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Word-internal ambisyllabic consonants are codas in American English

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Karthik Durvasula[a] and Ho-Hsin Huang[b]

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[a]Department of Linguistics and Languages, Michigan State University

B330 Wells Hall, 619 Red Cedar Road, East Lansing, MI 48824, USA, durvasul@msu.edu

[b]Department of Linguistics and Languages, Michigan State University

B320 Wells Hall, 619 Red Cedar Road, East Lansing, MI 48824, USA, huanghoh@msu.edu

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Corresponding author: Karthik Durvasula

Address: B330 Wells Hall, 619 Red Cedar Road, East Lansing, MI 48824, USA

Telephone: 1-517-432-0194

Fax: 1-517-432-2736

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Word-internal ambisyllabic consonants are codas in American English

1. Introduction

In this paper, we present two separate sets of arguments that suggest that word-medial *ambisyllabic consonants* [1] are simply word-medial codas 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 following both tense (long) and lax (short) vowels, and that there is no evidence of their "intermediate" nature or that they are simultaneously the onsets of the follow syllable.

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 *Dan* have been analyzed with an [n] that is unarguably in syllable coda positions, words such as *Danny* have been argued to have an [n] 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 syllable and an unstressed syllable. This is the environment that we focus on throughout the paper, though

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[1] Henceforth, we use the term "ambisyllabic" as a descriptive term to refer to consonants in a certain position (between a stressed and an unstressed vowel); and we reserve the term "multiply-linked" for the representational claims presented in Figure 1.

1   consonants in other positions have also been identified as ambisyllabic, namely, those

2   between two unstressed vowels within a word (e.g., [ɪˌlɛkˈtrɪsɪ**ɾ**i] "electricity"), and those that

3   are between vowels straddling a word boundary (e.g., [ˈæ**ɾ** ˈɪʃu] "at issue").
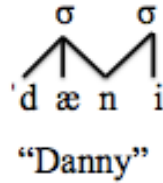
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"Danny"

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

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8   In the following subsections, we present the different views on the syllabic affiliation of

9   ambisyllabic consonants. In Section 1.1, we present the different phonological analyses of

10   phonological patterns attributed to ambisyllabic consonants, particular focusing on the case of

11   flapping for expository convenience. In Section 1.2, we present previous experimental

12   findings that have a bearing on the issue.

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14   1.1 Phonological Arguments

15   A paradigm case from American English that is used to discuss ambisyllabicity is the flapping

16   of alveolar stops (Gussenhoven, 1986; Hayes, 2009; Kahn, 1976). As presented in Table **1**,

17   voiceless alveolar stops that are clearly in onset position are realized as aspirated, while those

18   that are clearly in coda positions are typically realized as glottalized, while those following a

19   stressed syllable and preceding an unstressed syllable are realized as flaps. To account for the

1 flapped environment, some have proposed a multiply-linked representation (Gussenhoven,

2 1986; Hayes, 2009; Kahn, 1976).

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Aspirated	Glottalized	Flapped
[ˈtʰæksi] 'taxi'	[mæˀt] 'mat'	[ˈmæɾɚ] 'matter'
[əˈtʰɛmt] 'attempt'	[æˀtləs] 'atlas'	[ˈfæɾɚ] 'fatter'
[ˈsæˌtʰɑɹɪ] 'satire'		

4   Table 1: Flapping in American English

5 Most (if not all) of the crucial arguments presented for such multiply-linked representations

6 can be boiled down to two analytical strategies: (a) evincing phonological *alternations* that

7 show that ambisyllabic consonants behave differently from both onsets and codas, (b)

8 evincing *phonotactic* arguments that show ambisyllabic consonants behave both like onsets

9 and codas. However, showing that ambisyllabic consonants are subject to alternations that are

10 different from prototypical onsets and codas does not provide strong evidence of multiple-

11 linkage of such consonants. This is because, to establish the multiple-linkage representation in

12 the first place, such analyses still depend on further prosodic conditions that separate

13 ambisyllabic consonants from prototypical onsets and coda. If so, the prosodic conditions

14 could potentially be used directly without the intermediate step of creating multiply-linked

15 representations to account for the patterns adduced. For example, word-medial multiply-

16 linked representations needed in such accounts of ambisyllabicity are seen to be triggered by

17 stress location, i.e., a segment in onset position is also attracted to the preceding syllable if

1   that syllable is stressed, therefore, there is a unique multiply-linked representation that can

2   now be the target of a process such as flapping. However, as should be clear, the same

3   environment for flapping is equally identifiable from the stress facts themselves; therefore, it

4   seems a priori simpler to account for flapping using the stress, or more generally, prosodic,

5   facts. What would be much more convincing evidence of such a representational analysis of

6   multiple-linkage are patterns that reveal that ambisyllabic consonants are subject to

7   alternations that target both onsets and codas simultaneously[2]. To our knowledge, such

8   patterns have not been provided by proponents of multiple-linkage representations for

9   ambisyllabic consonants. Furthermore, the use of phonotactic arguments is also subject to

10   criticism as it has been shown recently that such arguments have problems generally with

11   respect to probing syllable-structure affiliations[3] (Berg & Koops, 2015). Given the static

12   nature of phonotactic generalizations, it has long been argued that phonotactic evidence is

13   weak evidence about phonological representations/knowledge compared to other sources of

14   evidence such phonological alternations (Ohala, 1986; Oostendorp, 2013). Berg & Koops

15   further show that large-scale phonotactic studies on languages reveal that looking at

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[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.

[3] We present a more elaborate discussion of this issue in Section 3.

1   phonotactic evidence *in toto* suggests syllabic analyses that conflict with other lines of

2   evidence[4]. Therefore, the evidence for multiple-linkage is actually weak, at best.

3   It is in fact due to the lack of evidentiary strength in the phonological patterns adduced

4   so far, in our opinion, that there are so many other mutually incompatible, but equally

5   successful, analyses of ambisyllabic consonants that have been proposed. The different

6   representational analyses vary depending on whether the vowel before the crucial consonant

7   is tense or lax. In the interest of space, these positions are summarized in Table **2**. As

8   mentioned in Footnote 1, for the sake of expository convenience, we refer to these specific

9   word-medial segments as *ambisyllabic segments*; however, by using such a term (which is

10   now standard in phonological discussions) we do not intend to suggest any related theoretical

11   representations. In fact, as was mentioned earlier, we will show that such segments

12   consistently pattern with coda consonants in the data we present in this article.

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[4] 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.

...'V$_{lax}$C V...	'V$_{tense}$C V	Suggested reasons
[e.g., madam]	**[e.g., matron]**	
ambisyllabic	ambisyllabic	Conditions satisfied for multiple linkage
		(Gussenhoven, 1986; Hayes, 2009; Kahn, 1976)
coda	coda	Through (re)syllabification from onset
		(Borowsky, 1986; Selkirk, 1982; Wells, 1990)
coda	onset	Due to Weight-to-Stress Principle
		(Duanmu, 2008, 2010)
onset	onset	Due to the Max-Onset principle. Ambisyllabic facts
		captured through a foot-based analysis
		(Bermúdez-Otero, 2007b; Harris, 2004, 2006; Jensen, 2000; Kiparsky, 1979)

1   Table 2: Theoretical positions on ambisyllabic consonants.[5]

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3   In contrast to the multiple-linked representations approach, proponents of the purely-coda

4   approach suggest a staged-syllabification process, wherein ambisyllabic representations are

5   first syllabified as onsets at a deep-level and then re-syllabified as codas at the surface-level

6   (Borowsky, 1986; Selkirk, 1982). To account for the fact that ambisyllabic alveolar stops are

7   flapped in American English, they suggest that at the deep-level, the feature [+release] is

8   inserted on all onset consonants, including ambisyllabic consonants. Later at a surface-level,

9   the ambisyllabic onsets are re-syllabified to the coda of the preceding syllable. And at this

10   surface level, there is a phonological process by which all alveolar stops marked [+released]

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[5] We have excluded from this table the claims of Giegerich (1992), who claims that ambisyllabic consonants are multiply-linked after lax vowels, and onsets after tense vowels. We do so because he does not actually account for the traditional phonological patterns evinced in discussions of ambisyllabicity, but rather basis his analytical choice primarily on syllable-judgment tasks that we discuss in the following section.

1   in the coda get flapped. It is important to note that, in their analysis, the feature [+released] is

2   crucial to differentiate between ambisyllabic consonants and other coda consonants. This is so

3   because, as discussed above, regular voiceless alveolar coda stops are typically glottalized in

4   English, but ambisyllabic voiceless stops are flapped. The feature [+released] allows them to

5   distinguish between the two types of voiceless coda stops. It is clear that the account of the

6   American English flapping facts comes at the cost of additional features (which are otherwise

7   unnecessary).

8   Another approach to ambisyllabic consonants is taken by Duanmu (2008, 2010). In an

9   extensive review of English phonotactics based on corpus statistics, Duanmu (2010) argues

10   that the maximal syllable in American English is CV(X), where the X stands for either a coda

11   consonant or a vowel. He also proposes a Weight-to-Stress principle to account for the stress

12   patterns of American English, which states that a stressed syllable must be heavy. Crucially,

13   since both long/tense vowels or short vowels followed by a coda consonant count as heavy for

14   Duanmu, he reaches the conclusion that ambisyllabic consonants after short/lax stressed

15   vowels are in the coda of the preceding syllable (e.g. [ˈtɛn.ɪs] 'tennis'), while those after long

16   (tense) vowels are in the onset of the next syllable because (e.g., [ˈvi.nəs] 'Venus'); the latter

17   syllabification is because the stressed syllable is already heavy as the long vowel occupies the

18   V(X) positions. His analysis suggests based purely on word-phonotactics that ambisyllabic

19   consonants after short/lax vowels are codas, while those after long/tense vowels are onsets.

20   Finally, foot-based proposals of ambisyllabic consonants suggest that the standard

21   view of multiple-linkage, and the view of ambisyllabic consonants as codas are unnecessary

1   to account for the facts typically attributed to ambisyllabic representations (Bermúdez-Otero,

2   2007b; Harris, 2004, 2006; Jensen, 2000; Kiparsky, 1979). In particular, Jensen (2000)

3   addresses multiple phonological processes from English (and other languages). In particular,

4   he focuses on the following processes in English dialects: r-tapping in British English,

5   Compensatory Syllabification, l-velarization, schwa-insertion before /r/, the British English

6   process of voiceless stop-insertion between a nasal and a fricative, American English flapping.

7   He argues that all of these above processes can be re-analyzed a foot-medial phenomena;

8   therefore, there is no need for multiply-linked representations.

9   Given the above brief discussion of the different phonological claims, it is easy to

10   observe that the purely coda approach to accounting for phonological facts attributed to

11   ambisyllabic consonants can be done only at the cost of introducing phonological features that

12   are perhaps not otherwise justifiable. Similarly, the multiply-linked representations approach

13   also introduces complex representations, which while having the phonological structure of

14   geminates have phonetic consequences that are far-removed from them. Therefore, multiple-

15   linkage has been argued to be a rather vacuous formal device (Picard, 1984) that leads to a

16   quite opaque view of the phonology-phonetics interface. In contrast, the foot-based approach

17   is able to account for the patterns using phonological representations and structures

18   independently needed, and is therefore the simplest or most economical approach to

19   accounting for the facts. Therefore, in our opinion, the foot-based approach then is the current

20   best analysis of such data. Consequently, this should provide the point of departure for future

1 work on ambisyllabic consonants; one needs to show that foot-based analyses cannot account

2 for the data before proposing additional representational complexity.

3   However, this leaves open the question, what exactly is the syllabification of foot-

4 medial consonantal positions, especially those that ambisyllabic consonants occupy? It is still

5 possible for ambisyllabic consonants to be either onsets (Kiparsky 1979, *inter alia*), or codas

6 (Borowsky 1986), or codas/onsets depending on the preceding vowel (Duanmu 2010), or even

7 multiply-linked. It is this question that we try to address in this paper, and show that the

8 evidence we present supports the claim that they are codas[6].

9

10 1.2 Experimental evidence

11 The issue of ambisyllabic representations has also been probed through a variety of

12 experimental techniques, namely, behavioral experiments on syllable-boundary judgments,

13 speech errors, and production experiments. In the following sub-sections, we discuss these

14 results. We suggest that while such experiments have been extremely useful and informative

15 in understanding the complexities of testing phonological representations, there is in many

16 cases a substantial gap between the experimental results and the theoretical claims made in

17 the phonological literature.

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[6] We would like to note, as the preceding discussion should already make clear, we are *not* suggesting that all generalizations previously attributed to ambisyllabic consonants are to now be analyzed as contingent on such consonants being codas. We are in fact suggesting that given foot-based analyses can quite economically account for previously furnished phonological data, it should then be treated as the best analysis of the relevant data. As a result, there is a need to establish what exactly is the syllabic affiliation of such consonants.

1   1.2.1   Behavioral experiments based on syllable-boundary judgments

2   A variety of meta-linguistic tasks have been used to argue that ambisyllabic consonants

3   behave like onsets and codas simultaneously (Derwing, 1992; Elzinga & Eddington, 2014;

4   Hayes, 2000; Treiman & Danis, 1988). For example, in a now classic study, Treiman & Danis

5   (1988) gave participants a syllable-reversal task, where participants had to move the first

6   syllable to the end of the word (e.g., *snowman* → *man*…[pause]…*snow*; *grandfather* →

7   *father*…[pause]…*grand*). The test items included words with word-medial codas, word-

8   medial onsets, and medial consonants. The participants in their experiment were more likely

9   to associate medial liquid and nasal consonants with both syllables than with following

10   syllables; obstruent consonants had fewer responses associated with both syllables. And

11   typically, medial consonants following tense vowels were more likely to be associated with

12   the following syllables than those following lax vowels (e.g., [ˈto.nɚ] 'toner' >> [ˈspæ.nɚ]

13   'spanner')[7]. To summarize, the results from these experiments suggest that *ambisyllabic*

14   *consonants* are intermediate between codas and onset; they appear to be more onset-like

15   following tense vowels than following lax vowels; and finally, typically in such experiments,

16   obstruent ambisyllabic consonants are much more likely to be judged as affiliated to the

17   following syllable, than sonorant ambisyllabic consonants.

18   However, the results of such metalinguistic tasks have been questioned by more recent

19   research. As noted by some of the original authors themselves, the tasks are confounded by

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[7] For example, the word 'toner' is typically broken up as [ˈto.nɚ]; each of the "syllables" is consistent with
word-boundary phonotactics. Therefore, the parse might not reveal syllable-boundary judgments at all.

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 phonotactics (Harris, 2004, 2006; Steriade, 1999). For example, 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, many of the practice items that were given to the participants by Treiman & Danis (1988) had a crucial first syllable that could have been an independent word (e.g., *grandfather, snowman, jetliner, jawbreaker*). Furthermore, the examples also did not allow the participants to distinguish between using syllable-boundary intuitions versus word-boundary phonotactics. 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 of identifying potential or real words based on word-boundary phonotactics instead of identifying the first syllable. Finally, Treiman & Danis (1988) while supporting ambisyllabic representations 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[8] (Selkirk, 1982).

Another important point in regard to the behavioral experiments presented above is that the results are actually inconsistent with (theoretical) phonological claims about

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[8] An anonymous reviewer comments that "no-one believes in such a staged model of syllabification". However, as Bermúdez-Otero (2011) points out, some sort of staged syllabification is necessary to account for the process of voicing that affects *only* resyllabified onset [s] in Quito Spanish.

1   ambisyllabic consonants. Such experiments appear to consistently have data where an

2   ambisyllabic consonant following a tense vowel is largely associated with the following

3   syllable, while those following lax vowels are more ambisyllabic. However, theoretical

4   proposals that provide an account for multiply-linked representations of ambisyllabic

5   consonants *do not* seem to make this distinction (Hayes, 2009; Kahn, 1976), as the

6   phonological patterns used in such arguments always treat ambisyllabic consonants after both

7   tense and lax vowels similarly (e.g., flapping in American English happens after both tense

8   and lax vowels). Furthermore, the theoretical proposals also do not distinguish between

9   sonorant and obstruent consonants. However, as mentioned above, the results in such

10   experiments often show substantial variation based on whether or not the ambisyllabic

11   consonant is an obstruent or sonorant. Finally, the results of such experiments typically show

12   that while participants vary between identifying the ambisyllabic consonant as belonging to

13   the preceding or following syllable, the choice of the relevant consonant being associated with

14   both syllables[9] is in a minority as compared to just the preceding or following syllable. In

15   light of such large divergences from the theoretical claims, if the behavioral evidence is taken

16   as support for multiply-linked representations, then we believe it is incumbent on such

17   proponents to explain why the experimental results are so divergent from the theoretical

18   predictions. We are unaware of any such systematic attempt to do so. Therefore, it is unclear

19   to us that the behavioral evidence discussed above is actually good evidence for multiply-

20   linked representations proposed in the theoretical literature.

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[9] "1-2" in (Treiman and Danis 1988).

1 ### 1.2.2 Speech Errors

2 Another very interesting line of experimental research that has figured in the discussion about

3 ambisyllabic consonants is from speech errors[10]. As has been observed by a number of

4 researchers, speech errors appear to largely respect syllable positions, i.e., two segments that

5 interact are either both in onsets or both in codas (Fromkin, 1971, 1973; Meringer & Mayer,

6 1895; Shattuck-Hufnagel, 1979, 1979; Stemberger, 1982, 1983). Stemberger (1983) points out

7 that in his corpus of speech errors, while typical onsets interact with other onsets, and typical

8 codas interact with other codas, ambisyllabic consonants[11] interact with both onsets and codas.

9 In his corpus, 108 ambisyllabic consonants interacted with onsets, while another 72 of them

10 interacted with codas. He argues that the results are difficult to account for if such consonants

11 are viewed as linked to just the preceding or just the following consonant.

12 However, the results are also difficult to square with multiply-linked representations[12].

13 While at-first-sight they appear to be excellent evidence for multiply-linked ambisyllabic

14 consonants, it is unclear what linking hypothesis between the theoretical claims and the

15 experimental results will allow us to see them as such. The multiply-linked representation

16 view suggests that ambisyllabic consonants are *both* in onsets and in codas, and not *just*

17 onsets or codas, therefore, it is unclear why such consonants are able to interact with just

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[10] Thanks to an anonymous reviewer for bringing this to our notice.

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

[12] We would like to 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.

1   onsets or codas independently. What would be expected (on a precise, arguably rigid,

2   interpretation) is that given ambisyllabic consonants have a syllabic affiliation neither like

3   regular onsets nor like regular codas, therefore, they should only interact with other

4   ambisyllabic consonants; however, this is not the case. Furthermore, a more serious issue with

5   interpreting the results stems from the fact that, right from the beginning of modern

6   phonological research on ambisyllabic consonants (Kahn, 1976), it has been claimed that the

7   environments that lead to multiple-linkage are completely predictable, and therefore,

8   multiply-linked representations are *not* in underlying or lexical representations. However, in

9   contrast to claims related to ambisyllabic consonants, other predictable patterns do not seem

10 to transfer between positions or segments in speech errors. In Stemberger's own data, flapping

11 seems to always respect the appropriate phonological environment, i.e., if a /t/ appears due to

12 a speech error in a flapping environment, then it is flapped; but flapping does not move to an

13 inappropriate position. Similarly, the rounding or /ʃ/ in American English, another predictable

14 pattern, does not seem to ever transfer from segment to segment, but remains with the original

15 /ʃ/ when it is transposed (Clements & Ridouane, 2006; Fromkin, 1973). As a rebuttal to this

16 particular issue, it is in our opinion insufficient to say that the relevant syllabic representations

17 are in the underlying/lexical representations without independent argument/evidence in the

18 case of ambisyllabic consonants, especially given the fact that at least some syllable

19 affiliations appear to involve syllabication that is not present in lexical representations,

20 namely, resyllabification effects, particularly across words.

1   It is also worth noting that the results that Stemberger furnishes are also potentially

2   inconsistent with those from syllable-boundary experiments. While the latter typically find

3   differences between ambisyllabic consonants after lax and tense vowels, Stemberger does not

4   note any differences between the two.

5   In conclusion, we would like to highlight that before using speech errors as evidence

6   for multiply-linked representations of ambisyllabic consonants, it is important clarify what

7   exactly is the linking hypothesis that would correctly separate the facts about ambisyllabic

8   consonants from other phonological/phonetic patterns. Minimally, what we hope to have

9   pointed out is that, in the absence of a clear linking hypothesis, it is not clear that one can

10 interpret such data as (unambiguous) evidence for syllabic affiliations of ambisyllabic

11 consonants.

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13 1.2.3   Production Experiments

14 There have also been a variety of production experiments that have attempted to answer the

15 question of how ambisyllabic consonants are syllabically represented (Gick, 2003; Krakow,

16 1989, 1999; Scobbie & Wrench, 2003; Sproat & Fujimura, 1993; Turk, 1994). For example,

17 Krakow (1989, 1999) in a production study looking at the magnitude of the velum movement

18 during nasal consonants showed that an [m] in some intervocalic contexts (e.g., 'homey' and

19 'seamy') behaved like codas, while in others intervocalic contexts behaved like onsets (e.g.,

20 'pomade'); and the [m] in some other words appeared to be inconsistent (e.g.. 'Seymour',

21 'helmet'). In another production study, focusing on the gestural dynamics of the ambisyllabic

1 consonant [l], Gick (2003) argued that the [l] in the phrase 'hall otter' has durational

2 properties intermediate between the [l] in the phrase 'hall hotter' (where it is a coda), and the

3 phrase 'ha lotter' (where it is an onset). He suggested that this intermediacy is a manifestation

4 of different syllabic affiliations of the [l] in the three phrases; thereby, suggesting that the

5 ambisyllabic [l] is syllabically different from both onsets and codas [l].

6   As can be seen from the brief summary above, the results from previous production

7 studies have been inconclusive. Some have claimed that ambisyllabic consonants largely

8 pattern with codas (Krakow, 1989, 1999; Turk, 1994); others have claimed that they are

9 intermediate between onsets and codas (Gick, 2003); and some others have argued that there

10 is too much gradience in the phonetics to allow for an abstract categorization (Sproat &

11 Fujimura, 1993). The inconsistent nature of the results could be attributed to at least two

12 separate factors. First, there has been a conflation of *ambisyllabic* consonants with

13 *intervocalic* consonants; however, as noted above, consonants that are followed by a vowel

14 with secondary stress in American English, though intervocalic, indisputably pattern with

15 proto-typical onsets in phonological patterns, and should not be lumped with ambisyllabic

16 consonants. Second, some of the results are also confounded by domain-edge effects; for

17 example, the [l] in Gick's stimuli was either before a word boundary or after a word-

18 boundary; however, such contexts are known to be affected by domain-edge (durational)

19 effects (Cho, Keating, Fougeron, & Hsu, 2003; Fougeron & Keating, 1997). Therefore, such

20 domain-edge lengthening and strengthening effects most probably affected the measurements

21 made.

1   1.3 Summarizing the state of affairs

2   A careful examination of the previous literature seems to suggest that standard multiple-

3   linkage analyses of ambisyllabic consonants have both theoretical and experimental problems.

4   The review of the experimental evidence also suggests a need for better alignment between

5   theoretical and experimental work, and a need for more appropriate experimental controls in

6   studying the issue of ambisyllabic representations. One way in which the latter can be

7   achieved is by focusing purely on word-internal ambisyllabic consonants - this would avoid

8   the effect of phonetic domain-edge effects (Cho et al., 2003; Fougeron & Keating, 1997). A

9   second aspect that is worth probing more carefully is the issue of ambisyllabic consonants

10   following phonologically[13] lax and tense stressed vowels, to see if there are any differences

11   between the two contexts. Finally, though the theoretical literature has consistently argued for

12   a uniform treatment of both obstruent and sonorant ambisyllabic consonants, there seem to be

13   some suggestions in the experimental literature that sonorant ambisyllabic consonants behave

14   differently from obstruent ambisyllabic consonants. Therefore, it is also important to present

15   independent representational arguments for both types of consonants.

16   It is important to point out that, our critical evaluation of the previous (particularly,

17   experimental) literature might allow one to misconstrue us as being dismissive. However, far

18   from it, we intend the criticism as a means for a more constructive dialogue between theory

---

[13] The distinction that matters is *phonological* laxness vs. tenseness, not *phonetic* laxness vs. tenseness. For example, based on its durational properties, [æ] has been described as a phonetically tense vowel; however, both in the phonological evidence and the experimental evidence related to ambisyllabicity, [æ] behaves like other phonological lax vowels. We will use the terms lax and tense to refer to the phonological distinction henceforth.

1 and experiments, and we hope minimally that it will allow researchers with different views on

2 ambisyllabic consonants to more carefully address discrepancies between (and problems with)

3 the multiple lines of evidence that have been used in the debate on ambisyllabic

4 representations. In fact, the previous work on the issue has been instrumental in our

5 understanding of the issues at stake, and has informed us of the appropriate way to proceed.

6 Furthermore, we can honestly say, that our own theoretical hope before starting work on this

7 article was to show that word-medial ambisyllabic consonants pattern with word-medial

8 onsets, as this would have allowed us to maintain a rather nice theoretical expectation that all

9 syllables have onsets. However, in the following sections, we present two separate arguments

10 that, contradictory to our initial hope, suggest that ambisyllabic consonants pattern with codas

11 in American English. Given that we believe we have correctly controlled for relevant

12 confounds, we have indeed been forced to accept that there is at least some evidence for the

13 position that such consonants are in fact codas.

14   More specifically, in Section 2, we present the results of a production experiment

15 looking at the nasalization of tense and lax vowels that precede word-medial ambisyllabic

16 nasal consonants and compare the nasalization patterns to those of the same vowels before

17 prototypical word-medial coda and word-medial onset nasal consonants. Our results suggest

18 that word-medial ambisyllabic consonants behave like word-medial codas both after tense and

19 lax vowels. In Section 3, we discuss devoicing patterns from Pennsylvania Dutchified English

20 (PDE) that suggest the same inference for obstruent consonants. Finally, in Section 4, we

21 conclude with a brief discussion.

1 **2. Experiment on American English nasalization**

2 In this section, we present the results of a production experiment on American English

3 speakers focused on the patterns of vowel nasalization due to the following nasal consonant in

4 different syllabic positions. The reason we focus on nasals is that it has been extensively

5 recorded that nasal consonants produce systematic patterns of vowel nasalization based on

6 their syllabic affiliation (Krakow, 1989, 1999; Solé, 1992, 1995, 2007). Therefore, these

7 vowel nasalization patterns can be used to probe the syllabic affiliation of ambisyllabic nasal

8 consonants. In particular we focus on two questions: (a) What are the vowel nasalization

9 patterns observed before word-medial ambisyllabic nasal consonants, i.e., do word-medial

10 ambisyllabic nasal consonants pattern with word-medial onsets, or word-medial codas, or are

11 they intermediate between the two? (b) Do we see different patterns of vowel nasalization for

12 word-medial ambisyllabic nasal consonants following tense and lax vowels? The reason we

13 focus on word-medial segments is to avoid confounds due to domain-edge effects (Cho et al.,

14 2003; Fougeron & Keating, 1997). And the reason we look at both tense and lax preceding

15 vowel contexts is because, as discussed in the preceding section, at least some theoretical and

16 experimental work has argued for different syllabic affiliations of ambisyllabic consonants

17 based on the quality (or length) of the preceding vowel.

18   In what follows, we show that word-medial ambisyllabic nasal consonants pattern

19 with word-medial coda consonants after both tense and lax vowels in American English. In

20 fact, when the relevant confounds are controlled for, there is no evidence of the intermediate

21 nature of ambisyllabic consonants that has previously been claimed.

1   *2.1 Method*

2   *2.1.1   Stimuli*

3   The test items were all real English words that had the nasal consonants [n] and [m] in four

4   different environments: word-medial onset of a syllable with secondary stress, word-medial

5   coda, word-final coda, and word-medial ambisyllabic context (Table **3**). Word-medial

6   consonants preceding a vowel with secondary stress were chosen particularly because, based

7   on the aspiration and flapping generalizations, there is a clear consensus that these consonants

8   are in the onset of the following syllable in American English. The two pre-nasal vowels we

9   used were lax [æ] and tense [oʊ][14]. These two vowels were chosen since there is no lexical

10   gap among all four environments. All the test items also had primary stress on the first vowel.

11

	Ambisyllabic nasal	Word-medial nasal coda	Word-medial onset	Word-final coda
V1= lax [æ]	**gamm**a	**gam**ble	**gam**ete	**gam**
V1= tense [oʊ]	**don**or	**bon**ehead[15]	**gon**ad	**bon**e

12   Table 3: Test items.

13

14   It can further be noticed that the vowel following the crucial nasal consonant has not been

15   controlled for in the stimuli. This is because it was impossible to get such a set of words for

---

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

[15] It is worth noting that this item has a word-medial coda, but is not mono-morphemic – something that we earlier suggested should be avoided if possible. This word was included due to the fact that there were very few words with a word-medial coda nasal preceded by the tense vowel [oʊ]. We elaborate on this issue in Section 2.3, when we discuss if the interpretation of the results is confounded by this fact.

1   all four environments. However, there is simply no evidence that the following vowel affects

2   the vowel nasalization patterns of a nasal consonant onto the preceding vowel in American

3   English. Therefore, any differences in the vowel nasalization patterns observed on a vowel

4   before the different types of nasal consonants are unlikely to be a result of the differences in

5   the quality of the following vowel.

6   Another aspect of the stimuli that is important to highlight is the initial consonant.

7   Because our measurements were all acoustic measures, and it is difficult to mark the relevant

8   boundaries in the case of many consonants, we decided it was best to have an initial

9   consonant that was either a voiced obstruent (or a voiceless fricative, if we found any). Non-

10   nasal sonorant consonants were avoided because identifying vowel boundaries adjacent to

11   such consonants is difficult. Nasal consonants were also avoided; while their segment

12   boundaries are reasonably easy to identify, they would have interfered with the nasalization

13   measures of the following nasal consonant. Finally, aspirated consonants were avoided

14   because aspiration has acoustic cues (crucially, increase in F1 bandwidth) that are very similar

15   to nasalization cues (Arai, 2006), and would have led to inaccurate vowel nasalization

16   measurements.

17   The words used in the fillers were also all real English words that had the

18   phonological structure $(C_1)(V_1)C_2V_2(C_3)$, where V_1 was either [æ] and [oʊ] (Table **4**).

19

20

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

1 Table 4: Filler items.

2

3 *2.1.2   Participants*

4 Eight native speakers of American English without any speech or hearing problems were

5 recruited for the acoustic data collection. The participants were all students from Michigan

6 State University. Six participants (two male, four female) were selected for the final data

7 analysis. One of the participants who was excluded from the analysis produced the words

8 *gamete* and *gonad* as [gəˈmit] and [gəˈnæd]; thus, the speaker's crucial onset context tokens

9 did not have stress on the first syllable as is necessary for proper comparison with the other

10 word-medial contexts. The second participant who was excluded had poor recording quality

11 (for reasons unknown) and had a reasonable amount of ambient noise during recording for us

12 to distrust annotating the recordings. Both subjects were excluded before any measurements

13 were made on the recordings. All students received course extra credit for participation.

14

15 *2.1.3   Procedure*

16 The participants produced 15 repetitions at 3 different speech-rates of 16 English words (8

17 test and 8 fillers) in the carrier phrase "Say _____ here". Therefore, each participant produced

18 720 sentences in total (15x3x16=720). We manipulated speech-rate because, as discussed

19 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[16].

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 experiment had a total of three blocks - one for each speech-rate. At the beginning

of each block, the participants were asked to produce the stimuli 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.

---

[16] However, as we discuss below, on the recommendation of an anonymous reviewer, 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.

1   The demo sentence had no nasal consonants so as to avoid any undue influence of

2   nasalization patterns from the *demo* sentence.

3   Furthermore, at the beginning of each speech-rate session, there was a practice session.

4   Each practice session had other real English words in the same carrier phrase. For example, if

5   the first session was a slow speech-rate session, in the practice session, the participant would

6   be prompted with the slow speech-rate *demo* sentence, and then they would see the target

7   sentence, e.g. "Say book here", on the screen.

8   Again, it is important to note that the speech rates themselves were not crucial to the

9   experiment; however, they were a part of the experiment design so that we could get a good

10   spread of vowel durations, and vowel nasalization durations during the experiment.

11

12   *2.1.4   Measurements*

13   Previous studies have shown that nasal coda consonants have a substantial influence on the

14   vowel nasalization of the preceding vowel in American English (Cohn, 1993; Solé, 1992,

15   1995, 2007). More particularly, it has been argued that there is a consistent proportion of

16   vowel nasalization due to a following coda consonant (Solé, 1992, 1995, 2007). Therefore, in

17   this experiment, we measured the total duration of the vowel and the duration of nasalization

18   so that we could calculate the proportion of vowel nasalization for each token.

19   The recorded test items were analyzed using Praat (Boersma & Weenink, 2015). For

20   each token, the duration of nasalization, and the duration of the whole vowel were measured.

21   The onset of a vowel before the nasal consonant was identified based on the sudden

1   appearance of strong formant structure, and based on a substantial increase in intensity in the

2   waveform. The offset of a vowel was identified again by looking for a sudden flattening out

3   of the waveform (as is common with nasal consonants (Pruthi & Espy-Wilson, 2004)), and a

4   substantial change in the intensity of the formants. Finally, the onset of nasalization on the

5   pre-nasal vowel was identified using the following criteria available in spectrographic

6   representations: (a) abrupt changes in F1 intensity, (b) the appearance of anti-formants, (c) the

7   appearance of a nasal pole (Chen, 1997; Stevens, 1998). In Figure 2, we provide an example

8   of the relevant cues and corresponding annotations made for the tokens, using the single
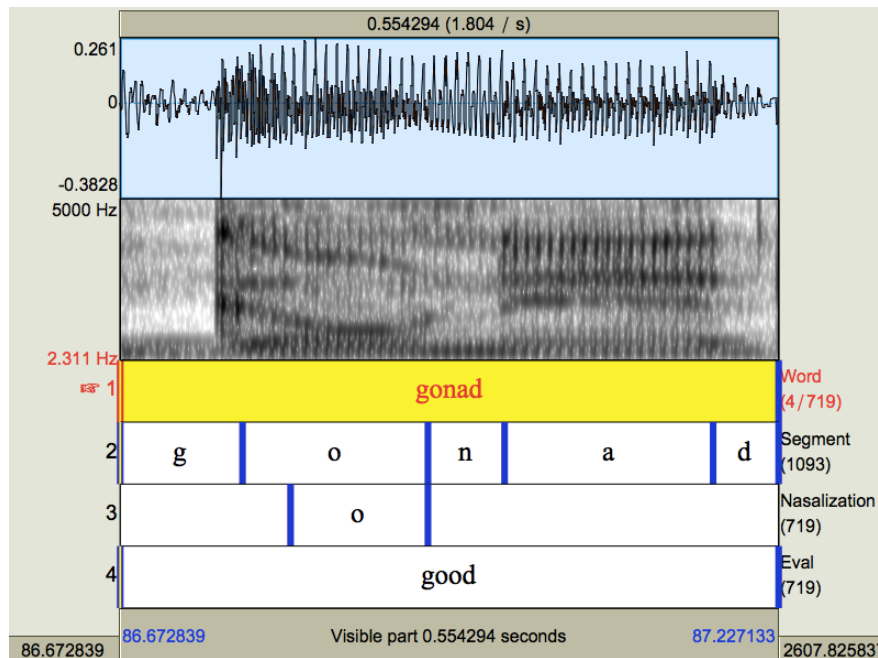
9   production of the test item *gonad*.

10

11

12   Figure 2: Nasalization measurements for the test item *gonad*. The onset of vowel nasalization

13   (3rd annotation tier) is clearly demarcated by the weakening of F1 intensity, widening of F1

14   bandwidth, and the sudden disappearance of F3 (most likely due to nasal anti-formants).

1   The recordings were annotated in Praat for word duration (Word), vowel duration (Segment),

2   vowel nasalization (Nasalization), and acoustic quality of the token (Eval) by two trained

3   annotators (one of whom was a native American English speaker). Each of them annotated the

4   productions of half of the participants. To ensure reliability in marking the vowel nasalization,

5   each annotation was later checked by the other annotator, and in places where there was a

6   disagreement, the two annotators either collaboratively decided on the best point of the onset

7   of vowel nasalization, or the token was discarded due to insufficiently clear cues (very few

8   tokens were discarded). A Praat script was then used to extract the relevant durations from the

9   annotations. These durations were used to calculate the percentage of vowel nasalization of

10   each vowel (vowel nasalization duration / total vowel duration).

11

12   2.2 *Results*

13   2.2.1   *Nasalization Patterns*

14   As discussed above, we used the vowel durations and vowel nasalization durations to

15   calculate the percentage of vowel nasalization, following Solé (1992, 1995, 2007). An initial

16   visual inspection of the results suggested that ambisyllabic consonants following both lax

17   vowels and tense vowels appear to induce roughly the same percentage of nasalization as

18   word-medial codas at all three speech-rates (Figure **3**)[17]. Furthermore, the ambisyllabic

19   consonants clearly did not pattern intermediate between word-medial onsets and word-medial

20   codas. Finally, nasalization due to word-final coda nasals appeared to be substantially

---

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

1 different from that due word-medial coda nasals, particularly at the Normal and Slow speech-
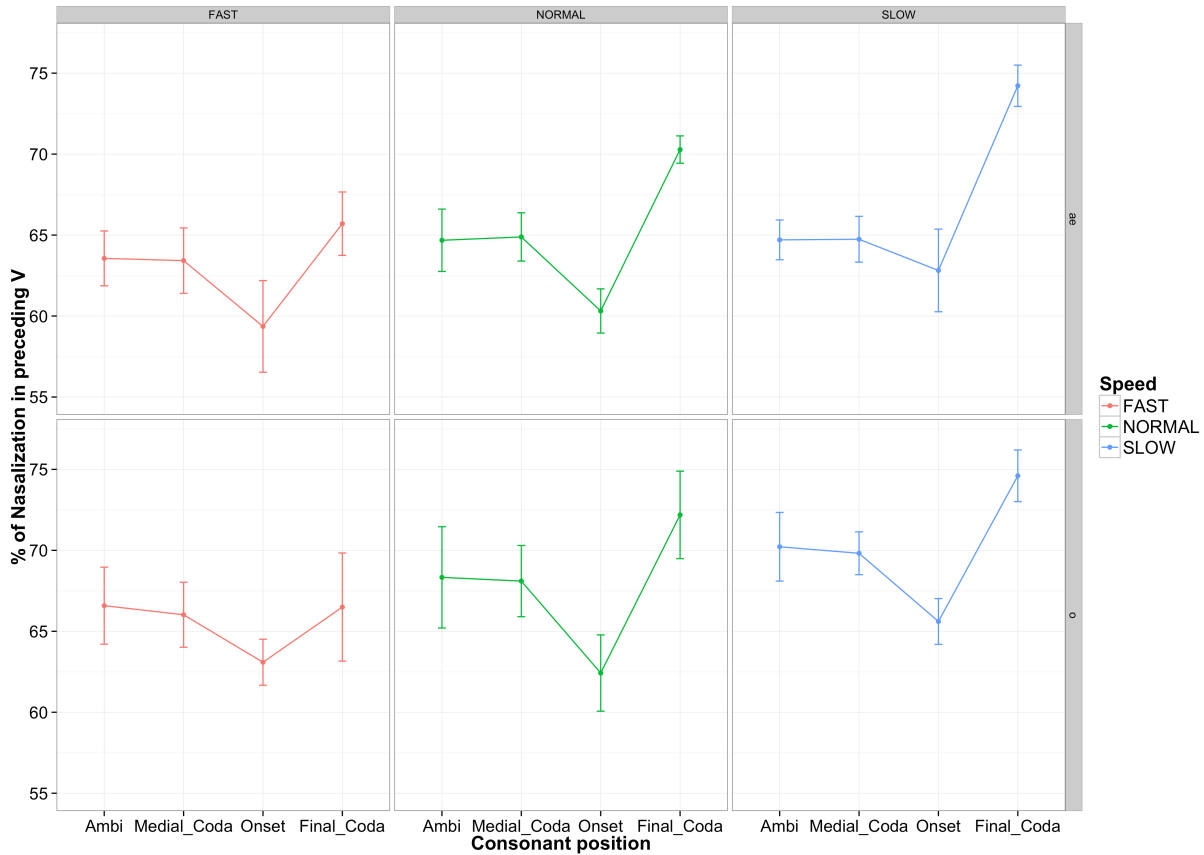
2 rates.

3

Figure 3: Percentage of nasalization of the preceding vowel in different syllabic contents
spoken at different speeds (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

1   comparison was performed through backwards elimination of non-significant terms,

2   beginning with the interactions, through a Chi-squared test of the log likelihood ratios. The

3   most complex model entertained was the full model with all interaction terms, and the least

4   complex model entertained was the model with only an intercept term and no fixed effects.

5   The dependent variable was the percentage of vowel nasalization on the preceding

6   vowel, and the independent variables were *Syllabic position (SP), Vowel Type (VT), and*

7   *Speed*. The variable *SP* had four levels (Ambisyllabic, Word-medial Coda, Word-medial

8   Onset and Word-final Coda); variable *VT* had two levels (lax vowel [æ] and tense vowel

9   [oʊ]); and the variable *Speed* has three levels (Fast, Normal, Slow). The baseline was the

10   ambisyllabic nasal consonant adjacent to the lax vowel [æ] spoken at the Fast rate; therefore,

11   the intercept term refers to that particular measure.

12   The model with two interacting factors for *SP* and *Speed* and a non-interacting factor

13   for VT was the best model. This model is shown in more detail below (Table **5**).

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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

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

3

4   As compared to the baseline ambisyllabic nasal consonant adjacent to the lax vowel [æ] at the

5   Fast speech-rate, there was a statistically significant decrease in percentage of nasalization for

6   the word-medial onset nasal consonant adjacent to the lax vowel [æ] at the Fast speech-rate;

7   however, there was no statistically significant difference compared to the word-medial coda at

8   the Fast speech-rate. Furthermore, compared to the lax vowel [æ] contexts at the Fast speech-

9   rate, the tense vowel contexts have a statistically significant increase in the percentage of

10 nasalization on the preceding vowel. However, there was no interaction, thereby suggesting

11 that the patterns of vowel nasalization observed with both the lax vowel context and the tense

1   vowel context were similar at the Fast speech-rate. The interaction terms for the word-medial

2   SP levels and other speech rates were also statistically non-significant, which suggests that the

3   pattern of nasalization for word-medial nasals found at the Fast speech-rate extends to the

4   other speech-rates. Finally, compared to the baseline, there was a statistically significant

5   increase in percentage of nasalization for Final Codas (FC) in both the Normal and Slow

6   speech rates. This suggests that, while there is no evidence of difference between Final Codas

7   and Ambisyllabic contexts (or word-medial codas) in the Fast speech rate, there is evidence

8   that the percentage of nasalization in the ambisyllabic contexts at the Fast speech-rate was

9   less than that for the Final Codas in the other two speech rates.

10

11   2.2.2   *Vowel Durations*

12   In this section, we present the measurement results of vowel durations in the different

13   contexts[18]. This is to ensure that the above differences in anticipatory nasalization cannot be

14   attributed to differences in vowel duration in different contexts.

15   As can be seen in Figure **4**, the differences in vowel duration between the three crucial

16   word-medial contexts are negligible. Therefore, the differences in nasalization patterns cannot

17   be attributed to differences in vowel duration. The figure also shows that vowels in word-final

18   syllables are substantially longer than those in word-medial syllables; and as with the

19   percentage of nasalization, there appears to an increase in vowel duration of word-final

20   syllables as the speech-rate slowed down. This again is consistent with the expectation of

---

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

1 domain-final lengthening that we discussed earlier. Another aspect of the vowel durations that

2 is worth noting is that the vowel durations of the phonological lax vowel [æ] are at least as

3 long as those of the phonologically tense vowel [oʊ]. This might suggest that, at least

4 phonetically, the vowel [æ] is tensed. We return to this issue in the discussion below (Section

5 2.3). Finally, as would be expected, the vowel durations increase as we go from the Fast to the
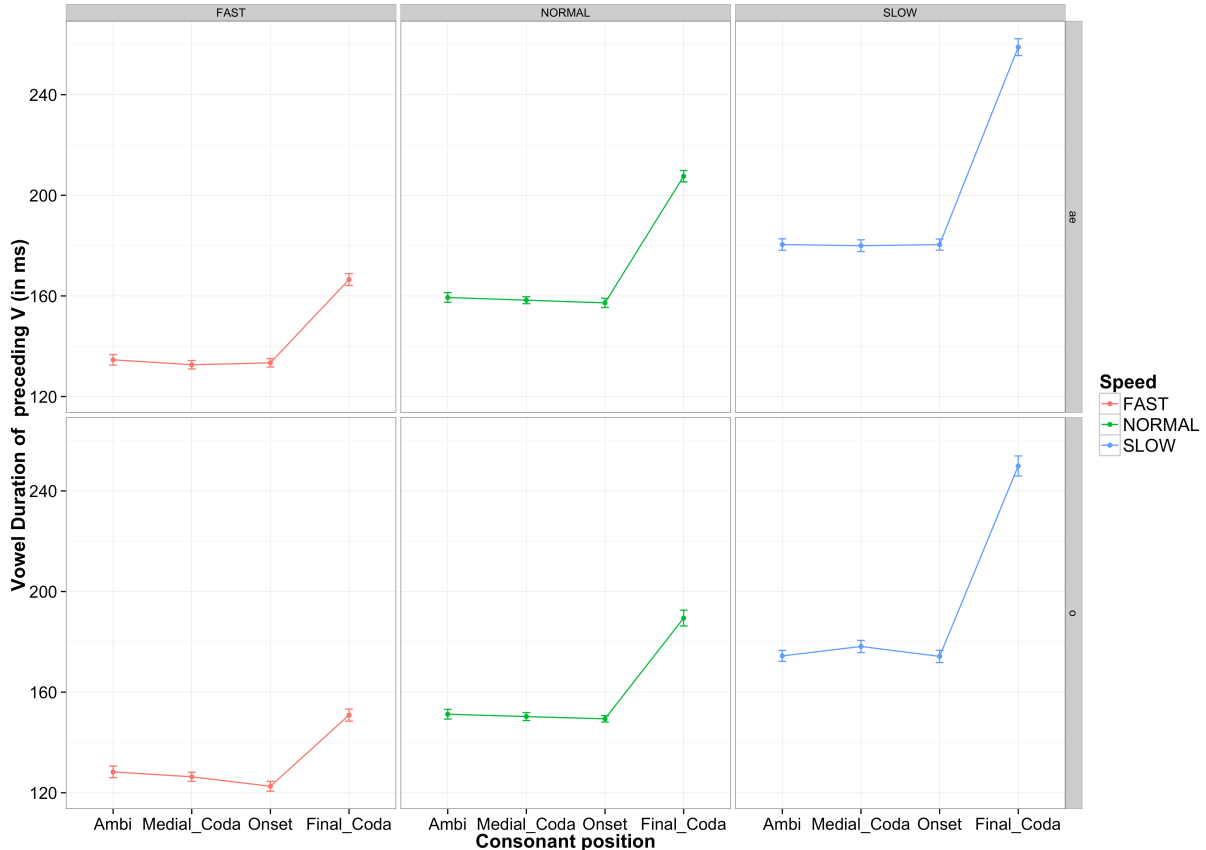
6 Slow speech-rate.

7

9 Figure 4: Vowel durations in different contents spoken at different speeds (Error bars

10 represent standard error).

11

1   A linear mixed effects model was fitted to these data following the method described above

2   (Section 2.2.1). The dependent variable was the total vowel duration of the preceding vowel,

3   and the independent variables were *Syllabic position (SP), Vowel Type (VT), and Speed*. As

4   before, the variable *SP* had four levels (Ambisyllabic, Word-medial Coda, Word-medial

5   Onset and Word-final Coda); the variable *VT* had two levels (lax vowel [æ] and tense vowel

6   [oʊ]); and the variable *Speed* had three levels (Fast, Normal, Slow). The baseline was the

7   vowel duration of the lax vowel [æ] before the ambisyllabic nasal consonant in the Fast

8   context; therefore, the intercept term refers to that particular measure.

9   The model with all three factors with pairwise two-way interactions was the best

10   model. This model is shown in more detail below (Table **6**).

11

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 in 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

1 speeds. Finally, as with the percentage of nasalization, the vowel durations before the word-

2 final codas in the Slow and Normal speech-rate conditions was statistically significantly

3 larger that the baseline.

4

5 2.3 *Discussion*

6 The results suggest that the percentage of nasalization on the preceding vowel due to a word-

7 medial ambisyllabic consonant is intermediate between that due to onset and word-final coda

8 nasals, especially at Normal and Slow speech-rates; however, the percentage of nasalization

9 on the preceding vowel due to an ambisyllabic consonant is *not* observably different from that

10 due to word-medial codas.

11 Crucially, the results reveal that if we had compared word-medial ambisyllabic

12 consonants to word-medial onsets and word-final codas, we would have erroneously observed

13 the intermediate nature of ambisyllabic consonants. This was in fact the confound that we

14 alluded to earlier in the Introduction when we discussed previous production results pertinent

15 to ambisyllabic consonants. The lengthened nasalization for the word-final codas can

16 independently be explained by domain-final lengthening (Cho et al., 2003; Fougeron &

17 Keating, 1997). More specifically, it has been observed that segments closest to a prosodic

18 domain boundary are lengthened more than those further away from the boundary (Byrd &

19 Saltzman, 2003). In our case, adjacent to a word-boundary, the nasalization gesture would

20 receive more domain-final lengthening that the vowel preceding it. This by itself would result

21 in an increased percentage of vowel nasalization due to word-final nasal consonants,

1 compared to word-medial ambisyllabic nasal consonants. So, clearly, comparing word-final

2 nasalization to word-medial nasalization is inappropriate.

3   However, when the correct comparison is made (word-medial ambisyllabic

4 consonants compared to word-medial onsets, and word-medial codas), it is clear from the

5 above results that there is no *intermediate* patterning of word-medial ambisyllabic consonants

6 with respect to word-medial codas and word-medial onsets. In fact, equally clearly, word-

7 medial ambisyllabic consonants behave exactly like word-medial codas (and not like word-

8 medial onsets) following both tense and lax vowel contexts at all speech-rates.

9   An unexpected finding, unrelated to the primary objective of the experiment, is that

10 the tense vowel context in general had a higher percentage of nasalization due to the

11 following nasal consonant. However, one should be careful about over-interpreting this result.

12 Acoustic measurements are after all indirect measures of the lowering of the velum. So while

13 any differences in the degree/percentage of nasalization for the same vowel is interpretable,

14 differences in degree/percentage of nasalization for different vowels could be either: (a) due

15 to real differences in degree/proportion of velum lowering associated with different vowels,

16 (b) due to differences in the acoustic manifestation of the same velum gestures under the

17 influence of difference vocalic gestures. The differences in the percentage of nasalization

18 could also be related to the differences in vowel duration as observed in Section 2.2.2[19].

19 Having identified the difficulty in interpreting the difference in the percentage of nasalization

20 of the two vowel qualities, we wish to point out that others have found similar differences

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

1   before tense and lax vowels. The results of an acoustic measurement study presented by

2   Beddor (2007, p. 252) on American English nasalization patterns clearly show that lax vowels

3   typically have a lower percentage of nasalization than tense vowels, as in the current article.

4   Again, the observed difference in Beddor (2007) could equally be because of possibilities (a-

5   b) laid out above, and we leave the exploration of this particular finding which is not directly

6   relevant to the purpose of the current article as a topic of future enquiry.

7   The nasalization results also indicate that the differences between word-medial codas

8   and word-medial ambisyllabic consonants as compared to word-medial onsets, while

9   consistent across all speech-rates, are quite small. There is an average difference in vowel

10   nasalization of about 4%, which translates to about 7-8ms in terms of raw duration. The

11   durations are above the *just noticeable difference,* which is about 5ms (Nooteboom &

12   Doodeman, 1980). The listeners, therefore, are sensitive to such small differences, and should

13   be able to manipulate them systematically to mark prosodic/syllable structure. The results

14   suggest, in line with a traditional understanding of vowel nasalization in English, that codas

15   trigger more vowel nasalization on the preceding vowel, than onsets on the preceding vowel.

16   The results from the measurement of vowel durations suggests that the differences

17   between the percentage of nasalization due to the nasal consonants in different syllable

18   positions cannot be attributed to differences in vowel duration; at least, not for the crucial

19   comparison of word-medial nasals.

20   The results also reveal that the percentage of nasalization and the vowel durations

21   decrease with increasing speech-rate for the final coda stimuli. This potentially could be

1   attributed to changing prosodic structure of the sentences at faster speech-rates. More

2   specifically, the test items were followed by the adjunct "again" from the carrier phrase.

3   Adjuncts, especially at slow deliberate speech-rates, are likely to be outside the phonological

4   phrase containing the test-item. Therefore, the test item is more likely to be at the end of a

5   phonological phrase domain. But, at faster speech rates, more words (and by extension the

6   adjunct in our stimuli) are likely to be part of the same phonological phrase (Jun, 2003),

7   thereby, decreasing the likelihood of the test-item (and the Final Coda) being in a phrase-final

8   position. This could explain why both the percentage of nasalization and the vowel durations

9   for the final codas decrease with increasing speech-rates.

10   There are three further issues that are very relevant while interpreting the results. First,

11 [æ] is not a prototypical lax vowel, phonetically speaking[20]. In fact, our own measurements

12 reveal that the [æ] vowel is at least as long as the tense vowel [oʊ]. However, it is important

13 to recognize, as pointed out earlier, that it is the phonological tenseness vs. laxness of vowels

14 that is relevant in the discussion of ambisyllabic consonants, i.e., it is their phonological

15 behavior that is important for the distinction. As far as we know, [æ] behaves like all other lax

16 vowels with respect to (a) not being allowed word finally (*tæ, *bæ), (b) in allowing an [ŋ] to

17 follow it with the same syllable (e.g., 'tang', bang') (Borowsky, 1986). Furthermore, the

18 distinction between tense and lax vowels was introduced into the experiment because some

19 researchers claim that ambisyllabic consonants are codas after lax vowels, but onsets after

20 tense vowels (Duanmu, 2008, 2010), and because experimental manipulations suggested

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[20] Thanks to all three anonymous reviewers for pointing this out.

1   differences between ambisyllabic consonants following tense and lax vowels (Derwing, 1992;

2   Elzinga & Eddington, 2014; Treiman & Danis, 1988). For these researchers, in the context of

3   ambisyllabic consonants, the [æ] vowel is clearly considered a lax vowel. In addition, in on-

4   going research, Duncan (2015) argues that even in NCS dialects, where the [æ] vowel is

5   substantially tensed phonetically, native speakers treat it like a lax vowel, as in other

6   American English dialects. Finally, even if one were to disregard the above arguments and

7   claim that [æ] is simply a tense vowel, then our experiment would have shown that

8   ambisyllabic consonants after two different tense vowels behave like codas. Given that we are

9   testing between multiple theoretical proposals in the literature, it is useful to recognize that

10 there is no one who argues that ambisyllabic consonants after tense vowels are codas, but

11 those after lax vowels are otherwise. As far as the theoretical proposals of the syllabic

12 affiliation ambisyllabic consonants are concerned, we think it is fair to say that if it can be

13 shown that ambisyllabic consonants pattern as codas after tense vowels, then it follows that

14 those after lax vowels do so too.

15   Second, the experimental stimuli set is small. While it is always nice to have as

16 extensive a set of stimuli as possible to ensure generalization to the language, in this particular

17 case, it was indeed quite hard to come up with (near) quadruplets of stimuli containing the

18 same vowel in words where the medial consonant has different syllabic affiliations. In fact, an

19 extensive search in the CMU Pronouncing Dictionary (Weide, 1994) revealed at most one or

1   two more quadruplets that satisfied our criteria for the stimuli[21], which were discussed above

2   (Section 2.1.1). Therefore, an experiment with a more substantial stimulus list was not

3   possible with our design. Although such a stimulus set size is not atypical for production

4   experiments, given this limitation, we advise the reader to interpret the results with some

5   caution.

6   Third, we have assumed, like most (if not all) other production studies related to

7   ambisyllabicity till now, that there is no direct role for lexical frequencies[22]. The crucial

8   word-medial onsets in our stimuli, namely, *gamete* and *gonad*, are both rather low-frequency

9   words compared to the rest. It is possible that the lexical frequencies of the words had an

10   influence on the nasalization patterns. However, the extant literature on the topic leads one to

11   somewhat conflicting expectations[23]. Scarborough (2004) suggests that speakers coarticulate

12   more in the case of words with lower lexical frequency for functional reasons having to do

13   with mitigating listeners' lexical access difficulties. In contrast, Zellou & Tamminga's (2014)

14   results suggest that coarticulation increases with lexical frequencies. Clearly, there is more

15   work that needs to be done on the issue before one can ascertain the influence of lexical

16   frequencies, and how such facts have a bearing on the coarticulatory patterns being discussed

17   here. We leave this particular issue as a topic for future inquiry.

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

[22] Thanks an anonymous reviewer for highlighting this assumption.

[23] Thanks to an anonymous reviewer for suggesting to us to incorporate this information.

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 not word-medial onsets for the stimuli in our experiment.

3. Phonological evidence from Pennsylvania Dutch

In the preceding section, it was shown that word-medial ambisyllabic nasal consonants pattern with word-medial nasal codas, and not with word-medial nasal onsets for the stimuli in our experiment. However, as discussed in the Introduction, there have been some reports that suggest that ambisyllabic *sonorant* consonants are more likely to be codas than ambisyllabic *obstruent* consonants[24] (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.

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

---

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

1   ambisyllabic consonants are subject to alternations that are different from prototypical onsets

2   and codas is very weak evidence for multiple-linkage representations, given that such

3   alternations can more directly be accounted for by the use of the very same prosodic

4   conditioning factors that are used to establish the multiply-linked representation in the first

5   place. In fact, this is exactly the stance of those who account for such alternations using foot-

6   structure based analyses (Bermúdez-Otero, 2007b; Harris, 2004, 2006; Jensen, 2000;

7   Kiparsky, 1979). Furthermore, the use of phonotactic arguments to probe syllable-structure

8   affiliations is also slightly suspect given that it has recently been argued that such analyses

9   lead to sub-syllabic parses that are inconsistent with the rest of the evidence in a language

10   (Berg & Koops, 2010, 2015). Of course, given their static nature, phonotactics have long been

11   argued to be a weaker source of evidence for phonological knowledge compared to

12   phonological alternations (Ohala, 1986; Oostendorp, 2013), and this view has received more

13   support recently, as Becker, Nevins, & Ketrez (2011) showed for Turkish speakers that not all

14   phonotactic patterns observed in the language are reflected in native-speaker intuitions. The

15   additional interest in Berg & Koops' (2015) paper results from the fact that they argue that

16   phonotactic evidence can also be inconsistent with other sources of evidence. In particular,

17   they show that phonotactic generalizations have an inherent rightward bias wherein the

18   prevalence of phonotactic constraints increases from earlier to later portions in a word. And as

19   a consequence of the above bias, when phonotactic generalizations are considered in their

20   entirety in a language, they lead to a representation of sub-syllabic constituency that

21   sometimes contrasts with constituency inferred from other types of generalizations. In

41

1 particular, both Korean and Finnish have been clearly argued to have left-branching syllable

2 structure based on speech errors, language games, morphophonological processes, and other

3 behavioral experiments; however, phonotactic generalizations suggest a flat syllable structure

4 in Korean, and a right-branching structure in Finnish. Based on this mismatch between the

5 inference about sub-syllabic constituency from phonotactic generalizations and those from

6 many other lines of evidence, Berg and Koops state that "[t]he results of our analyses

7 demonstrate a striking disconnect between phonotactic constraints and sub-syllabic

8 constituency" (pg. 31), and later conclude that "[a] somewhat surprising overall conclusion of

9 the present paper is that phonotactics is a poor indicator of sub-syllabic structure. Other lines

10 of evidence, whether naturalistic or experimental, appear to have a more direct bearing on the

11 question of sub-syllabic constituency" (pg. 35). Consequently, given the inherent right-ward

12 bias of phonotactic generalizations as identified by Berg and Koops and their potential

13 untrustworthiness with sub-syllabic constituency, one should also proceed with extreme

14 caution in interpreting any phonotactic evidence as strong evidence in support of multiply-

15 linked syllabic representations in the case of ambisyllabic consonants. Of course, it is in our

16 opinion an entirely reasonable response for those especially in favor of phonotactic arguments

17 for syllabic constituency to suggest that results such as Berg & Koops (2010, 2015) only

18 suggest more nuance in interpreting phonotactic evidence for syllabic affiliation; however, for

19 there to be progress on the issue, we think it is necessary for those in favor to provide exactly

20 what that nuance needs to be and how it accounts for the facts presented by Berg & Koops.

21 Otherwise, it is difficult to assess whether such a strategy is a reasonable one.

1   In contrast to previous analytical strategies, in what follows, we show a case where

2   ambisyllabic consonants are necessarily subject to the *same* alternation as either prototypical

3   onsets or codas. As we show below, Pennsylvania Dutchified English (PDE) provides us with

4   the necessary conditions to test if such predictions of the multiple linkage analysis are borne

5   out. And as in the previous section, we show that when we look at the appropriate

6   environments in PDE, word-medial ambisyllabic obstruent consonants pattern with word-

7   medial codas, and not with word-medial onsets. It is important to note that all the data we

8   present on PDE are based on work by Vicki Anderson and colleagues (Anderson, 2001, 2011;

9   Anderson & Davis, 2013). The data were collected during field-work by Vicki Anderson on

10   the PDE dialect spoken in northern Lebanon County, Pennsylvania, and depended on taped

11   interviews, native speaker intuitions, and spectrographic analysis.

12   PDE is a dialect of American English that has been influenced by German (Anderson,

13   2001; Anderson & Davis, 2013). However, as with Standard American English (SAE),

14   alveolar stops are realized as flaps in word-medial positions if preceded by a stressed syllable

15   and followed by an unstressed syllable (Table **7**). In fact, the flapping environments for PDE

16   are exactly those of SAE (Anderson & Davis 2013). Therefore, the consonants in flapping

17   environments must have the same representational analysis as in SAE. As noted above, the

18   process of flapping in SAE is the paradigm example used by Kahn (1976) to argue for

19   multiply linked representations. We return to this issue towards the end of this section.

20

21

	Obstruent stop		Flapped	
[ˈdʌk]	'duck'	[ˈbɛɾɪŋ]	'bedding'
[əˈdɪkʃən]	'addiction'	[ˈɹaɪɾɪŋ]	'riding'

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

3 While flapping in PDE by itself does not allow us to tease apart different hypotheses about

4 ambisyllabic representations, PDE also has a devoicing rule (presumably, as an influence

5 from German), whereby syllable-final voiced stops become voiceless[25]. Before presenting the

6 facts from PDE, we will present the devoicing facts from German, as the pattern in German

7 forms a nice comparison point for the facts in PDE. As pointed out by Wagner (2002), the

8 German devoicing pattern is better accounted for as a generalization that is sensitive to

9 phonological word boundaries.

10   As can be see in Table **8**, German allows for voiced obstruents in word-initial and

11 inter-vocalically in word-medial contexts, but not in a word-final context.

Word-initial onset		Word-medial onset		Word-final coda		
[b̥auɐ]	'peasant'	[ɛbə]	'low tide'	[li:pʰ] /li:b/	'nice'
[d̥oɐf]	'village'	[kladə]	'songs'	[ra:tʰ] /ra:d/	'wheel'

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

---

[25] 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.

1 Furthermore, as can be seen in Table **9**, not all word-medial coda contexts trigger devoicing of

2 voiced obstruents. Only codas before what Wagner calls "non-cohering" suffixes are

3 devoiced[26]. As a consequence, crucially, morpheme medial codas are not devoiced.

4

Word-medial (before cohering affixes)		Word-medial (before non-cohering affixes)		Morpheme medial codas[27]	
[ra:**d**+l+ə]	'bike (1sg.)'	[ra:**t**+los]	'without wheel'	e[**d**].les	'noble'
[li:**b**+l+ə]	'flirt (1sg.)'	[li:**p**+lıç]	'lovely'	Loe[**b**].ner	name
				a[**d**].ler	'eagle'
				ma[**g**].ma	'magma'

5 Table 9: Voiced obstruents in word-medial coda contexts

6

7 To account for the fact that voiced obstruents devoice in word-final coda positions and before

8 non-cohering suffixes, but not before cohering suffixes and morpheme-medially, Wagner

9 suggests that the coda devoicing in German is sensitive to the boundary of the phonological

10 word. As per his analysis, the codas adjacent to non-cohering suffixes and those that are

11 word-final, are immediately followed by a phonological word-boundary, but those in the other

---

[26] Wagner also points out that the term "coda" is entirely unnecessary if one assumes that obstruent clusters share one laryngeal node.

[27] An anonymous reviewer points out that the word 'absurd' is pronounced [apzurt] in German, where the word-medial obstruent coda appears to be devoiced. Given the evidence we presented in Table 9, there are two possibilities: (a) the underlying phoneme, despite the spelling, is indeed a [p]; (b) there are other factors involved in the German devoicing process. However, our main point, following Wagner (2002) that the devoicing process in German is not general coda devoicing stands.

1   positions are not. Therefore, the German devoicing pattern is not a purely coda-phenomenon,

2   and is actually sensitive to higher-level prosodic structure.

3   While in German, it is only voiced coda stops at the end of phonological words that

4   are devoiced as pointed out above, in PDE even word-medial codas are devoiced, as is

5   evidence by words such as 'a[**k**]nes', and 'a[**t**]mission' (Table **10**); therefore, the appropriate

6   generalization in PDE, unlike German, is that of general *coda devoicing*. As with flapping in

7   SAE, *coda devoicing* does not apply to word-initial consonants ('[**b**]less'), or to initial

8   consonants of stressed syllables ('ha[**b**]itual'), or to initial consonants of secondary stressed

9   syllables ('cari[**b**]ou', 'Penta[**g**]on'). Thereby, extending further support to the standard

10 analyses of the consonants in these contexts as onset consonants.

11

12

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'
habi[t]ual	Penta[g]on	[g]orilla	lea[**f**]	'leave'	a[**t**]mission	'admission'
			be[**t**]	'bed'	o[**p**]tuse	'obtuse'

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

14
15
16
17
18
19
20

1   Though somewhat tangential to present purposes, there is one further environment in PDE

2   that is worth considering carefully when trying to understand the voicing alternation pattern;

3   that is the word-internal obstruent-initial clusters preceding primary stress[28] (Table **11**).

4

Word-initial Obstruent-initial Clusters	Word-medial Obstruent-initial Clusters	
[b]rianna	Sa.[pʰ]rina	'Sabrina'
[b]lender	o.[pʰ]lige	'oblige'
[g]uano	re.[kʰ]et	'regret'
	i.[kʰ]wana	'iguana'

5   Table 11: Word-initial vs. word-medial voiced obstruent-initial clusters
6

7   In accounting for the data in Table **11**, we follow Anderson & Davis (2013), in suggesting

8   that there must be two steps to the syllabification to account for the pattern. In the first step,

9   the obstruent in the medial onset cluster is syllabified as a coda (where it gets devoiced),

10 followed by a re-syllabification to onset of the following stressed syllable. Anderson & Davis

11 themselves suggest that this is potentially a diachronic two-step process. However, there is no

12 direct evidence that shows it to be a diachronic or a synchronic pattern. We leave this issue

13 for future work/analysis.

14   Returning to the more relevant issue of coda-devoicing in PDE, we can now look at

15 how voiced ambisyllabic obstruent consonants behave. If, in fact, ambisyllabic consonants are

---

[28] Thanks to an anonymous reviewer for pointing this out. The same reviewer asks if this pattern could be taken
as evidence of multiple-linkage. However, it is not clear to us how the data could be taken as evidence of
multiple-linkage; furthermore, it can be accounted for by straightforward process of staged syllabification.

1   multiply linked, then they should be blocked from devoicing due to the condition of geminate

2   inalterability that is consistently seen in other cases of multiple linkage (Hayes, 1986; Schein

3   & Steriade, 1986). One could further argue that the multiple-linkage analysis would also lead

4   to a paradoxical claim that ambisyllabic consonants should simultaneously be voiced and

5   voiceless[29]. On the other hand, if ambisyllabic consonants are really just codas, then they

6   should be devoiced like all other codas. As can be seen below, word-medial ambisyllabic

7   consonants behave like codas, in that they are also devoiced (Table **12**). In contrast, the

8   faithfulness to voicing exhibited by onsets is not shared by these ambisyllabic consonants. It

9   is also important to note that the devoicing of ambisyllabic consonants happens both after lax

10   vowels and after tense vowels.

11

Preceding Vowel Type	Ambisyllabic context	
Lax	ha[**p**]it	'habit'
	di[**s**]y	'dizzy'
Tense	ba[**k**]le	'bagle'
	ei[**θ**]er	'either'

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

13

---

[29] 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.

1   Given that ambisyllabic obstruent consonants behave like codas in PDE [30], the most

2   reasonable hypothesis would be to assume that alveolar obstruent stops in the same context

3   are also codas, unless independent evidence to the contrary is furnished. Therefore, the most

4   straightforward analysis of flapping in PDE is one wherein the flapping of alveolar obstruent

5   stops happens in codas (provided certain other prosodic conditioning facts are satisfied). One

6   might rightly ask why ambisyllabic alveolar consonants do not undergo devoicing in PDE. In

7   this context, it is important to recognize that both /t/ and /d/ flap in the relevant environment.

8   Therefore, even if an ambisyllabic /d/ devoiced, it would surface as a flapped consonant in

9   that environment. This can be cashed out in a variety of theoretical ways. In rule-based

10   theories, it can be accounted for by (a) as rule ordering, whereby devoicing is ordered before

11   flapping, (b) as an effect of the Elsewhere Condition (Halle & Idsardi, 1997; Kiparsky,

12   1973b), whereby the more specific generalization of the flapping rule (only alveolar obstruent

13   stops) overrides the more general devoicing that applies to all obstruents. In Optimality

14   Theoretic accounts it can be cashed out by ranking the markedness constraint that motivates

15   the flapping of ambisyllabic alveolar obstruent stops high just as the constraint that motivates

16   devoicing, both of which have to be ranked higher that the relevant faithfulness constraints for

17   voicing in obstruents, and obstruency in alveolar obstruents. We ourselves prefer the analysis

18   in terms of the Elsewhere Condition (an insight that the OT account shares too), since there is

19   no need for any additional support of such an analysis, as the facts follows from the very

20   nature of rule (or constraint) interaction.

---

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

1   Furthermore, as mentioned previously, the flapping facts in SAE and PDE are

2   identical. Therefore, the analysis of flapping in PDE must extend to the analysis of flapping in

3   SAE (and other American English dialects), unless arguments to the contrary are presented.

4   Therefore, it seems most reasonable to conclude that like PDE, the alveolar stops that are

5   flapped in SAE (and other American English dialects) are also codas.

6   Before concluding this section, we would like to mention that Anderson & Davis

7   (2013) themselves analyze these facts as resulting from a foot-initial faithfulness to the feature

8   [voice]; as per their analysis, the voicing in obstruents is preserved only foot-initially, but not

9   foot-medially or foot-finally. Such a foot-based analysis is forced to invoke the phonological

10   feature [voice] for PDE. However, as noted above, the obstruent segments in both standard

11   American English and German (the two main influencing languages of PDE) have been

12   argued to contrast in the feature [spread glottis], and not the feature [voice]; in fact, the

13   feature [voice] has been argued to be phonologically inactive in the two languages (Beckman,

14   Jessen, & Ringen, 2013; Iverson & Salmons, 2003b, 1995). Since the featural claims needed

15   for the foot-based analysis of the devoicing patterns in PDE are at odds with those supported

16   by related dialects/languages, such featural claims themselves need independent justification.

17   On the other hand, the coda-devoicing (or fortition) generalization that we propose appears to

18   be an extension of the pattern in German, and does not invoke phonological features that are

19   not already active in American English or German. To this extent, we suggest the coda

20   devoicing analysis is the more parsimonious account of the facts in PDE.

21

4. Conclusion

This article presents acoustic and phonological evidence that suggests 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 are 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 the same percentage of nasalization on the preceding vowel as word-medial nasal codas. There is simply 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 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 behave like codas following both tense and lax vowels. As a clarificatory note, we suggest, in line with Borowsky (1986), Selkirk (1982), and Wells (1990), that word-medial ambisyllabic representations have the structure below (Figure **5**)[31].

---

[31] Note that we are not making any additional claims about syllable-internal structure. The data we presented is consistent with both flat syllables and more hierarchically organized syllables.

σ σ   σ σ
'd æ n i   't i n a
"Danny"   "Tina"

Figure 5: Syllabic representations of the word *Danny* and *Tina*

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.

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 (Table **13**). In recent times, it has become especially popular to reanalyze standard data originally presented as evidence for multiple-linkage in terms of foot-based generalizations (Bermúdez-Otero, 2007b; Harris, 2004, 2006; Jensen, 2000). The nasalization data we present in this article however are also problematic for this viewpoint. 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

1   that there are domain-edge related lengthening and strengthening patterns, which appear to be

2   universal. Therefore, if ambisyllabic consonants are onsets (for a foot-based analysis), one

3   runs into the same problem that other analyses run into, namely, that one cannot explain why

4   there is no observable difference in the nasalization patterns between them and word-medial

5   codas, but there is an observable difference between them and word-medial onsets. So, even

6   within foot-based analyses of typical ambisyllabic phonological patterns, the nasalization

7   facts are readily interpretable only if one further posits that the relevant ambisyllabic

8   consonants are codas.

9

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

10   Table 13: How the different representational solutions fare?

11

12   An anonymous reviewer points out that the introductory discussion and our results rather

13   surprisingly suggest a divergence between word-edge phonotactics and syllabification. This

14   we believe is correct, and has, to our minds, been established in the theoretical phonological

15   discussions since at least the mid-1980's, especially, once the concept of *appendix* was

16   introduced. In fact, Borowsky (1989) starts her paper with the following: "It has been

1   recognized that the possible sequences of consonants found in word-initial and word-final

2   positions are not an altogether true reflection of the possible sequences found in syllable-

3   initial and syllable-final positions. Languages often allow various violations of syllable

4   structure at word edges – the APPENDICES". For example, word-finally, English allows quite

5   complex sequences (e.g., [ksθs] in "sixths"), but such codas are not possible word-medially or

6   morpheme-medially (excluding of course the case of compounds). Even without the facts

7   used to motivate appendices, there is sufficient cross-linguistic evidence that suggests that

8   word-boundary phonotactics are not isomorphic with syllable phonotactics. To   take   but   one

9   example, Telugu (except in recent loanwords, and casual speech truncations) has no word-

10 final consonants, except for the consonants [m,n,w,j] (Krishnamurti, 2003); yet, word-

11 medially, it has all sorts of consonant sequences not allowed either word-initially or word-

12 finally, e.g., [ʃ] is not possible word-finally (*ʃ#), and complex obstruent sequences involving

13 [ʃ]   are   not   allowed   word-initially   (*ʃʈ); however, word-medially, you can get sequences such

14 as [ʃʈ] ([ˈkʌʃʈ̃w̃] 'difficult'). If word-boundary   sequences   were   indeed   isomorphic   with

15 syllabic-phonotactics,   then   such   words   should   be   impossible;   however,   such   obstruent

16 sequences (as mentioned above) are quite common in the Telugu. On a related note, in French,

17 sO clusters (where, O = obstruent) are possible word-initially, but word-medial sO clusters

18 are broken up into separate syllables, with the [s] as part of the preceding syllable (Dell, 1995).

19 Such data suggest (along with those motivating appendices) that a belief in an isomorphism

20 between word-edge sequences and syllable phonotactics is incorrect[32].

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

1   Returning to the main issue focused on in this paper, while previous data that has been

2   used in relation to ambisyllabicity can be accounted for by foot-structure, and word-

3   phonotactics (as pointed out by other researchers), the evidence presented herein suggests that

4   (word-medial) ambisyllabic consonants do not behave like onsets or multiply-linked segments,

5   but in fact behave like codas in American English.

6   Finally, given the vast literature surrounding ambisyllabic consonants and their

7   syllabic affiliation, it would be, in our opinion, somewhat ambitious of us to argue that we

8   have shown beyond reproach that ambisyllabic consonants are codas; we ourselves believe

9   this is just a step towards a more nuanced understanding of the issues plaguing ambisyllabic

10   consonants. And therefore, we minimally hope to have shown that the standard view of such

11   consonants being multiply-linked is far from obvious, both theoretically (Jensen, 2000; Picard,

12   1984) and experimentally; and we also hope to have shown that there is a need for more

13   explicit discussion of the actual theoretical claims, the experimental evidence presented as

14   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 massive multiple comparison problem; correcting for which, decreases the power of the tests substantially (as an anonymous reviewer rightly noted). 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.