Word-internal "ambisyllabic" consonants are not multiply-linked in American English

1. Introduction

In this paper, we present two separate sets of arguments that suggest that word-medial consonants that have been called *ambisyllabic* are not multiply-linked to both the preceding and following syllables simultaneously in American English. The first argument is based on a production experiment focused on the anticipatory nasalization patterns conditioned by word-medial nasals in American English. The second argument is based on the phonological devoicing patterns exhibited by word-medial consonants in a dialect of American English, Pennsylvania Dutchified English (PDE). In both cases, our results reveal that the word-medial ambisyllabic segments pattern with word-medial codas,[1] following both tense (long) and lax (short) vowels. Crucially, they show no evidence of an intermediate nature or that they simultaneously act as onsets and codas.

The standard position on ambisyllabic consonants is that they are simultaneously linked to the preceding and following syllables (Gussenhoven, 1986; Hayes, 2009; Kahn, 1976). So, while words such as *dancer* and *dandy* have been analyzed with an [n] that is unarguably in syllable coda positions, words such as *Danny* have been argued to have an [n]

[1] This does not automatically imply that they necessarily *are* codas. The most obvious analysis of the facts is of course that ambisyllabic consonants are indeed codas, and this is the possibility that we will highlight throughout the paper. However, one might be able analyze them as foot-medial onsets. This latter possibility, while not completely problem-free, might still be defensible contingent on other assumptions. This is discussed further in Section 4.

that is simultaneously linked to both the first and the second syllables as depicted in Figure **1**. The typical position for such segments word-medially is between a stressed vowel and an unstressed vowel, e.g. ˈV**C**V. This is the environment that we focus on throughout the paper, though consonants in other positions have also been identified as ambisyllabic, namely, those between two unstressed vowels within a word (e.g., [ɪˌlɛkˈtrɪsɪ**ɾi**] "electricity"), and those that are between vowels straddling a word boundary (e.g., [ˈæ**ɾ** ˈɪʃu] "at issue").

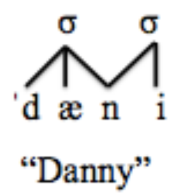

Figure 1: Ambisyllabic nasal consonant in the word *Danny*.

It is important to note that we use the term *ambisyllabic* to identify the relevant segments in American English, namely, those between a stressed and unstressed vowel; however, by using such a term, which is now standard in phonological discussions, we do not intend to suggest any related syllabic analysis of the relevant consonants.

A pattern for which the special status of ambisyllabic consonants has been invoked is the flapping of alveolar stops in American English (Gussenhoven, 1986; Hayes, 2009; Kahn, 1976). In what follows, we use flapping to exemplify, but not motivate, the use of multiply-linked representations (the standard position) to analyze the target segments of interest, namely, those between a stressed and unstressed vowel in American English. As presented in

Table **1**, which lists words with aspirated/glottalized/flapped variants of /t/, voiceless alveolar stops that are clearly in onset position are realized as aspirated, while those that are clearly in coda positions are typically realized as glottalized, and those following a stressed syllable and preceding an unstressed syllable are realized as flaps. To account for the fact that the relevant flapped segments behave differently from both typical onsets and codas, some have proposed a multiply-linked representation (Gussenhoven, 1986; Hayes, 2009; Kahn, 1976).

Aspirated		**Glottalized**		**Flapped**	
[ˈ**tʰ**æksi]	‘taxi’	[mæˀ**t**]	‘mat’	[ˈmæ**ɾ**ɚ]	‘matter’
[əˈ**tʰ**ɛmt]	‘attempt’	[ˈæˀ**t**ləs]	‘atlas’	[ˈfæ**ɾ**ɚ]	‘fatter’
[ˈsæˌ**tʰ**ɑɹ]	‘satire’				

Table 1: Flapping in American English

The crucial arguments presented for such multiply-linked representations can be boiled down to two analytical strategies: (a) evincing phonological *alternations* that show that ambisyllabic consonants behave differently from both onsets and codas, (b) evincing *phonotactic* arguments that show ambisyllabic consonants behave like both onsets and codas. However, showing that ambisyllabic consonants are subject to alternations that are different from prototypical onsets and codas does not provide strong evidence of multiple-linkage of such consonants. This is because, to establish the multiple-linkage representation in the first place, such analyses still depend on further prosodic conditions that separate ambisyllabic consonants from prototypical onsets and coda. If so, the prosodic conditions could be used directly without the intermediate step of creating multiply-linked representations to account for the patterns adduced. For example, word-medial multiply-linked representations needed in such accounts of ambisyllabicity are seen to be triggered by stress location, i.e., a segment in onset position is also attracted to the preceding syllable if that syllable is stressed; therefore, there is a unique multiply-linked representation that can now be the target of a process such as flapping. However, as should be clear, the same environment for a process, such as flapping, is equally identifiable from the stress facts themselves; therefore, it seems a priori simpler to account for it using the stress, or more generally, prosodic, facts. What would be much more convincing evidence of such a representational analysis of multiple-linkage are patterns that reveal that ambisyllabic consonants are subject to alternations that target both onsets and codas simultaneously[2]. To our knowledge, such patterns have not been provided by proponents of multiple-linkage representations for ambisyllabic consonants. Furthermore, the use of phonotactic arguments is also subject to criticism as it has been shown recently that such arguments have problems generally with respect to probing syllable-structure affiliations (Berg & Koops, 2015). Given the static (non-alternating) nature of phonotactic generalizations, it has long been argued that phonotactic evidence is weak evidence about phonological representations compared to other sources of evidence such as phonological alternations (Ohala, 1986; Oostendorp, 2013). Berg & Koops further show that large-scale

[2] Note, while at first such patterns seem to be impossible, it is easy to imagine them with a little thought. For example, imagine a language with glottalization *only* in coda positions, and *only* onsets spread nasality regressively; then a multiple linkage analysis of ambisyllabic consonants would predict that ambisyllabic nasal consonants should be both glottalized and should spread nasality.

phonotactic studies of languages reveal that looking at phonotactic evidence *in toto* suggests syllabic analyses that conflict with other lines of evidence[3]. Therefore, the evidence for multiple-linkage is actually weak, at best. A more elaborate discussion of this issue is presented in Section 3.

It is in fact due to the lack of evidentiary strength in the phonological patterns adduced so far, in our opinion, that there are so many other mutually incompatible, but equally successful, analyses of ambisyllabic consonants that have been proposed. The different representational analyses vary depending on whether the vowel before the crucial consonant is tense or lax. In the interest of space, these positions are summarized in Table **2**, which lists the claimed representations for ambisyllabic consonants after lax vowels (first column) and tense vowels (second column) based on specific theoretical reasons proposed by different researchers (third column).

[3] While phonotactic evidence has a long history of being used to infer abstract structure, we are unaware of any work prior to Berg & Koops (2010, 2015) that attempts to probe its justification as a valid source of evidence for syllabic affiliations.

…ˈV_{lax}C V… **[e.g., a$\underline{t}$om]**	**ˈV_{tense}C V** **[e.g., Pe$\underline{t}$er]**	**Suggested reasons**
ambisyllabic	ambisyllabic	Conditions satisfied for multiple linkage (Gussenhoven, 1986; Hayes, 2009; Kahn, 1976)
coda	onset	Due to Weight-Stress Principle (Duanmu 2010)
onset	onset	Due to the Max-Onset principle. Ambisyllabic facts captured through a foot-based analysis (Bermúdez-Otero, 2007; Harris, 2004, 2006; Jensen, 2000; Kiparsky, 1979)
coda	coda	Through (re)syllabification from onset (Borowsky, 1986; Selkirk, 1982; Wells, 1990)

Table 2: Theoretical positions on ambisyllabic consonants.[4]

The issue of ambisyllabic representations has also been probed through experimental techniques since the early 1980s, particularly meta-linguistic syllable-boundary tasks, analysis of speech errors and production experiments. First, a variety of meta-linguistic tasks have been used to argue that ambisyllabic consonants behave like onsets and codas simultaneously (Derwing, 1992; Elzinga & Eddington, 2014; Hayes, 2000; Treiman & Danis, 1988). For example, in a now classic study, Treiman & Danis (1988) gave participants a syllable-reversal

[4] In the case of flapping, all of these analyses have to be further constrained to never happen across Utterance Phrases (Nespor & Vogel, 1986). Thanks to an anonymous reviewer for pointing this out. It is worth noting that the issue of domain-restrictedness is tangential to the current issue of where within the domain does flapping apply. Furthermore, while it is true that Nespor & Vogel (1986) invoke higher prosodic structure to constrain where flapping happens, a closer look at their analysis reveals that they essentially suggest a foot-based analysis (constrained further by the utterance-phrase). Specifically, they argue that flapping happens only to [t] that are [-tense] and are intervocalic, and not [t] that are [+tense]; however, for them, [t] that are [+tense] are only possible foot-initially, and those that are [-tense] elsewhere. Therefore, the aspiration and flapping facts in American English are captured by Nespor & Vogel through an indirect foot-based analysis that is further constrained by higher prosodic structure.

task, where participants had to move the first syllable to the end of the word (e.g., *snowman* → *man*…[pause]…*snow*; *grandfather* → *father*…[pause]…*grand*). The test items included words with word-medial codas, word-medial onsets, and medial ambisyllabic consonants. The participants in their experiment were more likely to associate medial ambisyllabic liquid and nasal consonants with the preceding syllables than with following syllables; however, this pattern was not observed for medial ambisyllabic obstruent consonants. And typically, medial ambisyllabic consonants following tense vowels were more likely to be associated with the following syllables than those following lax vowels (e.g., [ˈto.nɚ] ‘toner’ >> [ˈspæ.nɚ] ‘spanner’). To summarize, the results from these experiments suggest that ambisyllabic consonants are intermediate between codas and onset; they appear to be more onset-like following tense vowels than following lax vowels; and finally, obstruents appear to behave more onset-like than sonorants.

However, the results of such metalinguistic tasks have been questioned by more recent research. As noted by some of the original authors themselves, the tasks are confounded by orthography. So, doubled consonants in the orthography affect such metalinguistic judgments (Derwing, 1992; Elzinga & Eddington, 2014; Treiman & Danis, 1988). Furthermore, such metalinguistic tasks have also be argued to be confounded with word-edge and morpheme-edge judgments (Harris, 2004, 2006; Steriade, 1999). For example, stressed lax vowels are not found at the end of words in English; this might be the reason participants had difficulty in breaking up words with a lax vowel, such as ‘lemon’. In fact, most of the practice items that were given to the participants by Treiman & Danis (1988) involved a morpheme or a word-boundary after the crucial first syllable (e.g., *grandfather, snowman, jetliner, jawbreaker*). Since, the participants were not given any other explicit instructions except that they were going to ‘play a game,’ and they had to figure out the task, they could quite easily have thought of the task as one identifying potential words or morphemes instead identifying the first syllable. Another important point in regard to such experiments is that the results are actually inconsistent with (theoretical) phonological claims about ambisyllabic consonants. Such experiments appear to consistently have data where an ambisyllabic consonant following a tense vowel is largely associated with the following syllable, while those following lax vowels are more ambisyllabic. However, theoretical proposals that provide an account for multiply-linked representations of ambisyllabic consonants *do not* seem to make this distinction (Hayes, 2009; Kahn, 1976), as the phonological patterns used in such arguments always treat ambisyllabic consonants after both tense and lax vowels similarly (e.g., flapping in American English happens after both tense and lax vowels). Furthermore, the theoretical proposals also do not distinguish between sonorant and obstruent consonants. However, as mentioned above, the results in such experiments often show substantial variation based on whether or not the ambisyllabic consonant is an obstruent or sonorant. Therefore, it is unclear that the behavioral evidence discussed above is actually good evidence for multiply-linked representations proposed in the theoretical literature. Finally, while supporting ambisyllabic representations, Treiman and Danis (1988) actually acknowledged that their results were consistent both with theories that analyze ambisyllabic consonants as multiply linked (Kahn, 1976), and with theories that analyze ambisyllabic consonants as re-syllabification to codas (Selkirk, 1982).

Second, another very interesting line of experimental research that has figured in the discussion about ambisyllabic consonants is from speech errors. As has been observed by a number of researchers, speech errors appear to largely respect syllable positions, i.e., two segments that interact are either both in onsets or both in codas (Fromkin, 1971, 1973; Meringer & Mayer, 1895; Shattuck-Hufnagel, 1979, 1979, Stemberger, 1982, 1983). Stemberger (1983) points out that in his corpus of speech errors, while typical onsets interact with other onsets, and typical codas interact with other codas, ambisyllabic consonants[5] interact with both onsets and codas. In his corpus, 108 ambisyllabic consonants interacted with onsets, while another 72 of them interacted with codas. He argues that the results are difficult to account for if such consonants are viewed as linked to just the preceding or just the following consonant. However, the results are also difficult to square with multiply-linked representations[6]. While at-first-sight they appear to be good evidence for multiply-linked ambisyllabic consonants, it is unclear what linking hypothesis between the theoretical claims and the experimental results will allow us to see them as such. The multiply-linked representation view suggests that ambisyllabic consonants are *both* in onsets and in codas, and

[5] He is careful to note that he considers only those after stressed vowels, and before unstressed vowels, i.e. ˈVCV.

[6] We note that the following discussion is purely based on the logic of the argument. We were unable to study the actual speech errors involved in detail, as they were not listed in the book. The speech-errors might also be traced back to orthographic confounds; something we cannot confirm or reject due to the lack of access to the actual errors themselves.

not *just* onsets or codas, therefore, it is unclear why such consonants are able to interact with just onsets or codas independently. What would be expected on a precise, arguably rigid, interpretation is that given ambisyllabic consonants have a syllabic affiliation neither like regular onsets nor like regular codas, therefore, they should only interact with other ambisyllabic consonants; however, this is not the case. Furthermore, as with the previous line of research, it is unclear how much of the data could be attributed to the different prosodic structures of the segments involved.

Finally, there have also been a variety of production experiments that have attempted to answer the question of how ambisyllabic consonants are syllabically represented (Gick, 2003; Krakow, 1989, 1999; Scobbie & Wrench, 2003; Sproat & Fujimura, 1993; Turk, 1994). For example, in a production study looking at the magnitude of the velum movement during nasal consonants, Krakow (1989, 1999) showed that an [m] in some intervocalic contexts (e.g., ‘homey’ and ‘seamy’) behaved like codas in terms of both maximum velic lowering and duration of the velic plateau, while in other intervocalic contexts behaved like onsets (e.g., pomade); and the [m] in some other words appeared to be inconsistent (e.g.. ‘Seymour’, ‘helmet’). In another production study, focusing on the gestural dynamics of the ambisyllabic consonant [l], Gick (2003) argued that the [l] in the phrase ‘hall otter’ has durational properties intermediate between the [l] in the phrase ‘hall hotter’ (where it is a coda), and the phrase ‘ha lotter’ (where it is an onset). He suggested that this intermediacy is a manifestation of different syllabic affiliations of the [l] in the three phrases; thereby, suggesting that the ambisyllabic [l] is syllabically different from both onsets and codas [l].

As can be seen from the brief summary above, the results from previous production studies have been inconclusive. Some have claimed that ambisyllabic consonants largely pattern with codas (Krakow, 1989, 1999; Turk, 1994); others have claimed that they are intermediate between onsets and codas (Gick, 2003); and some others have argued that there is too much gradience in the phonetics to allow for an abstract categorization (Sproat & Fujimura, 1993). The inconsistent nature of the results could be attributed to at least two separate factors. First, there has been a conflation of *ambisyllabic* consonants with *intervocalic* consonants; however, as noted above, consonants that are followed by a vowel with secondary stress in American English, though intervocalic, indisputably pattern with proto-typical onsets in phonological patterns, and should not be lumped with ambisyllabic consonants. Second, some of the results are also confounded by domain-edge effects; for example, the [l] in Gick's stimuli was either before a word boundary or after a word-boundary; however, such contexts are known to be affected by domain-edge (durational) effects (Cho, Keating, Fougeron, & Hsu, 2003; Fougeron & Keating, 1997). Therefore, such domain-edge lengthening and strengthening effects most probably affected the measurements made.

Before summarizing the preceding discussion, we note that our brief evaluation of the previous (particularly, experimental) literature might allow one to misconstrue us as being dismissive. However, far from it, we intend the criticism as a means for a more constructive dialogue between theory and experiments, and we hope minimally that it will allow researchers with different views on ambisyllabic consonants to more carefully address discrepancies between (and problems with) the multiple lines of evidence that have been used in the debate on ambisyllabic representations.

Summarizing the above discussion, we suggest there is a need for more appropriate experimental controls in studying the issue of ambisyllabic representations. One way in which this can be achieved is by focusing purely on word-internal ambisyllabic consonants. In fact, to the extent possible, one should focus on mono-morphemic words to avoid the effect of morphological boundaries – as a consequence of either phonetic domain-edge effects (Cho et al., 2003; Fougeron & Keating, 1997) or paradigm uniformity effects, according to which the phonological exponence of a morpheme in a particular morphosyntactic context could be affected by the phonological alternations of the same morpheme in other morphosyntactic contexts (Raffelsiefen, 2005). A second aspect that is worth probing more carefully is the issue of ambisyllabic consonants following lax and tense stressed vowels, to see if there are any differences between the two contexts. Finally, though the theoretical literature has consistently argued for a uniform treatment of both obstruent and sonorant ambisyllabic consonants, there seem to be some suggestions in the experimental literature that sonorant ambisyllabic consonants behave differently from obstruent ambisyllabic consonants. Therefore, it is also important to present independent representational arguments for both types of consonants.

In the following sections, we present two separate arguments that suggest that ambisyllabic consonants consistently pattern with codas in American English. More specifically, in Section 2, we present the results of a production experiment looking at the anticipatory nasalization of tense and lax vowels that precede word-medial ambisyllabic nasal consonants and compare the nasalization patterns to those of the same vowels before prototypical word-medial coda and word-medial onset nasal consonants. Our results suggest that word-medial ambisyllabic consonants behave like word-medial codas both after tense and lax vowels. In Section 3, we discuss obstruent devoicing patterns from Pennsylvania Dutchified English (PDE) that suggest the behavior for obstruent consonants. Finally, in Section 4, we conclude with a brief discussion.

2. Experiment on American English nasalization

In this section, we present the results of a production experiment on American English speakers focused on the patterns of vowel nasalization due to the following nasal consonant in different syllabic positions. The reason we focus on nasals is that it has been extensively recorded that nasal consonants produce systematic patterns of vowel nasalization based on their syllabic affiliation (Krakow, 1989, 1999, Solé, 1992, 1995, 2007). Therefore, these vowel nasalization patterns can be used to probe the syllabic affiliation of ambisyllabic nasal consonants. In particular, we focus on two questions: (a) What are the vowel nasalization patterns observed before word-medial ambisyllabic nasal consonants, i.e., do word-medial ambisyllabic nasal consonants pattern with word-medial onsets, or word-medial codas, or are they intermediate between the two? (b) Do we see different patterns of vowel nasalization for word-medial ambisyllabic nasal consonants following tense and lax vowels? The reason we focus on word-medial segments is to avoid confounds due to domain-edge effects (Cho et al., 2003; Fougeron & Keating, 1997). And the reason we look at both tense and lax preceding vowel contexts is because, as discussed in the preceding section, at least some theoretical and experimental work has argued for different syllabic affiliations of ambisyllabic consonants based on the quality (or length) of the preceding vowel.

Based on Krakow (1989, 1999), we expect that nasals in coda positions will induce more overlap of nasalization with the preceding vowel than nasals in onset position, i.e., coda nasals are expected to cause more vowel nasalization than onset nasals. The crucial question is of course: how do word-medial ambisyllabic nasal consonants pattern? In what follows, we show that the percentage of vowel nasalization due to word-medial ambisyllabic nasal consonants is not different from that due to word-medial coda consonants after both tense and lax vowels in American English. In fact, when the relevant confounds are controlled for, there is no evidence of an intermediate nature of ambisyllabic consonants that has previously been claimed.

2.1 Method

2.1.1 Stimuli

The test items were all real[7] English words that had the nasal consonants [n] and [m] in four different environments: word-medial ambisyllabic context, word-medial coda, word-medial onset of a syllable with secondary stress, and word-final coda (Table **3**). Word-medial

[7] Note, we did not use nonce words, as vowels in different positions need to be stressed for different types of test items, but stress is not orthographically marked in English. So, participants would not know how to stress the nonce words appropriately.

consonants preceding a vowel with secondary stress were chosen particularly because, based on the aspiration and flapping generalizations, there is a clear consensus that these consonants are in the onset of the following syllable in American English. The two pre-nasal vowels we used were lax [æ] and tense [oʊ][8]. These two vowels were chosen since there is no lexical gap among all four environments. All the test items also had primary stress on the first vowel.

	Ambisyllabic nasal	Word-medial nasal coda	Word-medial onset	Word-final coda
V1= lax [æ]	ˈg**amm**a	ˈg**am**ble	ˈg**a**ˌ**m**ete	ˈg**am**
V1= tense [oʊ]	ˈd**on**or	ˈb**on**ehead	ˈg**o**ˌ**n**ad	ˈb**on**e

Table 3: Test items.

It can further be noticed that the vowel following the crucial nasal consonant has not been controlled for in the stimuli. This is because it was impossible to get such a set of words for all four environments. However, there is no evidence that the following vowel affects the vowel nasalization patterns of a nasal consonant onto the preceding vowel in American English. Therefore, any differences in the vowel nasalization patterns observed on a vowel before the different types of nasal consonants are unlikely to be a result of the differences in the quality of the following vowel.

[8] This vowel has also been transcribed as [ow] in the literature.

Another aspect of the stimuli that is important to highlight is the initial consonant. Because our measurements were all acoustic measures, and it is difficult to mark the relevant boundaries in the case of many consonants, we decided it was best to have an initial consonant that was either a voiced obstruent (or a voiceless fricative, if we found any). Non-nasal sonorant consonants were avoided because identifying vowel boundaries adjacent to such consonants is difficult. Nasal consonants were also avoided; while their segment boundaries are reasonably easy to identify, they would have interfered with the nasalization measures of the following nasal consonant. Finally, aspirated consonants were avoided because aspiration has acoustic cues (crucially, increase in F1 bandwidth) that are very similar to nasalization cues (Arai, 2006), and would have led to inaccurate vowel nasalization measurements.

The words used in the fillers were also all real English words that had the phonological structure $(C_1)(V_1)C_2V_2(C_3)$, where V_1 was either [æ] and [oʊ] (Table **4**).

V1= lax [æ]	baggy	dapper	dab	sap
V1= tense [oʊ]	bogus	boka	bogue	soak

Table 4: Filler items.

2.1.2 Participants

Eight native speakers of American English without any speech or hearing problems were recruited for the acoustic data collection. The participants were all students from Michigan State University. Six participants (two male, four female) were selected for the final data analysis. One of the participants who was excluded from the analysis produced the words *gamete* and *gonad* as [gəˈmit] and [gəˈnæd]; thus, the speaker's crucial onset context tokens did not have stress on the first syllable as is necessary for proper comparison with the other word-medial contexts. The second participant who was excluded had poor recording quality (for reasons unknown); the recording had a reasonable amount of ambient noise for us to distrust annotating it. The recordings of both subjects were excluded before any measurements were made. All students received course extra credit for participation.

2.1.3 Procedure

The participants produced 15 repetitions at 3 different speech-rates of 16 English words (8 test and 8 fillers) in the carrier phrase "Say _____ here". Therefore, each participant produced 720 sentences in total (15x3x16=720). We manipulated speech-rate because, as discussed below (Section 2.1.4), our crucial measure was the percentage of nasalization on the vowel preceding the relevant nasal consonant. In this regard, Solé (1992, 1995, 2007) argued that the percentage of nasalization is a more consistent measure (than raw duration) for American English nasalization, especially as it remains roughly constant across multiple speech-rates. Therefore, we originally manipulated the speech-rate to be able to get a good spread of vowel and nasalization durations and thereby get a more accurate estimate of the percentage of nasalization in American English[9].

The stimuli were presented through the experimental software PsychoPy (Peirce, 2007); and the participant productions were recorded through Audacity (Audacity Team, 2014) with a microphone (Logitech USB Desktop Microphone; Frequency Response – 100Hz-16KHz) at a 44KHz sampling rate (16-bit resolution; 1-channel).

The test order included three blocks - one for each speech-rate. At the beginning of each block, the participants were asked to produce the stimulus sentences at a particular speech-rate, namely, Slow, Normal, and Fast. Each of the speech-rate blocks and the target productions within each block were randomized for each participant. To ensure, to the extent possible, that each participant had roughly the same speech-rate for a target speech-rate, we presented participants with a *demo* sentence "Say word here" at the relevant speech-rate before every stimulus. The *demo* sentence was produced by a male American English speaker. The demo sentence had no nasal consonants so as to avoid any undue influence of nasalization patterns from the *demo* sentence.

Furthermore, at the beginning of each speech-rate block, there was a practice block. Each practice block had other real English words in the same carrier phrase. For example, if the first block was a slow speech-rate block, in the practice block, the participant would be

[9] However, as we discuss below, we analyzed the percentage of nasalization, with speech-rate as a factor (therefore, we did not collapse the percentages across speech-rates, as initially planned). In anticipation of our results, we note here that in contrast to Solé's results, there was a small but significant effect of speech-rate on the percentage of nasalization.

prompted with the slow speech-rate *demo* sentence, and then they would see the target sentence, e.g. “Say book here”, on the screen.

2.1.4 Measurements

Previous studies have shown that nasal coda consonants have a substantial influence on the vowel nasalization of the preceding vowel in American English (Cohn, 1993; Solé, 1992, 1995, 2007). More particularly, it has been argued that there is a consistent percentage of vowel nasalization due to a following coda consonant (Solé, 1992, 1995, 2007). Therefore, in this experiment, we measured the total duration of the vowel and the duration of nasalization so that we could calculate the percentage of vowel nasalization for each token.

The recorded test items were analyzed using Praat (Boersma & Weenink, 2015). For each token, the duration of nasalization, and the duration of the whole vowel were measured. The onset of a vowel before the nasal consonant was identified based on the sudden appearance of strong formant structure, and based on a substantial increase in intensity in the waveform. The offset of a vowel was identified again by looking for a sudden flattening out of the waveform (as is common with nasal consonants (Pruthi & Espy-Wilson, 2004)), and a substantial reduction in the intensity of the formants. Finally, the onset of nasalization on the pre-nasal vowel was identified using the following criteria available in spectrographic representations: (a) abrupt decrease in F1 intensity, (b) the appearance of anti-formants (or zeroes), (c) the appearance of a nasal pole (Chen, 1997; Stevens, 1998). In Figure 2, we provide an example of the relevant cues and corresponding annotations made for the tokens, using the single production of the test item *gonad.*

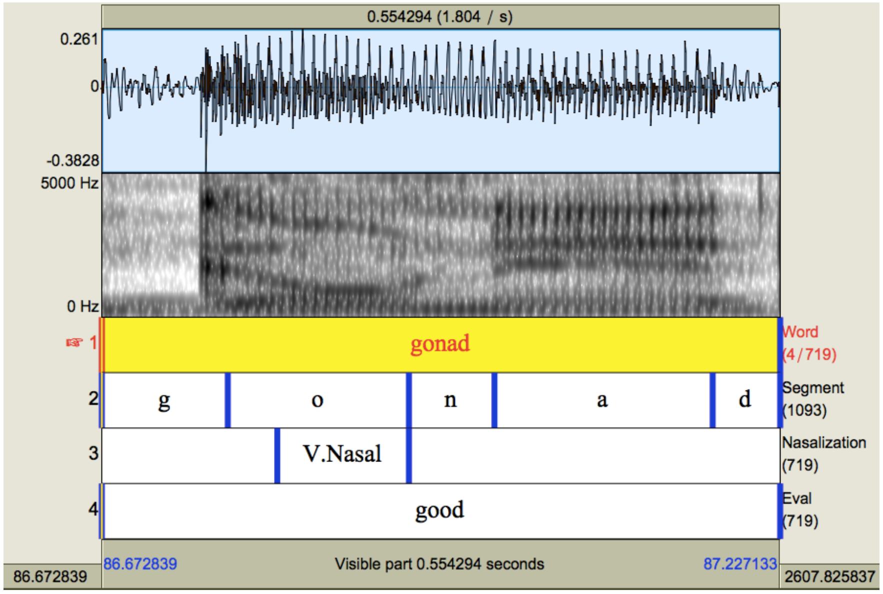

Figure 2: Nasalization measurements for the test item *gonad*. The onset of vowel nasalization (3rd annotation tier) is clearly demarcated by the weakening of F1 intensity, widening of F1 bandwidth, and the sudden disappearance of F3 (most likely due to nasal anti-formants).

The recordings were annotated in Praat for word duration (Word), vowel duration (Segment), vowel nasalization (Nasalization), and acoustic quality of the token (Eval) by two trained annotators (one of whom was a native American English speaker). Each of them annotated the productions of half of the participants. To ensure reliability in marking the vowel nasalization, each annotation was later checked by the other annotator, and in places where there was a disagreement, the two annotators either collaboratively decided on the best point of the onset of vowel nasalization, or the token was discarded due to insufficiently clear cues. A total of 8 tokens out of 2160 tokens (or 0.4% of the data) were discarded. A Praat script was then used to extract the relevant durations from the annotations. These durations were used to calculate the percentage of vowel nasalization of each vowel (vowel nasalization duration * 100 / total vowel duration).

2.2 *Results*

2.2.1 *Nasalization Patterns*

As discussed above, we used the vowel durations and vowel nasalization durations to calculate the percentage of vowel nasalization, following Solé (1992, 1995, 2007). Figure 3 presents six panels in each of which percentage of nasalization in the vowel is plotted across the four positions in a word. The six panels represent the three speaking rates (left to right) and the lax and tense vowels (top, bottom).[10] An initial visual inspection of the results suggested that ambisyllabic consonants following both lax vowels and tense vowels induce roughly the same percentage of nasalization as word-medial codas at all three speech-rates. Furthermore, the ambisyllabic consonants clearly did not pattern intermediate between word-medial onsets and word-medial codas. Finally, nasalization due to word-final coda nasals appeared to be substantially different from that due word-medial coda nasals, particularly at the Normal and Slow speech-rates.

[10] The data from each individual subject for each speech rate are presented in Table A.1 of the Appendix.

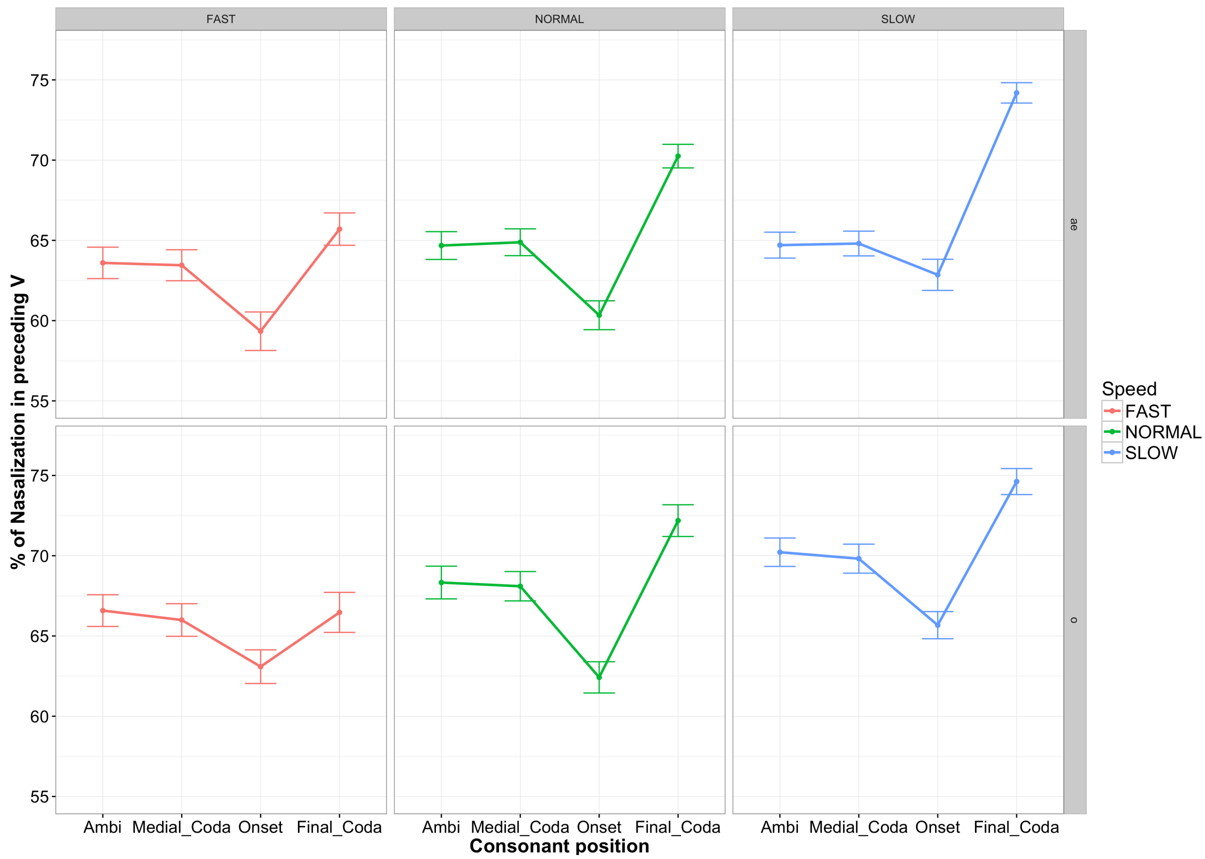

Figure 3: Percentage of nasalization of the preceding vowels ([æ] on top, [o] below) in different syllabic contents spoken at different speeds (Red = fast, Green = normal, Blue = slow). Error bars represent standard error.

The calculated percentages of nasalization were then analyzed using mixed-effects linear regression models in statistical software package R (R Development Core Team, 2014). The models were fitted using the *lmer* function available through the *lme4* package (Bates, Maechler, Bolker, & Walker, 2014). The models we compared all had a random intercept for Subjects and Tokens, and a random slope of *Syllabic position* (SP) for Subjects. Model comparison was performed through backwards elimination of non-significant terms, beginning with the interactions, through a Chi-squared test of the log likelihood ratios. The most complex model entertained was the full model with all interaction terms, and the least complex model entertained was the model with only an intercept term and no fixed effects.

The dependent variable was the percentage of vowel nasalization on the preceding vowel, and the independent variables were *Syllabic position (SP), Vowel Type (VT), and Speed*. The variable *SP* had four levels (Ambisyllabic, Word-medial Coda, Word-medial Onset and Word-final Coda); variable *VT* had two levels (lax vowel [æ] and tense vowel [oʊ]); and the variable *Speed* has three levels (Fast, Normal, Slow). The baseline was the ambisyllabic nasal consonant adjacent to the lax vowel [æ] spoken at the Fast rate; therefore, the intercept term refers to that particular measure.

The model with two interacting factors for *SP* and *Speed* and a non-interacting factor for VT was the best model. This model is shown in more detail below (Table **5**).

Fixed Effects	Estimate	Std. Error	t-value	P-value
Intercept	63.62	1.87	33.94	<0.0001
VT: Tense [oʊ]	2.90	0.67	4.35	<0.05
SP: Medial Coda (MC)	-0.33	1.67	-0.20	0.85
SP: Onset (Ons)	-3.85	1.56	-2.46	<0.05
SP: Final Coda (FC)	1.00	1.69	0.60	0.57
Speed: Normal	1.44	0.89	1.61	0.11
Speed: Slow	2.40	0.89	2.68	<0.01
SP (MC) : *Speed* (N)	0.32	1.27	0.25	0.80
SP (Ons) : *Speed* (N)	-1.27	1.27	-1.01	0.31
SP (FC) : *Speed* (N)	3.69	1.27	2.92	<0.01

SP (MC) : *Speed* (Slow)	0.18	1.26	0.14	0.89
SP (Ons) : *Speed* (Slow)	0.67	1.26	0.53	0.60
SP (FC) : *Speed* (Slow)	5.94	1.27	4.69	<0.001

Table 5: Mixed-effects linear regression model for the nasalization on the preceding vowel

As compared to the baseline ambisyllabic nasal consonant adjacent to the lax vowel [æ] at the Fast speech-rate, there was a statistically significant decrease in percentage of nasalization for the word-medial onset nasal consonant adjacent to the lax vowel [æ] at the Fast speech-rate; however, there was no statistically significant difference compared to the word-medial coda at the Fast speech-rate. Furthermore, compared to the lax vowel [æ] contexts at the Fast speech-rate, the tense vowel contexts have a statistically significant increase in the percentage of nasalization on the preceding vowel. However, there was no interaction, thereby suggesting that the patterns of vowel nasalization observed with both the lax vowel context and the tense vowel context were similar at the Fast speech-rate. The interaction terms for the word-medial SP levels and other speech rates were also statistically non-significant, which suggests that the pattern of nasalization for word-medial nasals found at the Fast speech-rate extends to the other speech-rates. Finally, compared to the baseline, there was a statistically significant increase in percentage of nasalization for Final Codas (FC) in both the Normal and Slow speech rates. This suggests that, while there is no evidence of difference between Final Codas and Ambisyllabic contexts (or word-medial codas) in the Fast speech rate, there is evidence that the percentage of nasalization in the ambisyllabic contexts at the Fast speech-rate was less than that for the Final Codas in the other two speech rates.

2.2.2 *Vowel Durations*

In this section, we present the measurement results of vowel durations in the different contexts. This is to ensure that the above differences in anticipatory nasalization cannot be attributed to differences in vowel duration in different contexts.

Figure 4 presents six panels in each of which the preceding vowel duration is plotted across the four positions in a word. The six panels represent the three speaking rates (left to right) and the lax and tense vowels (top, bottom). As can be seen, the differences in vowel duration between the three crucial word-medial contexts are negligible. Therefore, the differences in nasalization patterns cannot be attributed to differences in vowel duration. The figure also shows that vowels in word-final syllables are substantially longer than those in word-medial syllables; and as with the percentage of nasalization, there appears to an increase in vowel duration of word-final syllables as the speech-rate slowed down. This again is consistent with the expectation of domain-final lengthening that we discussed earlier. Another aspect of the vowel durations that is worth noting is that the vowel durations of the phonological lax vowel [æ] are at least as long as those of the phonologically tense vowel [oʊ]. This might suggest that, at least phonetically, the vowel [æ] is tensed. We return to this issue in the discussion below (Section 2.3). Finally, as would be expected, the vowel durations increase as we go from the Fast to the Slow speech-rate.

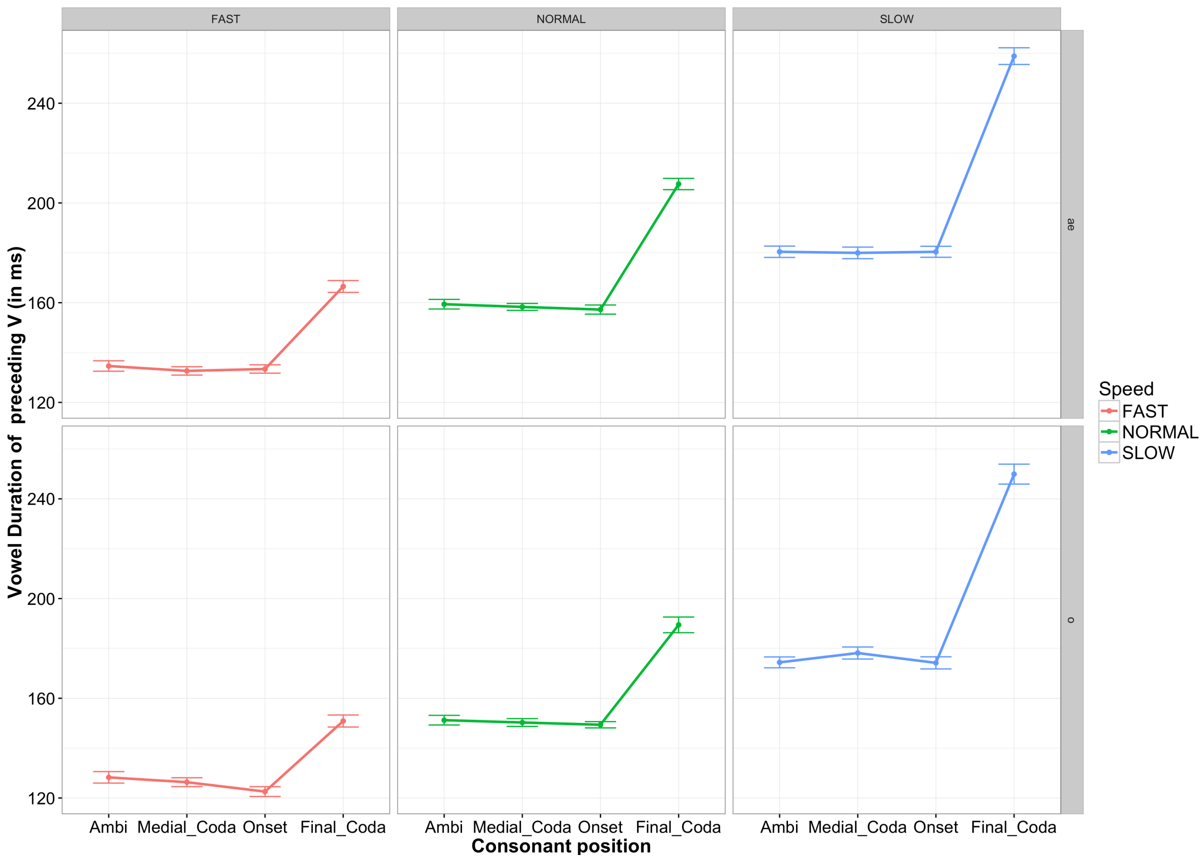

Figure 4: Vowel durations of [æ, o] in different contents spoken at different speeds (Red = fast, Green = normal, Blue = slow). Error bars represent standard error.

A linear mixed effects model was fitted to these data following the method described above (Section 2.2.1). The dependent variable was the total vowel duration of the preceding vowel, and the independent variables were *Syllabic position (SP)*, *Vowel Type (VT), and Speed*. As before, the variable *SP* had four levels (Ambisyllabic, Word-medial Coda, Word-medial Onset and Word-final Coda); the variable *VT* had two levels (lax vowel [æ] and tense vowel [oʊ]); and the variable *Speed* had three levels (Fast, Normal, Slow). The baseline was the vowel duration of the lax vowel [æ] before the ambisyllabic nasal consonant in the Fast context; therefore, the intercept term refers to that particular measure.

The model with all three factors with pairwise two-way interactions was the best model. This model is shown in more detail below (Table **6**).

Fixed Effects	Estimate	Std. Error	t-value	P-value
Intercept	135.33	21.05	6.43	0.99
VT: Tense [oʊ]	-7.84	29.16	-0.27	0.99
SP: Medial Coda (MC)	-2.69	29.25	-0.09	0.99
SP: Onset (Ons)	-2.59	29.19	-0.09	0.99
SP: Final Coda (FC)	31.09	29.42	1.06	0.99
Speed: Normal	24.30	2.22	10.95	<0.0001
Speed: Slow	44.06	2.22	19.86	<0.0001
VT [oʊ] : *SP* (MC)	1.39	41.21	0.03	0.99
VT [oʊ] : *SP* (Ons)	-1.60	41.21	-0.04	0.99
VT [oʊ] : *SP* (FC)	-7.31	41.21	-0.18	0.99
SP (MC) : *Speed* (N)	0.98	2.80	0.35	0.73
SP (Ons) : *Speed* (N)	1.43	2.80	0.51	0.61
SP (FC) : *Speed* (N)	15.71	2.81	5.59	<0.0001
SP (MC) : *Speed* (Slow)	3.64	2.80	1.30	0.19
SP (Ons) : *Speed* (Slow)	3.2	2.81	1.16	0.24
SP (FC) : *Speed* (Slow)	49.61	2.81	17.66	<0.0001
VT [oʊ] : *Speed* (N)	-0.80	1.98	-0.41	0.69
VT [oʊ] : *Speed* (S)	3.90	1.98	1.97	0.05

Table 6: Mixed-effects linear regression model for the vowel duration of the preceding vowel.

As compared to the baseline lax vowel [æ] before the ambisyllabic nasal consonant in the Fast speech-rate context, there was a statistically significant increase in vowel duration before the word-final codas at the Fast speech-rate. However, there was no statistically significant difference for the vowel durations in either the word-medial coda context or the word-medial onset context at the Fast speech-rate. Furthermore, compared to the lax vowel [æ] durations, the tense vowels are statistically significantly shorter at the Fast speech-rate. But, there was no interaction, thereby suggesting that the patterns of vowel nasalization observed with both the lax vowel context and the tense vowel context were similar. Since there was no statistically significant interaction between the vowel durations before word-medial nasal consonants and the other speech-rates, one could infer that there is no evidence to believe differences in the pattern of vowel durations before the word-medial nasals at the different speeds. Finally, as with the percentage of nasalization, the vowel durations before the word-final codas in the Slow and Normal speech-rate conditions was statistically significantly larger that the baseline.

2.3 *Discussion*

The results suggest that the percentage of nasalization on the preceding vowel due to a word-medial ambisyllabic consonant is intermediate between that due to onset and *word-final* coda nasals, especially at Normal and Slow speech-rates; however, the percentage of nasalization on the preceding vowel due to an ambisyllabic consonant is *not* observably different from that due to *word-medial* codas.

Crucially, the results reveal that if we had compared word-medial ambisyllabic consonants to word-medial onsets and word-final codas, we would have erroneously observed the *intermediate* nature of ambisyllabic consonants. This was in fact the confound that we alluded to earlier in the Introduction when we discussed previous production results pertinent to ambisyllabic consonants. The lengthened nasalization for the word-final codas can independently be explained by domain-final lengthening (Cho et al., 2003; Fougeron & Keating, 1997). More specifically, it has been observed that segments closest to a prosodic domain boundary are lengthened more than those further away from the boundary (Byrd & Saltzman, 2003). In our case, adjacent to a word-boundary, the nasalization gesture would receive more domain-final lengthening than the vowel preceding it. This by itself would result in an increased percentage of vowel nasalization due to word-final nasal consonants, compared to word-medial ambisyllabic nasal consonants. So, clearly, comparing word-final nasalization to word-medial nasalization is inappropriate.

However, when the correct comparison is made (word-medial ambisyllabic consonants compared to word-medial onsets, and word-medial codas), it is clear from the above results that there is no *intermediate* patterning of word-medial ambisyllabic consonants with respect to word-medial codas and word-medial onsets. In fact, equally clearly, word-medial ambisyllabic consonants pattern exactly with word-medial codas (and not like word-medial onsets) following both tense and lax vowel contexts at all speech-rates.

An unexpected finding, unrelated to the primary objective of the experiment, is that the tense vowel context in general had a higher percentage of nasalization due to the following nasal consonant. However, one should be careful about over-interpreting this result. Acoustic measurements are after all indirect measures of the lowering of the velum. So while any differences in the degree/percentage of nasalization for the same vowel is interpretable, differences in degree/percentage of nasalization for different vowels could be either: (a) due to real differences in percentage of vowel nasalization, or nasal co-articulation, associated with different vowels, (b) due to differences in the acoustic manifestation of the same velum gestures under the influence of difference vocalic gestures. The differences in the percentage of nasalization could also be related to the differences in vowel duration as observed in Section 2.2.2. Having identified the difficulty in interpreting the difference in the percentage of nasalization of the two vowel qualities, we wish to point out that others have found similar differences before tense and lax vowels. The results of an acoustic measurement study presented by Beddor (2007, p. 252) on American English nasalization patterns clearly show that lax vowels typically have a lower percentage of nasalization than tense vowels, as in the current article. Again, the observed difference in Beddor (2007) could equally be because of possibilities (a-b) laid out above, and we leave the exploration of this particular finding which is not directly relevant to the purpose of the current article as a topic of future enquiry.

The nasalization results also indicate that the differences between word-medial codas and word-medial ambisyllabic consonants as compared to word-medial onsets, while consistent across all speech-rates, are quite small. There is an average difference in vowel nasalization of about 4%, which translates to about 7-8 ms in terms of raw duration. The durations are above the *just noticeable difference,* which is about 5 ms (Nooteboom & Doodeman, 1980). The listeners, therefore, are sensitive to such small differences, and should be able to manipulate them systematically to mark prosodic/syllable structure. The results suggest, in line with a traditional understanding of vowel nasalization in English, that word-medial codas trigger more vowel nasalization on the preceding vowel, than word-medial onsets on the preceding vowel.

The results from the measurement of vowel durations suggests that the differences between the percentage of nasalization due to the nasal consonants in different syllable positions cannot be attributed to differences in vowel duration; at least, not for the crucial comparison of word-medial nasals.

The results also reveal that the percentage of nasalization and the vowel durations decrease with increasing speech-rate for the final coda stimuli. This could be attributed to changing prosodic structure of the sentences at faster speech-rates. More specifically, the test items were followed by the adjunct “again” from the carrier phrase. Adjuncts, especially at slow deliberate speech-rates, are likely to be outside the phonological phrase containing the test-item. Therefore, the test item is more likely to be at the end of a phonological phrase domain. But, at faster speech rates, more words (and by extension the adjunct “again” in our stimuli) are likely to be part of the same phonological phrase (Jun, 2003), thereby, decreasing the likelihood of the test-item (and the Final Coda) being in a phrase-final position. This could explain why both the percentage of nasalization and the vowel durations for the final codas decrease with increasing speech-rates.

There are four further issues that are very relevant while interpreting the results. First, [æ] is not a prototypical lax vowel, phonetically speaking. In fact, our own measurements reveal that the [æ] vowel is at least as long as the tense vowel [oʊ]. However, it is important to recognize, as pointed out earlier, that it is the phonological tenseness vs. laxness of vowels that is relevant in the discussion of ambisyllabic consonants, i.e., it is their phonological behavior that is important for the distinction. As far as we know, [æ] behaves like all other lax vowels with respect to (a) not being allowed word finally (*tæ, *bæ), (b) in allowing an [ŋ] to follow it with the same syllable (e.g., 'tang', bang') (Borowsky, 1986). Furthermore, the distinction between tense and lax vowels was introduced into the experiment because some researchers claim that ambisyllabic consonants are codas after lax vowels, but onsets after tense vowels (Duanmu, 2008, 2010), and because experimental manipulations suggested differences between ambisyllabic consonants following tense and lax vowels (Derwing, 1992; Elzinga & Eddington, 2014; Treiman & Danis, 1988). For these researchers, in the context of ambisyllabic consonants, the [æ] vowel is clearly considered a lax vowel. In addition, in on-going research, Duncan (2015) argues that even in Northern City Shift (NCS) dialects spoken in Inland North, Upper Midwest region of the United States, where the [æ] vowel is substantially tensed phonetically, native speakers treat it like a lax vowel, as in other American English dialects. Finally, even if one were to disregard the above arguments and claim that [æ] is a tense vowel, then our experiment would have shown that ambisyllabic consonants after two different tense vowels pattern like word-medial codas. Given that we are testing between multiple theoretical proposals in the literature, it is useful to recognize that there is no one who argues that ambisyllabic consonants after tense vowels pattern with codas, but those after lax vowels pattern differently. As far as the theoretical proposals of the syllabic affiliation ambisyllabic consonants are concerned, we think it is fair to say that if it can be shown that ambisyllabic consonants pattern with codas after tense vowels, then it follows that those after lax vowels do so too.

Second, the experimental stimulus set is small. While it is beneficial to have an extensive set of stimuli to ensure generalization to the language, in this particular case, it was indeed quite hard to come up with (near) quadruplets of stimuli containing the same vowel in words where the medial consonant has different syllabic affiliations. In fact, an extensive search in the Carnegie Mellon University (CMU) Pronouncing Dictionary (Weide, 1994) revealed at most one or two more quadruplets that satisfied our criteria for the stimuli[11], which were discussed above (Section 2.1.1). Therefore, an experiment with a more substantial stimulus list was not possible with our design. Although such a stimulus set size is not atypical for production experiments, given this limitation, we advise the reader to interpret the results with some caution.

Third, if the coda analysis of ambisyllabic consonants is indeed correct, and Selkirk's (1982) syllabification algorithm is assumed, then words such as "gamble" would be syllabified as [gæ̃mb.l̩]. An anonymous reviewer suggests that this might raise a problem for

[11] Note, even without the application of the criteria, there were very few quadruplets that would have worked.

the experiment because the word-medial coda now has a cluster. However, it is important to note that the crucial nasal [m] is still in a coda position. Therefore, such a syllabification can only be viewed as a problem with the additional assumption that such coda clusters result in changes to the temporal co-ordination of the relevant vowel-consonant sequences. This additional assumption needs to be independently justified for the stated issue to be a problem. Furthermore, there seems to be no evidence that such coda clusters with nasals are involved in changes to the preceding vowel durations (Katz, 2012). To the extent that durations can be used as a proxy for temporal organization, there is thus no evidence of a change in temporal organization of vowel-consonant sequences containing such complex codas. Therefore, we contend that, even if the syllabification proposed by Selkirk (1982) were correct, there is no obvious problem to the interpretation of the results presented here.

Fourth, like most (if not all) researchers conducting production studies related to ambisyllabicity till now, we have assumed that there is no direct role for lexical frequencies. The crucial word-medial onsets in our stimuli, namely, *gamete* and *gonad*, are both rather low-frequency words compared to the rest. It is possible that the lexical frequencies of the words had an influence on the nasalization patterns. However, the extant literature on the topic leads one to somewhat conflicting expectations. Scarborough (2004) suggests that speakers coarticulate more in the case of words with lower lexical frequency for functional reasons having to do with mitigating listeners' lexical access difficulties. In contrast, Zellou & Tamminga's (2014) results suggest that coarticulation increases with lexical frequencies. Clearly, there is more work that needs to be done on the issue before one can ascertain the influence of lexical frequencies, and how such facts have a bearing on the coarticulatory patterns being discussed here. We leave this particular issue as a topic for future enquiry.

Returning to the main issue probed by the experiment presented above, it is clear that word-medial ambisyllabic consonants consistently pattern with word-medial codas, and that they are not intermediate between word-medial codas and word-medial onsets for the stimuli in our experiment.

3. **Evidence from Pennsylvania Dutch**

The anticipatory nasalization patterns in American English presented in the preceding section suggested that word-medial ambisyllabic nasal consonants pattern with word-medial nasal codas for the stimuli. However, as discussed in the Introduction, there have been some reports that suggest that ambisyllabic *sonorant* consonants are more likely to pattern with codas than ambisyllabic *obstruent* consonants[12] (Treiman & Danis, 1988). However, the experimental results that suggested this viewpoint had crucial confounds (as mentioned before). While we did not conduct a separate production study of obstruent consonants, in what follows we provide crucial phonological evidence that also suggests that word-medial ambisyllabic obstruent consonants pattern with codas too.

Previous phonological analyses arguing for multiply-linked representations of ambisyllabic consonants base their arguments on two analytical strategies: (a) evincing phonological *alternations* that show that ambisyllabic consonants behave differently from

[12] But, note, this is only in the experimental literature.

both onsets and codas; (b) evincing *phonotactic* arguments that show ambisyllabic consonants behave both like onsets and codas. However, as elaborated in the Introduction, showing that ambisyllabic consonants are subject to alternations that are different from prototypical onsets and codas is very weak evidence for multiple-linkage representations, given that such alternations can more directly be accounted for by the use of the very same prosodic conditioning factors that are used to establish the multiply-linked representation in the first place. In fact, this is exactly the stance of those who account for such alternations using foot-structure based analyses (Bermúdez-Otero, 2007; Harris, 2004, 2006; Jensen, 2000; Kiparsky, 1979). Furthermore, the use of phonotactic arguments to probe syllable-structure affiliations is also slightly suspect given that it has recently been argued that such analyses lead to claims about sub-syllabic representations, like rhyme/onset/coda constituents, that are inconsistent with the rest of the evidence in a language (Berg & Koops, 2010, 2015), i.e., using phonotactic evidence leads to positing syllabic representations that are different from those based on other types of evidence. Of course, given their static (non-alternating) nature, there is no direct way to ascertain if a speaker has knowledge of that pattern; it is possible that the speaker has not learned the static pattern though it is present in the data. Therefore, it is unclear that such patterns should have a bearing on syllable-structure. In fact, this possibility has received more support recently, as Becker, Nevins, & Ketrez (2011) showed for Turkish speakers that not all phonotactic patterns observed in the language are reflected in native-speaker intuitions. More specifically, they show that though the presence of stem-final voiced stops in the Turkish lexicon can be predicted by the place of articulation of the stop, by word-length, and by the preceding vowel quality, in nonce-word judgment tasks, Turkish speakers only seemed to be using the place of articulation and word-length. As a consequence of such problems with phonotactic data, phonotactics have long been argued to be a weaker source of evidence for phonological representations, and phonological knowledge more generally, compared to phonological alternations (Ohala, 1986; Oostendorp, 2013). The additional interest in Berg & Koops' (2015) paper results from the fact that they argue that phonotactic evidence can also be inconsistent with other sources of evidence. In particular, they show that phonotactic generalizations have an inherent rightward bias wherein the prevalence of phonotactic constraints increases from earlier to later portions in a word. And as a consequence of the above bias, when phonotactic generalizations are considered in their entirety in a language, they lead to a representation of sub-syllabic constituency that sometimes contrasts with constituency inferred from other types of generalizations. In particular, both Korean and Finnish have been clearly argued to have left-branching syllable structure based on speech errors, language games, morphophonological processes, and other behavioral experiments; however, phonotactic generalizations suggest a flat syllable structure in Korean, and a right-branching structure in Finnish[13]. Based on this mismatch between the inference about sub-syllabic constituency from phonotactic generalizations and those from many other lines of evidence, Berg and Koops state that "[t]he results of our analyses demonstrate a striking disconnect between phonotactic constraints and sub-syllabic

[13] Finnish might perhaps be more accurately described as a language that allows only simple onsets, but more complex codas. Thanks to an anonymous reviewer for pointing this out to us.

constituency" (pg. 31), and later conclude that "[a] somewhat surprising overall conclusion of the present paper is that phonotactics is a poor indicator of sub-syllabic structure.[14] Other lines of evidence, whether naturalistic or experimental, appear to have a more direct bearing on the question of sub-syllabic constituency" (pg. 35). Consequently, given the inherent right-ward bias of phonotactic generalizations as identified by Berg and Koops and their potential untrustworthiness with sub-syllabic constituency, one should also proceed with extreme caution in interpreting any phonotactic evidence as strong evidence in support of multiply-linked syllabic representations in the case of ambisyllabic consonants. Of course, it is in our opinion an entirely reasonable response for those especially in favor of phonotactic arguments for syllabic constituency to suggest that results such as Berg & Koops (2010, 2015) only suggest more nuance in interpreting phonotactic evidence for syllabic affiliation; however, for there to be progress on the issue, we think it is necessary for those in favor to provide exactly what that nuance needs to be and how it accounts for the facts presented by Berg & Koops. Otherwise, it is difficult to assess whether such a strategy is a reasonable one.

In contrast to previous analytical strategies, in what follows, we show a case where ambisyllabic consonants are necessarily subject to the *same* alternation as either prototypical onsets or codas. As we show below, Pennsylvania Dutchified English (PDE) provides us with the necessary conditions to test if such predictions of the multiple linkage analysis are borne out. And as in the previous section, we show that when we look at the appropriate environments in PDE, word-medial ambisyllabic obstruent consonants pattern with word-

[14] We discuss this disconnect between phonotactic constraints and sub-syllabic constituency further in Section 4.

medial codas, and not with word-medial onsets. It is important to note that all the data we present on PDE are based on work by Vicki Anderson and colleagues (Anderson, 2001, 2011; Anderson & Davis, 2013). The data were collected during field-work by Vicki Anderson on the PDE dialect spoken in northern Lebanon County, Pennsylvania, and depended on taped interviews, native speaker intuitions, and spectrographic analysis.

PDE is a dialect of American English that has been influenced by German (Anderson, 2001; Anderson & Davis, 2013). However, as with Standard American English (SAE), alveolar stops are realized as flaps in word-medial positions if preceded by a stressed syllable and followed by an unstressed syllable[15]. In fact, the flapping environments for PDE are exactly those of SAE (Anderson & Davis 2013). As shown in Table **7**, before a stressed vowel, the /d/ does not flap and is pronounced as [d] (Table **7**, column 1), but between a stressed vowel and an unstressed vowel, the /d/ is pronounced as a flap [ɾ] (Table **7**, column 2). Therefore, the consonants in flapping environments must have the same representational analysis as in SAE. As noted above, the process of flapping in SAE is the example used by Kahn (1976) to argue for multiply linked representations. We return to this issue towards the end of this section.

[15] The stress transcriptions for PDE are from Anderson (2001, 2011). Furthermore, throughout we assume that the stress patterns, more generally, in PDE are similar to those of SAE.

Obstruent stop		Flapped	
[ˈ**d**ʌk]	‘duck’	[ˈbɛ**ɾ**ɪŋ]	‘bedding’
[əˈ**d**ɪkʃən]	‘addiction’	[ˈɹɑɪ**ɾ**ɪŋ]	‘riding’

Table 7: Flapping in PDE (Anderson & Davis, 2013)

While flapping in PDE by itself does not allow us to tease apart different hypotheses about ambisyllabic consonants, PDE also has a devoicing rule (presumably, as an influence from German), whereby syllable-final voiced stops become voiceless[16]. Before presenting the facts from PDE, we will present the devoicing facts from German, as the pattern in German forms a nice comparison point for the facts in PDE. As pointed out by Wagner (2002), the German devoicing pattern is best accounted for as a generalization that is sensitive to phonological word boundaries.

As can be seen in Table **8**, German allows for voiced obstruents in word-initial and inter-vocalically in word-medial contexts, but not in a word-final context.

Word-initial onset		Word-medial onset		Word-final coda	
[**b̥**auɐ]	‘peasant’	[ɛ**b**ə]	‘low tide’	[li:$\mathbf{p}^{\mathbf{h}}$] /li:b/	‘nice’
[**d̥**oɐf]	‘village’	[kla**d**ə]	‘rough draft’	[ra:$\mathbf{t}^{\mathbf{h}}$] /ra:d/	‘wheel’

Table 8: Voiced obstruents in onsets and word-final codas

[16] This can be reinterpreted as syllable-final fortition through the addition of a [spread glottis] feature (a la (Iverson & Salmons, 2003b, 1995). However, the exact featural analysis is not directly pertinent to the point being made above. What is more important is the environment in which the process is triggered.

Furthermore, as can be seen in Table **9**, not all word-medial coda contexts trigger devoicing of voiced obstruents. Only codas before what Wagner calls "non-cohering" suffixes are devoiced[17]. As a consequence, crucially, morpheme medial codas are not devoiced.

Word-medial (before cohering affixes)		Word-medial (before non-cohering affixes)		Morpheme medial codas	
[ra:**d**+l+ə]	'bike (1sg.)'	[ra:**t**+l̥os]	'without wheel'	e[**d**].les	'noble'
[li:**b**+l+ə]	'flirt (1sg.)'	[li:**p**+l̥ɪç]	'lovely'	Loe[**b**].ner	name
				a[**d**].ler	'eagle'
				ma[**g**].ma	'magma'

Table 9: Voiced obstruents in word-medial coda contexts

To account for the fact that voiced obstruents devoice in word-final coda positions and before non-cohering suffixes, but not before cohering suffixes and morpheme-medially, Wagner suggests that the coda devoicing in German is sensitive to the boundary of the phonological word. As per his analysis, the codas adjacent to non-cohering suffixes and those that are word-final, are immediately followed by a phonological word-boundary, but those in the other positions are not. Therefore, the German devoicing pattern is not a purely coda-phenomenon, and is actually sensitive to higher-level prosodic structure.

[17] For Wagner, "cohering" affixes are those which allow re-syllabification across the stem-affix boundary, and "non-cohering" affixes are those which do not allow such re-syllabification. It is also worth noting here that Wagner suggests that the term "coda" is entirely unnecessary if one assumes that obstruent clusters share one laryngeal node.

Table **10** lists the variants of voiced obstruents in PDE in different positions within a word. Unlike in German, in PDE, even word-medial codas are devoiced, as is evidenced by words such as ‘a[**k**]nes’, and ‘a[**t**]mission’ (Table **10**); therefore, the appropriate generalization in PDE is that of general *coda devoicing*[18]. As with flapping in SAE, *coda devoicing* does not apply to word-initial consonants (‘[**b**]less’), or to initial consonants of stressed syllables (‘ha[**b**]itual’), or to initial consonants of secondary stressed syllables (‘cari[**b**]ou’, ‘Penta[**g**]on’). Thereby, extending further support to the standard analyses of the consonants in these contexts as onset consonants.

Stressed syllable	Secondary Stress Syllable	Word-initial	Word-final		Word-medial	
[b]less	cari[b]ou	[b]elow	do[**k**]	‘dog’	a[**k**]nes	‘Agnes’
ha[b]itual	Penta[g]on	[g]orilla	lea[**f**]	‘leave’	a[**t**]mission	‘admission’
			be[**t**]	‘bed’	o[**p**]tuse	‘obtuse’

Table 10: Environments for devoicing in PDE (Anderson & Davis, 2013)

Though somewhat tangential to present purposes, there is one further environment in PDE that is worth considering carefully when trying to understand the voicing alternation pattern; that is the word-internal obstruent-initial clusters preceding primary stress. As can be seen in Table **11**, obstruent stops [b, g] undergo devoicing if they are the first segment of an onset

[18] It could also potentially be analyzed as non-foot-initial obstruent devoicing. We return to this issue below and in Section 4.

cluster (Table **11**, column 2). However, this does not apply to the same obstruents in a simplex onset (Table **11**, column 3). This exceptional pattern does not hold of alveolar stops in the same position, which behave as expected.[19] For example, both 'Madrid' and 'address' have a medial [d] (Anderson 2011: 90).

Word-initial Obstruent-initial Clusters	Word-medial Obstruent-initial Clusters		Word-medial singleton obstruent-onsets
[b]rianna	Sa.[$\mathbf{p}^{h}$]rina	'Sabrina'	a.[b]out
[b]lender	o.[$\mathbf{p}^{h}$]lige	'oblige'	a.[g]ast
[g]uano	re.[$\mathbf{k}^{h}$]ret	'regret'	
	i.[$\mathbf{k}^{h}$]wana	'iguana'	

Table 11: Word-initial vs. word-medial voiced obstruent-initial clusters

It is worth noting here that the reason we regard the above data as tangential to present purposes is that the data present a challenge for all the different analyses of ambisyllabic consonants we presented earlier. Each of the analyses would have to say something additional (potentially, ad-hoc) about the surprising devoicing of the obstruents in Table **11**. Therefore, the data, while interesting, do not allow us to tease apart the many different analyses. Having said that, we follow Anderson & Davis (2013), in suggesting that there must be two steps to the syllabification to account for the pattern. We believe this to be the appropriate analysis, as the difference in the voicing patterns of the word-medial obstruent in 'Sabrina' and 'about'

[19] Thanks to an anonymous review for high-lighting this fact.

(Table **11**) suggest that such a two-step syllabification account is necessary. In the first step, the obstruent in the medial onset cluster is syllabified as a coda (where it gets devoiced), followed by a re-syllabification to onset of the following stressed syllable. Anderson & Davis themselves suggest that this is potentially a diachronic two-step process. However, there is no direct evidence that shows it to be a diachronic or a synchronic pattern. We leave this issue for future work/analysis.

Returning to the more relevant issue of coda-devoicing in PDE, we can now look at how voiced ambisyllabic obstruent consonants behave. If, in fact, ambisyllabic consonants are multiply linked, then they should be blocked from devoicing due to the condition of geminate inalterability[20] that is consistently seen in other cases of multiple linkage (Hayes, 1986; Schein & Steriade, 1986). One could further argue that the multiple-linkage analysis would also lead to a paradoxical claim that ambisyllabic consonants should simultaneously be voiced and voiceless[21]. On the other hand, if ambisyllabic consonants pattern with codas, then they should be devoiced. Table **12** lists words from PDE with ambisyllabic obstruent consonants after both lax vowels (top) and tense vowels (bottom). As can be seen, word-medial ambisyllabic consonants pattern with codas, in that they are also devoiced. In contrast, the faithfulness to voicing exhibited by onsets is not shared by these ambisyllabic consonants. It

[20] This is because, if ambisyllabic consonants have a multiply linked representation, then they would be representationally identical to geminates, as per standard claims. Therefore, they should have the same behavior as geminates in that they should resist patterns that target singleton consonants.

[21] This paradoxical claim could be counteracted by a particular ranking of violable constraints in an Optimality Theoretic fashion, of course. However, as far as we know, there would be no independent evidence for the proposed constraint ranking.

is also important to note that the devoicing of ambisyllabic consonants happens both after lax vowels and after tense vowels.

Preceding Vowel Type	Ambisyllabic context	
Lax	ha[**p**]it	‘habit’
	di[**s**]y	‘dizzy’
Tense	ba[**k**]el	‘bagel’
	ei[**θ**]er	‘either’

Table 12: Consonants in ambisyllabic contexts get devoiced (Anderson & Davis, 2013)

Given that ambisyllabic obstruent consonants pattern with codas in PDE[22], the most reasonable hypothesis would be to assume that alveolar obstruent stops in the same context also pattern with codas, unless independent evidence to the contrary is furnished. One might rightly ask why ambisyllabic alveolar consonants do not undergo devoicing in PDE. In this context, it is important to recognize that both /t/ and /d/ flap in the relevant environment. Therefore, even if an ambisyllabic /d/ devoiced, it would surface as a flapped consonant in that environment. This can be cashed out in a variety of theoretical ways. In rule-based theories, it can be accounted for by (a) as rule ordering, whereby devoicing is ordered before flapping, (b) as an effect of the Elsewhere Condition (Halle & Idsardi, 1997; Kiparsky, 1973b), whereby the more specific generalization of the flapping rule (only alveolar obstruent stops) overrides the more general devoicing that applies to all obstruents. In Optimality

[22] Except alveolar stops, which as discussed below flap in the same environment.

Theoretic accounts it can be cashed out by ranking the markedness constraint that motivates the flapping of ambisyllabic alveolar obstruent stops high along with the constraint that motivates devoicing, both of which have to be ranked higher than the relevant faithfulness constraints for voicing in obstruents, and obstruency in alveolar obstruents. We ourselves prefer the analysis in terms of the Elsewhere Condition (an insight that the OT account shares too), since there is no need for any additional support of such an analysis, as the facts follows from the very nature of rule (or constraint) interaction.[23]

Furthermore, as mentioned previously, the flapping facts in SAE and PDE are identical. Therefore, the analysis of flapping in PDE must extend to the analysis of flapping in SAE (and other American English dialects), unless arguments to the contrary are presented. Therefore, it seems most reasonable to conclude that like PDE, the alveolar stops that are flapped in SAE (and other American English dialects) also pattern with word-medial codas. It is important to note that, here, we are interested only in what the flapping facts can tell us about ambisyllabic consonants, and not the precise analysis of flapping itself. We acknowledge (as in Footnote 4) that flapping is also domain-limited to the Utterance Phrase, as pointed out by Nespor & Vogel (1986).[24]

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[23] An anonymous reviewer pointed out that there is something strange about claiming that devoicing (potentially, a fortition process) and flapping (a lenition process) occur in the same environment. We acknowledge that it is somewhat puzzling that it happens, but it is not entirely problematic if we acknowledge that there are multiple factors that result in phonological patterns. Some phonological patterns might have their origin in articulatory factors, while others might have them in perceptual factors, and some others due to innate biases (these are of course not the only factors). Given the multiple historical sources of phonological patterns, there is therefore nothing necessarily paradoxical about finding both fortition and lenition in the same environment.

[24] Thanks to an anonymous reviewer for raising this issue.

One additional sub-pattern related to the devoicing facts in PDE is that there is devoicing of the word-medial obstruent in words such as [fɑ̃ʊ̃ntri] ‘foundry’. While the sub-pattern is not directly relevant to the issue of ambisyllabic consonants, the analysis suggested above does suggest that such medial obstruent consonants may have been in a coda position at some point in the phonological derivation. In fact, the syllabification algorithm proposed by proponents of the coda-analysis of ambisyllabic representations, such as Selkirk (1982) and Wells (1990), which places the relevant consonants in the coda of the preceding syllable, naturally accounts for such patterns without any extension.[25]

Before concluding this section, we note that Anderson & Davis (2013) themselves analyze these facts as resulting from a foot-initial faithfulness to the feature [voice]; as per their analysis, the voicing in obstruents is preserved only foot-initially, but not foot-medially or foot-finally. Such a foot-based analysis is forced to invoke the phonological feature [voice] for PDE. However, as noted above, the obstruent segments in both standard American English and German (the two main influencing languages of PDE) have been argued to contrast in the feature [spread glottis], and not the feature [voice]; in fact, the feature [voice] has been argued to be phonologically inactive in the two languages (Beckman, Jessen, & Ringen, 2013; Iverson & Salmons, 2003b, 1995). Since the featural claims needed for the foot-based analysis of the devoicing patterns in PDE are at odds with those supported by related dialects/languages, such featural claims themselves need independent justification. On the other hand, the coda-devoicing (or fortition) generalization that we propose appears to be an

[25] Thanks to an anonymous reviewer for pointing this out to us.

extension of the pattern in German, and does not invoke phonological features that are not already active in American English or German. To this extent, we suggest the coda devoicing analysis is the more parsimonious account of the facts in PDE.

4. Conclusion

This article presents acoustic data from the production of nasalized vowels in American English and evidence from phonological patterning of devoicing in Pennsylvania Dutchified English that suggest that word-medial ambisyllabic consonants are not multiply-linked, and that they do not have a phonetic behavior that is intermediate between onsets and codas. In fact, all the evidence presented in this article indicates that they pattern with word-medial codas in American English.

In the production experiment looking at the vowel nasalization patterns of a vowel preceding nasal consonants in different syllabic positions, we showed that, when crucial confounds present in previous experiments are controlled for, word-medial ambisyllabic nasal consonants induce about the same percentage of nasalization on the preceding vowel as word-medial nasal codas. There is no evidence of their intermediate behavior or that they are like onsets. Furthermore, through phonological data focused on devoicing patterns in Pennsylvania Dutchified English (PDE), we again showed that word-medial ambisyllabic obstruents devoiced exactly like other coda obstruent consonants in the dialect. The results also present no evidence that the syllabic affiliations of word-medial ambisyllabic *sonorant* consonants is different from word-medial ambisyllabic *obstruent* consonants. Finally, both the nasalization patterns and the devoicing patterns show that word-medial ambisyllabic consonants pattern with codas following both tense and lax vowels.

Returning to the issue of theoretical positions, we hope to have shown that representational analyses that argue for multiple-linkage, or that argue that ambisyllabic consonants in some contexts are onsets have been contradicted by our results.[26] As shown in Table **13**, which shows how different analyses fair with respect to the results presented in this paper, analyses that claim multiple-linkage of ambisyllabic consonants in both lax-vowel and tense-vowel contexts are inconsistent with the present facts that suggest that they pattern with codas in both contexts. Similarly, analyses that claim that ambisyllabic consonants are onsets only after tense vowels (but codas otherwise) are also inconsistent with the results presented here.

Ambisyllabic representations	**After V_{lax}**	**After V_{tense}**
Always multiply-linked	×	×
Coda after lax, onset otherwise	√	×
Always onset (foot-based analysis)	√?	√?
All are codas	√	√

Table 13: How the different representational solutions fare?

[26] It is important to note that throughout the article, we have been careful to focus purely on "word-medial" contexts. This was done to avoid any confounds present with domain-edge effects. However, we see no reason why one could not extend the representational claims made here to ambisyllabic consonants in other contexts.

In contrast to the first two analyses in Table **13**, it is less straightforward to evaluate the foot-based proposals of ambisyllabic consonants (Bermúdez-Otero, 2007; Harris, 2004, 2006; Jensen, 2000). For the PDE data, while the particular analysis presented by Anderson & Davis (2013) was argued to be problematic above for reasons related to associated claims about the laryngeal features involved, there is no way to rule out foot-based analyses *in toto*, as some other foot-based analysis might account for all the data without problematic associated claims. The onus we believe is on the proponents to present such an analysis. In regards to the nasalization data we present in this article, there is a potential argument against the foot-based analyses. Typically, analyses that account for ambisyllabic patterns in terms of foot-structure, further propose that the ambisyllabic consonants are foot-medial onsets. If this were indeed the analysis of the word-medial ambisyllabic nasal consonants in American English, then it is quite surprising that there are no observable differences in nasalization patterns between the word-medial codas and the word-medial ambisyllabic consonants in our results. As pointed out earlier, there is clear evidence that there are domain-edge related lengthening and strengthening patterns, which appear to be universal. Therefore, if ambisyllabic consonants are onsets (for a foot-based analysis), one runs into the same problem that other analyses run into, namely, that one cannot explain why there is no observable difference in the nasalization patterns between them and word-medial codas, but there is an observable difference between them and word-medial onsets.[27] So, even within foot-based analyses of typical ambisyllabic phonological patterns, the nasalization facts are readily interpretable only if one further posits that the relevant ambisyllabic consonants are codas.[28] It is, however, important for us to acknowledge here that the above argument against the relevant (onset-related) foot-based accounts is weak and depends on a null result. For this reason, unlike with the first two analyses presented in Table **13**, the foot-based account cannot be said to be clearly inconsistent with the facts presented here. Therefore, we use a "√?" in Table **13** to register the somewhat inconclusive results with respect to the claims made by proponents of the foot-structure based analyses.

The astute reader might have observed that the introductory discussion and our results rather surprisingly suggest a divergence between word-edge phonotactics and syllabification. This we believe is correct, and has, to our minds, been established in the theoretical phonological discussions since at least the mid-1980's, especially, once the concept of *appendix* was introduced. In fact, Borowsky (1989) starts her paper with the following: "It has

[27] Note that the issue raised here does not disappear if the correct domain of nasalization is argued to be some larger domain, such as the *phonological word*. There would still be a prosodic difference between codas and ambisyllabic consonants, which are onsets as per the relevant foot-based analyses; therefore, the absence of any phonetic differences between segments in different prosodic positions is still surprising. This argument is clearly contingent on the putative universality of such domain-edge effects, and is unsustainable if it is shown that such effects are not consistent or universal.

[28] Another possibility in order to maintain purely foot-based analyses is to reject syllables completely (Samuels, 2009; Steriade, 1999). This would also account for why there is no difference between ambisyllabic consonants and codas, as they would then be in identical prosodic positions, and would be expected to behave similarly. It remains to be seen whether the removal of syllables as a unit of representation can still allow researchers to account for the relevant facts attributed to them. We consider this to be a difficult view to maintain currently, given the extensive evidence adduced to support the existence of syllables.

been recognized that the possible sequences of consonants found in word-initial and word-final positions are not an altogether true reflection of the possible sequences found in syllable-initial and syllable-final positions. Languages often allow various violations of syllable structure at word edges – the APPENDICES". For example, word-finally, English allows quite complex sequences (e.g., [ksθs] in "sixths"), but such codas are not possible word-medially or morpheme-medially (excluding of course the case of compounds). Even without the facts used to motivate appendices, there is sufficient cross-linguistic evidence that suggests that word-boundary phonotactics are not isomorphic with syllable phonotactics. To take but one example, Telugu (except in recent loanwords, and casual speech truncations) has no word-final consonants, except for the consonants [m, n, w, j] (Krishnamurti, 2003); yet, word-medially, it has all sorts of consonant sequences not allowed either word-initially or word-finally, e.g., [ʃ] is not possible word-finally (*ʃ#), and complex obstruent sequences involving [ʃ] are not allowed word-initially (*ʃʈ); however, word-medially, you can get sequences such as [ʃʈ] ([ˈkʌʃʈʌ̃w̃] 'difficult'). If word-boundary sequences were indeed isomorphic with syllabic-phonotactics, then such words should be impossible; however, such obstruent sequences (as mentioned above) are quite common in the Telugu. On a related note, in French, sO clusters (where, O = obstruent) are possible word-initially, but word-medial sO clusters are broken up into separate syllables, with the [s] as part of the preceding syllable (Dell, 1995). Such data suggest (along with those motivating appendices) that a belief in an isomorphism between word-edge sequences and syllable phonotactics is incorrect[29].

[29] This is not to deny, as Borowsky notes, that there is some parallelism between the two.

Another issue that surfaces from the results is the syllabification of segments between two unstressed syllables. The fact that the medial alveolar obstruent is flapped in words such as capi[ɾ]al, digi[ɾ]al, sena[ɾ]or etc[30], indicates (as per our suggested analysis) that the second syllable in all these case while being unstressed is heavy due to the presence of a coda [ɾ]; but such syllables appear to violate the Weight-to-Stress Principle, according to which heavy syllables ought to be stressed (Prince, 1990).[31] However, there is no immediate problem with such an analytical consequence, as other words where there is more consensus that the second syllable is indeed heavy also display the same stress patterns, e.g., character, faculty, galaxy. Such words suggest that the Weight-to-Stress Principle describes a pattern that is not exceptionless, and therefore needs to be employed with caution when used to argue for syllabic affiliation.

Returning to the main issue focused on in this paper, the evidence presented herein suggests that (word-medial) ambisyllabic consonants do not pattern with (word-medial) onsets, but in fact pattern with (word-medial) codas in American English. Therefore, the simplest analysis of the facts is to analyze the relevant consonants as codas. Though, as pointed out above, a foot-based account with ambisyllabic consonants analyzed as foot-medial onsets might also be sustainable depending on how one views the universality of

[30] Note, unlike with the contexts discussed so far, there is dialectal variation in the flapping of the relevant segments in such contexts, and therefore such patterns surely involve other analytical claims that are tangential to issue at hand.

[31] Thanks to an anonymous reviewer for pointing this out to us.

domain-edge strengthening/lengthening processes. Crucially, there is no evidence of any intermediate behavior of ambisyllabic segments.

Finally, given the vast literature surrounding ambisyllabic consonants and their syllabic affiliation, it would be, in our opinion, somewhat ambitious of us to argue that we have clarified the relevant issues beyond reproach; we ourselves believe this is just a step towards a more nuanced understanding of the issues related to ambisyllabic consonants. And therefore, we minimally hope to have shown that the standard view of such consonants being multiply-linked is far from well-established, both theoretically (Jensen, 2000; Picard, 1984) and experimentally; and we also hope to have shown that there is a need for more explicit discussion of the actual theoretical claims, the experimental evidence presented as support for such claims, and the linking hypotheses that connect the two.

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Appendix A

We have not statistically analyzed each subject separately, as this would have resulted in a massive multiple comparison problem; correcting for which, decreases the power of the tests substantially. Furthermore, running standard statistical tests on individual subjects is also a very highly debated topic in the statistical literature, due to the violation of important background assumptions, which results in substantial differences in inferences (or associated p-values) depending on which test is employed (Nourbaksh & Ottenbacher, 1994). Therefore, we just present all the participant data below in case it might be useful to other researchers for modeling purposes.

Sub	Vowel	Speed	Ambisyllabic	Medial Coda	Onset	Final Coda
1	[æ]	FAST	59.95	60.82	52.39	60.22
		NORMAL	65.65	66.49	64.04	70.92
		SLOW	64.63	65.23	56.21	70.20
	[oʊ]	FAST	69.82	62.52	62.22	64.93
		NORMAL	74.03	72.05	69.84	81.24
		SLOW	75.95	73.81	69.38	79.40
2	[æ]	FAST	70.21	72.03	62.22	70.3
		NORMAL	70.63	68.37	58.21	70.04
		SLOW	65.28	66.71	59.47	76.85
	[oʊ]	FAST	65.71	66.56	67.26	70.8
		NORMAL	66.64	65.10	59.06	71.36
		SLOW	71.18	68.24	67.18	69.87
3	[æ]	FAST	64.22	59.19	59.06	67.01
		NORMAL	67.30	62.68	58.65	70.76
		SLOW	69.09	62.72	66.71	74.24
	[oʊ]	FAST	66.68	69.12	60.64	61.38
		NORMAL	77.08	67.59	63.96	69.79
		SLOW	76.13	67.33	69.45	71.7

4	[æ]	FAST	66.3	66.72	71.42	71.47
		NORMAL	64.39	68.42	64.09	71.25
		SLOW	65.94	61.99	60.27	75.92
	[oʊ]	FAST	75.76	73.81	67.42	78.4
		NORMAL	73.03	76.03	68.10	79.16
		SLOW	68.95	70.56	62.99	78.99
5	[æ]	FAST	60.23	60.97	57.62	64.83
		NORMAL	63.58	64.34	61.04	72.36
		SLOW	63.26	70.45	73.5	77.42
	[oʊ]	FAST	59.01	60.28	61.96	54.66
		NORMAL	61.48	60.58	57.85	65.93
		SLOW	64.96	73.16	62.33	72.79
6	[æ]	FAST	60.44	60.81	53.44	60.4
		NORMAL	56.52	59.01	55.84	66.34
		SLOW	60.01	61.34	60.74	70.67
	[oʊ]	FAST	62.51	63.82	59.04	68.81
		NORMAL	57.72	67.24	55.73	65.64
		SLOW	64.15	65.80	62.30	74.86

A. 1: Percentage of nasalization for each subject for each condition.