllabic responses. The /b/ in *harbour* 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 favoured 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).

It is important to consider the small number of responses that were actually ambisyllabic – between 3% and 6%. In addition to the small number of ambisyllabic responses, there is another reason for treating these results with caution. While the model correctly predicts 95.5% of the responses, the by-chance accuracy rate is 90.8%, which is quite high as well. The model only surpasses the by-chance rate by 8.7%, which suggests that the variables, although statistically significant, aren't accounting for much of the data. We are hesitant to make any conclusions based on these data as a result.

	Odds Ratio	% Ambisyllabic
Word-level Phonotactics (p = .001)		
Cluster is attested word-finally	1.96*	6
Cluster is not attested word-finally	Ref. Value	3
Stress (p = .001)		
Initial	2.00*	6
Final	Ref. Value	3
All Other Variables (not significant)		

*Significant at p = .001

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

3.5.3. Factors that influence the ambisyllabicity of both consonants in a two-consonant cluster

Only 17 responses place 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 16 of the 17 instances of ambisyllabic consonant clusters, while 11 of them have final stress. Only 10 of the 17 cases involve clusters, such as /st/, that are

attested in both word-final and word-initial position.

3.6. Results for words with three medial consonants

Ambisyllabic responses are rare for words of this sort. The 8.3% of responses that put one or more of the three consonants into both syllables are spread among six categories containing from one to 23 ambisyllabic responses. The first, second or third consonant is ambisyllabic in 2.1%, 4.5% and 0.4% of the cases, respectively. The last two consonants are ambisyllabic in about 1% of the cases, while in less than 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 23 instances, which allows for some tendencies to be mentioned. In 16 of the 23 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, 16 of 23 have initial stress, and 16 have a lax vowel in the first syllable.

4. Conclusions

In the present study, 16.7% of the responses made by the subjects were ambisyllabic, which is somewhat smaller than the 22% rate of Fallows (1981) and the 22.8% rate observed by 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.

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 to a small extent; the influence of phonotactics was observed 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 sometimes made ambisyllabic. This appears to be 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 there are no English words such as *[*gmit*]. Of course, the fact that this strategy holds for English by no means implies that having identical word and syllable phonotactics is a universal process in all languages.

It could be argued that the written nature of the experiment is responsible for the subjects tendency to apply word-level phonotactics to the syllable, and that the effect of phonotactics should therefore be considered an artefact of the experimental design. We recognize that orthography was one of the influencing factors in the study, but reiterate that phonological variables

such as stress, vowel quality, and consonant quality affected the outcome as well. This attests to the fact that the participants were also influenced by the phonological properties of the test words that are not derivable from their orthographic representation. What is more, previous studies that did not employ written test items but were carried out with auditory or oral stimuli found those same phonological variables to be significantly related to syllabification.

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 speakers' pronunciations with their syllabification intuitions in order to determine whether a correlation between the two exists. At present, few studies have empirically tested formal claims about ambisyllabicity and allomorphy in English. Whether demonstrable ambisyllabicity and formal proposals about it coincide must be determined experimentally in order to avoid charges that the use of ambisyllabicity in an analysis is a purely formal mechanism that lacks empirical evidence.

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