



Ambisyllabicity revisited: An acoustic study of intervocalic nasals in American English^{*}

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Lee, Joo-Kyeong. 2026. *Ambisyllabicity revisited: An acoustic study of intervocalic nasals in American English*. *Linguistic Research* 43(2): 475-496. The phonetic status of ambisyllabic consonants in English has long been debated, yet previous studies on intervocalic nasals have rarely established clear or robust phonetic correlates of ambisyllabicity, largely due to methodological limitations and restricted coverage of intervocalic configurations. The present study addresses this limitation by providing a comprehensive acoustic investigation of ambisyllabic nasal consonants in American English. Specifically, we examine intervocalic [m] and [n] across three logically distinct contexts: ambisyllabic nasals preceded by stressed lax vowels, non-ambisyllabic intervocalic nasals preceded by stressed tense vowels, and non-ambisyllabic intervocalic nasals followed by stressed vowels. Ten native speakers of English produced target words embedded in a carrier sentence, yielding 1,500 tokens for analysis. Using A1-P0, the amplitude difference between the first formant and the nasal pole as an acoustic measure of vowel nasality, the results show that ambisyllabic nasals do not pattern with either word-initial onset or word-final coda nasals. Instead, they exhibit acoustic properties closely resembling those of non-ambisyllabic intervocalic nasals preceded by stressed tense vowels, a pattern that is consistent with Kahn's notion of ambisyllabicity. (University of Seoul)

Keywords ambisyllabic, nasals, A1-P0, nasalization

1. Introduction

Ambisyllabicity is one of the most frequently invoked yet least directly tested notions in the study of English syllable structure (Briere et al. 1968; Kahn 1976; Fallows

* This work was supported by the Ministry of Education of the Republic of Korea and the National Research Foundation of Korea (NRF-2021S1A5A2A01070152).

1981; Krakow 1988, 1989; Treiman and Danis 1988; Hayes 1989; Giegerich 1992; Zamuner and Ohala 1999; Treman et al. 2002; Gick 2003; Durvasula and Huang 2017; Nesbitt 2018; Lee and Seo 2019; Lee 2024, 2025). For several decades, the idea that an intervocalic consonant may be simultaneously affiliated with two syllables has played a central role in accounts of resyllabification, stress-sensitive allophony, and the mapping between phonological representation and phonetic realization (Kahn 1976; Selkirk 1982; Hayes 1989). Ambisyllabic consonants are routinely assumed in analyses of flapping (Kahn 1976) and syllable weight (Giegerich 1992), and the concept is now firmly embedded in standard descriptions of English phonology. Yet despite its theoretical prominence, a striking paucity remains; there is remarkably little direct phonetic evidence showing whether ambisyllabicity leaves any independent trace in the acoustic signal. It, therefore, remains an open empirical question whether ambisyllabicity is a phonological abstraction with no phonetic reflex, or a representational distinction that is systematically encoded in speech.

1.1 Theoretical background of ambisyllabicity

Two influential but conceptually divergent definitions of ambisyllabicity have structured much of the subsequent debate. Kahn (1976) proposed that any intervocalic consonant followed by an unstressed vowel should be treated as ambisyllabic. This stress-based criterion has been widely adopted, particularly in analyses of alveolar flapping in American English. In this context, an intervocalic position without following stress reliably conditions a categorical allophonic alternation. However, when extended beyond this specific phenomenon, Kahn's definition raises serious theoretical difficulties. By elevating a distributional environment motivated by a single allophonic process to a general principle of syllable affiliation, the analysis effectively collapses the distinction between dual-linked segments and ordinary intervocalic onsets or codas. Under this view, ambisyllabicity becomes a near-automatic consequence of stress configuration rather than a structurally licensed relation, rendering the notion descriptively overinclusive. As a result, the stress-based definition provides little independent justification for treating ambisyllabicity as a genuine representational category across the consonant inventory.

In contrast, Giegerich (1992) advances a substantially more constrained and

structurally grounded conception of ambisyllabicity. In his account, ambisyllabicity does not follow mechanically from stress configuration alone, but emerges from the interaction of vowel quality, syllable weight, and prosodic licensing. Specifically, when an intervocalic consonant follows a lax stressed vowel that fails to project a heavy syllable, the segment cannot be fully licensed as a coda of the preceding syllable, yet the following syllable independently requires an onset under the Onset Maximization Principle, which applies with priority in syllabification (Kahn 1976; Selkirk 1982; Hayes 1989). Ambisyllabicity thus arises not as a default property of intervocalic position, but as a structurally induced consequence of competing prosodic requirements. This restrictive definition sharply limits the class of consonants eligible for dual linkage and, crucially, generates clear empirical predictions: only those consonants whose syllabic affiliation is underdetermined by prosodic structure should qualify as ambisyllabic, while other intervocalic consonants—even in stressed–unstressed sequences—should pattern as unambiguously onset-affiliated if the preceding vowel is tense. In unstressed–stressed or unstressed–unstressed sequences, by contrast, intervocalic consonants are always onset-affiliated, since the preceding syllable is unstressed and therefore does not invoke any requirement for weight-by-stress licensing (Duanmu 2010). For example, in both /ə.'tæk/ 'attack' and /dɪ.'vɪ.nɪ.tɪ/ 'divinity', the intervocalic consonant /t/ follows an unstressed vowel and is therefore not ambisyllabic. The preceding syllable remains light, lacking a coda, as it is unstressed and thus does not require weight-by-stress licensing.

Under Giegerich's analysis, ambisyllabicity emerges in contexts where a consonant is licensed both as the coda of a stressed light syllable and as the onset of a following unstressed syllable. Crucially, this dual affiliation is not inferred from phonetic realization but is derived from independently motivated prosodic principles governing syllable weight and stress licensing. Ambisyllabicity thus reflects a specific configuration in prosodic structure rather than an attempt to accommodate allophonic variations.

This prosodic definition offers several theoretical advantages. First, it dissociates ambisyllabicity from particular segmental alternations, allowing the notion to be applied more generally across consonant types. Second, it situates ambisyllabicity within a broader theory of metrical structure, thereby providing explicit constraints on when and where dual affiliation is possible. Finally, it predicts systematic interactions between stress, syllable weight, and syllabification that can be tested

empirically. For these reasons, this definition serves as the theoretical basis for the experimental design. On the basis of Giegerich's analysis, the current work distinguishes three types of intervocalic nasal consonants and compares them with canonical word-initial onset and word-final coda nasals.

1.2 Empirical evidence on ambisyllabicity

In parallel with theoretical developments (Kahn 1976; Selkirk 1982; Giegerich 1992; Harris 2003; Duanmu 2010; Hayes 2011), a substantial body of early work on ambisyllabicity comes from psychological and metalinguistic studies that probed speakers' intuitions about syllable boundaries using various segmentation tasks. In a syllable doubling paradigm, participants were asked to repeat either the first or the second syllable of bisyllabic words; ambisyllabicity was inferred when the medial consonant appeared in both repetitions. Such responses accounted for only a minority of tokens, suggesting that ambisyllabicity may reflect a syllabification strategy motivated by general principles such as Onset Maximization and Weight-Stress principles rather than a stable representational property.

Later studies extended this line of work by examining the role of orthography and listener variability. Using modified doubling tasks, Treiman and Danis (1988) and Treiman and Zukowski (1990) found that ambisyllabic judgments were more likely for consonants preceded by stressed lax vowels than by stressed tense vowels. Treiman et al. (2002) conducted a similar syllable-doubling task and further demonstrated that consonants spelled as geminates were more likely to be judged as ambisyllabic. Eddington and Elzinga (2008) and Elzinga and Eddington (2014) reported in their modified doubling experiment that speakers often show considerable uncertainty in assigning syllable boundaries, especially for segments such as flaps, and that ambisyllabic judgments are shaped by multiple interacting factors rather than by a single categorical principle. Consequently, these psychological studies suggest that ambisyllabicity in listener judgments is highly variable and gradient, reflecting metalinguistic uncertainty or task-specific strategies rather than a direct window into the phonetic realization of intervocalic consonants. More specifically, they rarely established clear or robust phonetic correlates of ambisyllabicity, which can be attributed to inherent limitations of methods that rely on intuitive speaker responses.

As a result, this line of work did not directly examine whether ambisyllabic consonants possess any substantial phonetic properties distinct from onsets or codas.

Among acoustic studies on ambisyllabicity, Nesbit (2018) examined ambisyllabic consonants through the prosodic properties of the preceding vowels. Vowels preceding intervocalic ambisyllabic consonants were compared with those preceding clear medial onsets and codas, with a focus on temporal and pitch-related properties. Vowels before ambisyllabic consonants patterned more closely with those before medial codas than with those before medial onsets, particularly in duration, which was significantly shorter, while pitch differences were comparatively modest. These results were interpreted as supporting a coda-like acoustic realization of ambisyllabic consonants in American English. In contrast, Lee and Seo (2019) reported little evidence for a distinct ambisyllabic category in either temporal or spectral domains. Across obstruents, nasals, and liquids, intervocalic consonant durations did not differ reliably as a function of ambisyllabic status. Spectral analyses of the lateral /l/ likewise revealed no systematic differences between ambisyllabic and non-ambisyllabic tokens, although both differed from word-initial onset and word-final coda realizations. On this basis, Lee and Seo argued that intervocalic laterals form a separate phonetic class, independent of traditional ambisyllabic classifications, rather than instantiating a multiply affiliated segment.

Articulatory studies have likewise investigated ambisyllabicity. Using electromagnetic midsagittal articulography, Gick (2003) examined tongue tip and dorsum gestures of English /l/ in three word-boundary contexts: clear syllable-initial, clear syllable-final, and putatively ambisyllabic positions (e.g., *hall # otter*). Tongue dorsum backing did not differ reliably across contexts, leading Gick to conclude that there was no articulatory evidence for genuine ambisyllabicity. More recently, Lee (2024, 2025) conducted ultrasound experiments on American English /l/ and /ɫ/, directly comparing ambisyllabic and non-ambisyllabic intervocalic tokens. For /l/, SSANOVA analyses of tongue body lowering and tongue tip elevation revealed that although ambisyllabic laterals exhibited an intermediate degree of tongue body lowering, laterals in non-ambisyllabic contexts showed highly similar patterns, providing no support for a distinct ambisyllabic category (Lee 2024). In addition, GAM analyses of the overall tongue shape during intervocalic /ɫ/ production similarly revealed no reliable differences between ambisyllabic and non-ambisyllabic retroflexes (Lee 2025). These articulatory studies converge in showing that intervocalic /l/ and

/l/ did not display systematic gestural properties that distinguish ambisyllabic consonants from intervocalic non-ambisyllabic consonants.

1.3 Previous work on intervocalic nasal consonants

There seems to be few phonetic studies on ambisyllabicity, focusing on nasal consonants (Krakow 1988, 1989; Durvasula and Huang; 2017). If ambisyllabicity is indeed a structural property of prosodic organization, as proposed by Giegerich (1992), then it should in principle apply across consonant classes, including nasals. Krakow (1999) utilized a wide array of instrumental techniques to measure the movements of different articulators, including the Velotrace for velar movement and the Selspot System for optoelectronic tracking of the lips and jaw. To isolate the effects of syllable position from contextual variables, Krakow compared intervocalic nasal (e.g., *homey*) with word final coda (e.g., *home E*) and word initial onset (e.g., *hoe me*) The findings revealed distinct physiological patterns for intervocalic nasal consonants. The syllable affiliation of intervocalic nasals was primarily determined by the location of primary stress. Physiological evidence, including velum–lip coordination and movement patterns for [m], showed that in words such as *homey* and *seamy*, where the first syllable is stressed, the medial /m/ patterned as a syllable-final nasal, with velum lowering occurring earlier. Conversely, in words such as *pomade*, where the second syllable is stressed, it patterned as a syllable-initial nasal. These findings suggested that stress attracts intervocalic consonants to the stressed syllable.

Krakow (1999) did not, however, focus on ambisyllabic nasals per se, but rather on intervocalic nasals (*homey*, *seemy*, and *pomade*), which are not in fact ambisyllabic [m] according to Giegerich's criteria. In *homey* and *seemy*, the bilabial nasal is preceded by a tense vowel; consequently, the stressed first syllable already satisfies the Stress–Weight principle, and [m] is syllabified as the onset of the following syllable in accordance with the Onset Maximization principle. Similarly, in *pomade*, the first syllable is unstressed and does not require heaviness; hence, [m] is again affiliated with the onset of the following syllable, as required by Onset Maximization. Although both coda-like nasals (*homey* and *seemy*) and onset-like nasals (*pomade*) are theoretically affiliated with the onset of the following syllable, their articulatory coordination of velum and lip gestures differed systematically in Krakow's work. This

pattern draws attention to the need to compare intervocalic nasals across different structural contexts defined by stress placement and vowel tenseness, in order to shed light on the phonetic characteristics of ambisyllabic nasals of the present study.

Durvasula and Huang (2017) challenged the standard phonological view that word-medial consonants between a stressed and an unstressed vowel are multiply linked to both syllables. Building on the well-established finding that coda nasals induce greater anticipatory vowel nasalization than onset nasals (Krakow 1989, 1999; Solé 1992, 1995, 2007), they proposed that vowel nasalization patterns can serve as a diagnostic for syllabic affiliation. The central question of their production experiment was whether ambisyllabic nasals would show an intermediate degree of vowel nasalization or categorically with either onsets or codas, and whether this pattern would differ depending on whether the preceding vowel was tense or lax. The experiment compared four syllabic environments: ambisyllabic, word-medial coda, word-medial onset, and word-final coda, in two vowel contexts, lax [æ] and tense [õ]. For each vowel, near-quadruplets were constructed, such as *gamma* (ambisyllabic), *gamble* (medial coda), *gamete* (medial onset), and *gam* (final coda) for [æ], and *donor*, *bonehead*, *gonad*, and *bonefor* [õ]. Six native speakers of American English produced each item at three speech rates (Fast, Normal, Slow) in the carrier phrase “Say ___ here.” Nasalization was measured acoustically in Praat by manually identifying the onset of vowel nasalization based on three spectrographic cues: (i) a sudden decrease in F1 intensity, (ii) the appearance of anti-formants (F3 intensity damping), and (iii) the appearance of a nasal pole. The percentage of vowel nasalization was computed as their primary dependent measure, and results showed that the percentage of vowel nasalization consistently exhibited the pattern onset < ambisyllabic ≈ medial coda < final coda across both vowel types and all speech rates, with no statistically significant difference observed between the ambisyllabic and medial coda conditions. On this basis, they concluded that word-medial ambisyllabic nasals in American English patterned categorically with codas and provided no phonetic support for multiply-linked representations or for any independent ambisyllabic phonetic category.

While Durvasula and Huang’s experiment constitutes an important contribution, several aspects of their methodology are directly relevant for interpreting their conclusions and for motivating the present study. First, the identification of nasalization onset relies on manual, categorical boundary decisions based on

spectrographic inspection, introducing an unavoidable degree of subjectivity. Second, the primary dependent measure—the percentage of time classified as nasalized—captures only the temporal extent of nasalization, but not its acoustic magnitude, leaving open the possibility that ambisyllabic tokens differ from medial codas in degree rather than in timing. Third, nasality was measured exclusively through acoustic correlates of vowel nasalization, quantified as the proportion of the vowel exhibiting nasal spectral cues. This measure reflects coarticulatory overlap between the velum-lowering gesture of the nasal and the preceding vowel, but it does not directly index the timing or magnitude of the velic gesture itself. As the authors acknowledged, acoustic nasalization is an indirect proxy for articulatory nasal timing and may conflate genuine differences in velum coordination with vowel-specific acoustic effects. Finally, the stimulus set is extremely limited, with essentially one lexical quadruplet per vowel, raising concerns about lexical idiosyncrasy and the generalizability of the findings.

Both Krakow's (1999) articulatory study and Durvasula and Huang's acoustic investigation examined only a restricted subset of intervocalic nasal consonants. In Krakow's experiment, the relevant nasals would not be classified as ambisyllabic under Giegerich's analysis, since all preceding vowels were tense. Durvasula and Huang, following Kahn's (1976) conception of ambisyllabicity, focused on nasals between a stressed and an unstressed vowel, and varied the preceding stressed vowel only between two categories, tense [o̯] and lax [æ]. Under Giegerich's theoretical framework, nasals preceded by a stressed tense vowel are not ambisyllabic, and thus a substantial portion of their stimulus set would fall outside the ambisyllabic category.

1.4 The present study: An A1-P0-based approach

The limitations identified in the previous studies on intervocalic nasals (Section 1.3) suggest that a comprehensive evaluation of ambisyllabic nasals requires examining all logically possible intervocalic nasal configurations, taking into account both stress and syllable weight. The present study addresses this limitation by systematically investigating ambisyllabic nasals [m] and [n] preceded by stressed lax vowels, together with two types of non-ambisyllabic intervocalic nasals: those preceded by stressed tense vowels and those followed by stressed vowels. By incorporating the full range of intervocalic environments, the current study aims to provide a more comprehensive

and theoretically grounded phonetic basis for assessing the status of ambisyllabic nasal consonants.

Concerning the measure of nasality, we adopt a different acoustic measure of nasality: the amplitude difference between the first formant and the nasal pole (A1–P0) whose validity and robustness have been confirmed (Scarborough et al. 2015; Zellou and Dahan 2019). More specifically, vowel nasalization is acoustically characterized by the presence of a nasal murmur within the vowel, typically manifesting near the formant structure, especially in the region of the first formant (F1). This pattern arises from oral–nasal coupling, which leads to a lowering of F1 and a concomitant enhancement of the nasal resonance peak (P0) at approximately 250 Hz (cf. Chen 1996, 1997). As vowel nasality increases, the amplitude of the nasal peak (P0) rises, while the amplitude associated with F1 (A1) correspondingly decreases. Consequently, greater degrees of vowel nasalization induced by adjacent nasal consonants are reflected in lower A1–P0 values. This measure has become a standard diagnostic of vowel nasalization in contemporary acoustic studies. Unlike the duration-based percentage measure used by Durvasula and Huang (2017), A1–P0 provides a spectral estimate of the degree of nasal coupling at specific time points and is less directly tied to the temporal extent of coarticulatory overlap.

2. Experiment

2.1 Participants

Ten native speakers of English from the United States or Canada were recruited from a university in Seoul, Korea. All participants were exchange students residing in Korea for one or two academic semesters at the time of data collection. Gender was not treated as an experimental factor; the participant group consisted of four males and six females. All participants reported normal hearing and no history of speech or hearing disorders. They received monetary compensation for their participation.

2.2 Stimuli

The present study examined intervocalic nasal consonants [m] and [n]. These nasals

were classified into three categories, as summarized in Table 1: (i) ambisyllabic nasals, (ii) non-ambisyllabic nasals preceded by stressed tense vowels, and (iii) non-ambisyllabic nasals followed by unstressed vowels. Ambisyllabic nasals were consistently preceded by stressed lax vowels, following the definition proposed by Giegerich (1992). For each category, ten real English words were elicited, consisting of five words containing [m] and five containing [n].

In addition, Table 1 presents that ten words containing word-initial onset nasals and ten words containing word-final coda nasals were included as baseline controls. The nasality of vowels preceding intervocalic nasals was compared with that of vowels preceding word-final coda nasals, while the nasality of vowels following intervocalic nasals was compared with that of vowels following word-initial onset nasals.

Table 1. Stimuli

	V [+stress] ____ V [-stress]	V[-stress] ____ V [+stress]	onset	coda
inter-vocalic ambisyllabic	[m]	camel, timid, summit, grammar, semi	NA	[m]
	[n]	finish, honey, tennis, vinegar, senate		[m]
inter-vocalic non-ambisyllabic	[m]	gomer, humor, famous, comet, cimex	[n]	[n]
	[n]	final, donor, tiny, sonnet, vinyl	[n]	[n]

All target words presented in Table 1 were embedded in the carrier sentence ‘Please say ____ for me’ and were produced three times by each participant. Stimuli were randomized prior to recording. In total, 1,500 tokens were included in the analysis (50 words × 3 repetitions × 10 speakers).

2.3 Procedure

Each native English speaker participated in an individual recording session conducted in a university speech laboratory. Participants were seated in a sound-attenuated booth

and recorded a list of carrier sentences containing the target words. They were instructed to read the sentences at a comfortable pace and were allowed to take breaks as needed. If a participant encountered a word whose pronunciation was unfamiliar, the experimenter provided a model pronunciation and confirmed the participant's understanding prior to recording.

Recordings were made using a Behringer ECM8000 microphone connected to a Marantz PMD2000 recorder. Participants were instructed to read a printed list of stimulus sentences in a natural and comfortable voice at their preferred speaking rate. Speech was recorded at a sampling rate of 44,000 Hz and automatically force-aligned at the phone level using the Montreal Forced Aligner (MFA). The resulting sound files and TextGrid annotations generated by MFA served as input for subsequent Praat scripts (Styler 2015).

Given that vowel nasalization increases as a vowel approaches a nasal consonant, reflecting the gradient nature of coarticulatory nasalization in English (Cohn 1993), Nasality was measured at three temporal locations in both the preceding and following vowels. For the preceding vowel, measurements were taken at the vowel midpoint, the two-thirds point, and the vowel–nasal boundary (final point). For the following vowel, measurements were taken at the vowel–nasal boundary (initial point), the one-third point, and the vowel midpoint. Anticipatory nasalization was assessed by comparing A1–P0 values for the three types of intervocalic nasals with those for word-final coda nasals at three temporal points (mid, two-thirds, and final) of the preceding vowel. Likewise, carryover nasalization was evaluated by comparing A1–P0 values for the same intervocalic nasals with those for word-initial onset nasals at three measurement points (initial, one-third, and mid) of the following vowel.

For statistical analysis, linear mixed-effects regression models were fitted using the lme4 package in R (R Core Team 2025). A1–P0 values served as the dependent variable, while vowel measurement point and nasal category were included as fixed effects. A random intercept for word was included to account for item-level variability. A maximal random-effects structure, including random intercepts for both word and speaker, was initially specified; however, the model exhibited convergence and singular fit issues. The final model was therefore simplified to include a random intercept for word only. Post hoc pairwise comparisons were conducted using Tukey-adjusted tests.

2.4 Results

A1–P0 values of the vowels preceding three types of intervocalic nasals were compared with those preceding word-final coda nasals to determine whether ambisyllabic nasals pattern with the other two intervocalic nasal types. To examine whether intervocalic nasals exhibit coda-like properties, the degree of nasality in the preceding vowel was compared with that of vowels preceding word-final coda nasals at three temporal points relative to the nasal: the vowel midpoint, the two-thirds point, and the vowel-final point. Figure 1 displays the mean A1–P0 values of the preceding vowels extracted from the productions of ten native speakers of American English. When nasality at the utterance-final time point (fin) adjacent to the nasal consonant is compared, only vowels preceding word-final coda nasals show negative A1–P0 values at the final time points. In contrast, vowels preceding intervocalic nasals consistently exhibit positive A1–P0 values even at the final measurement point adjacent to the nasal. This pattern indicates that intervocalic nasals do not induce increased nasality on the preceding vowel and therefore do not pattern with word-final coda nasals in terms of their coarticulatory effects.

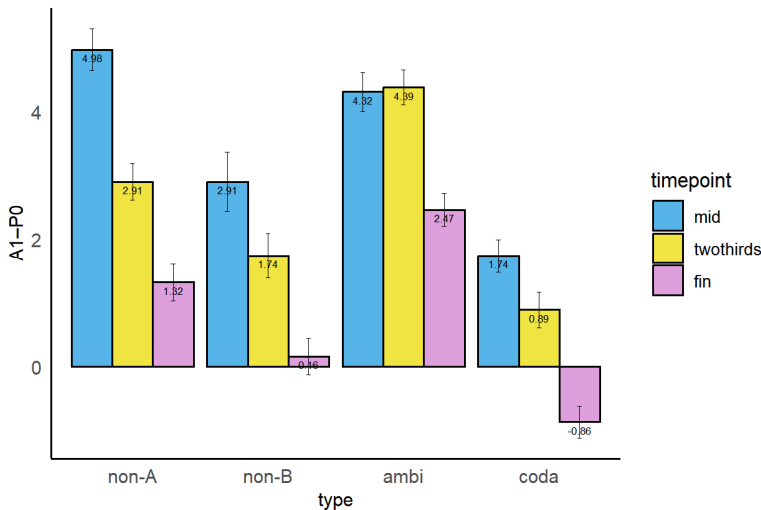


Figure 1. A1–P0 of the preceding vowels across three types of intervocalic and word-final coda nasals (non-A: intervocalic nasals preceded by stressed tense vowels, non-B: intervocalic nasals followed by stressed vowels, ambi: ambisyllabic nasals, coda: word-final coda nasals)

A linear mixed-effects model was fitted to the A1–P0 values of vowels preceding nasal consonants, with Type (non-A: non-ambisyllabic nasal with a preceding stressed tense vowel; non-B: non-ambisyllabic nasal with a following stressed vowel; ambi: ambisyllabic nasal; coda: word-final coda nasal) and Timepoint (mid, two-thirds, fin) as fixed effects. Word was included as a random intercept. The reference levels were word-final coda nasal and the vowel midpoint (mid). The model revealed reliable variability across lexical items (variance = 2.43, SD = 1.56), indicating that baseline A1–P0 values differed by word. Substantial residual variance (variance = 28.50, SD = 5.34) reflects considerable within-word variability in vowel nasality, justifying the inclusion of random intercepts for Word.

The intercept, corresponding to the vowel midpoint preceding a word-final coda nasal, was significantly positive ($\beta = 1.74$, $p = 0.004$), indicating relatively little nasalization at this measurement point. With respect to Type, vowels preceding non-A nasals ($\beta = 3.23$, $p < 0.001$) and ambisyllabic nasals ($\beta = 2.58$, $p = 0.003$) showed significantly higher A1–P0 values than those preceding word-final coda nasals, indicating less anticipatory nasal coarticulation relative to the coda baseline. In contrast, non-B nasals did not differ significantly from the coda condition ($p = 0.13$), suggesting comparable degrees of anticipatory nasalization between this non-B intervocalic context and word-final codas. A significant main effect of Timepoint was observed. Relative to the vowel midpoint, A1–P0 values were significantly lower at two-thirds ($\beta = -0.86$, $p = 0.05$) and markedly lower at the vowel-final point ($\beta = -2.60$, $p < 0.001$), indicating a progressive increase in anticipatory nasal coarticulation as the vowel approached the nasal consonant. No Type \times Timepoint interaction reached conventional levels of statistical significance, indicating that the temporal progression of anticipatory nasal coarticulation across the three timepoints does not differ systematically from that of the coda baseline.

Post-hoc pairwise comparisons were conducted using Tukey's HSD to further examine whether ambisyllabic nasals pattern with word-final coda nasals or with other intervocalic nasals, across three measurement points. When ambisyllabic nasal consonants are compared with coda nasals, the mean A1–P0 value of ambisyllabic nasals was significantly different from that of coda nasals ($p < 0.005$ at all time points). Direct comparisons among the intervocalic nasal types revealed that ambisyllabic nasals did not differ significantly from non-A nasals ($p = 0.960$ at midpoint, $p = 0.06$ at two-thirds point, $p = 0.355$ at final point), but that they differed significantly from non-B

nasals at three measurement points ($p < 0.05$ at midpoint, $p < 0.005$ at two-thirds and final points). Overall, these results provide clear acoustic evidence that ambisyllabic nasals do not exhibit coda-like coarticulatory behavior, and that they pattern together with non-A nasals, but distinctly from non-B nasals.

Moving on to comparisons of the nasality of the following vowels across the three intervocalic nasal types and word-initial onset nasals, the degree of nasality in the following vowel was examined to assess whether intervocalic nasals exhibit onset-like properties. Figure 2 presents the mean A1–P0 values extracted from the productions of ten native speakers of American English. Across all four conditions, A1–P0 values measured at four temporal points of the vowels (at the initial point, one-third point, and the final point) immediately. A1–P0 values are consistently negative at initial point across all four nasal types. In contrast, A1–P0 values measured at the vowel midpoint and one-third point were uniformly positive, indicating that the coarticulatory influence of the preceding nasal consonant does not extend beyond the one-third point of the vowel.

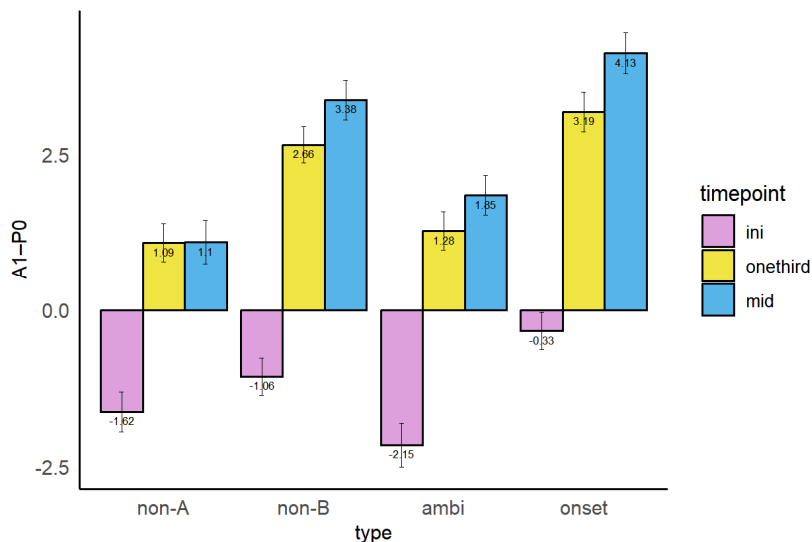


Figure 2. A1–P0 of the following vowels across three types of intervocalic and word-initial onset nasals (non-A: intervocalic nasals preceded by stressed tense vowels, non-B: intervocalic nasals followed by stressed vowels, ambi: ambisyllabic nasals, onset: word-initial onset nasals)

A linear mixed-effects model was fitted to the A1–P0 values of the ,with (non-A: non-ambisyllabic nasals with a preceding stressed tense vowel; non-B: non-ambisyllabic nasals with a following stressed vowel; ambi: ambisyllabic nasals; onset: word-initial onset nasals) and (vowel initial, one-third, and midpoints) as fixed effects, and included as a random intercept.

The model revealed variability across lexical items (variance = 1.27, SD = 1.13), indicating word-specific differences in baseline A1–P0 values. Substantial residual variance (variance = 29.09, SD = 5.39) reflects considerable within-word variability in following-vowel nasality, justifying the inclusion of random intercepts for Word. Concerning the main effect of Type, ambisyllabic nasals showed significantly lower A1–P0 values than the reference condition at the vowel-initial point ($\beta = -1.83$, $p = 0.008$), indicating greater carryover nasal coarticulation. A robust main effect of Timepoint was observed. Relative to the vowel-initial point, A1–P0 values were significantly higher at the one-third point ($\beta = 3.52$, $p < 0.001$) and further increased at the vowel midpoint ($\beta = 4.46$, $p < 0.001$), indicating a substantial reduction in carryover nasal coarticulation as the vowel progressed away from the nasal consonant.

Significant Type \times Timepoint interactions were observed only at the vowel midpoint for the non-A nasals. Specifically, non-A nasals exhibited a significantly smaller increase in A1–P0 values from vowel onset to the midpoint than the reference condition ($\beta = -1.74$, $p = 0.007$), indicating a more persistent carryover nasalization across the vowel. No significant interactions were observed for non-B or ambisyllabic nasals at either the one-third point or the midpoint, suggesting that their temporal patterns of A1–P0 change do not differ reliably from the reference condition.

Post-hoc pairwise comparisons were conducted using Tukey's HSD to further examine the onset-like properties of intervocalic nasals by comparing the nasality of the following vowel across nasal types and timepoints. A1-P0 values were significantly different between ambisyllabic and word-initial onset nasals at all three measurement points of the following vowels (all, $p < 0.005$). Direct comparisons among the intervocalic nasals revealed no significant differences between ambisyllabic and non-A nasals at both measurement points ($p = 0.99$ at initial point, $p = 0.99$ at one-third point, and 0.88 at midpoint). However, the mean A1-P0 value of ambisyllabic nasals was not statistically different from that of non-B nasals at initial point ($p = 0.35$), but there was a significant difference at one-third and midpoints ($p < 0.05$). This pattern suggests that ambisyllabic nasals pattern more closely with Type A than with

Type B in the temporal persistence of carryover nasalization.

3. Discussion

The present study examined vowel nasality in segments adjacent to nasal consonants in order to assess whether ambisyllabic nasals pattern with intervocalic non-ambisyllabic nasals or instead constitute an independent phonetic category in English. The results showed that the degree of anticipatory nasalization associated with ambisyllabic nasals differed significantly from that observed for word-final coda nasals at the vowel-final measurement point. Specifically, A1–P0 values of vowels preceding ambisyllabic nasals were uniformly positive, a pattern that was also observed for the two intervocalic non-ambisyllabic nasal types (non-A and non-B). In contrast, vowels preceding word-final coda nasals exhibited negative A1–P0 values, consistent with previous findings (Krakow 1989, 1999; Solé 1992, 1995).

These results indicate that intervocalic nasals, including ambisyllabic nasals, do not induce substantial backward spreading of nasality onto the preceding vowel, unlike nasal consonants in word-final coda position. One plausible articulatory interpretation is that, for intervocalic nasals, velum lowering is initiated concurrently with the onset of the oral constriction (e.g., lip or tongue-tip articulation), whereas for coda nasals, velum lowering occurs earlier - either prior to or at least by the vowel-final portion of the preceding vowel. A parallel asymmetry was observed in carryover nasalization. The degree of nasalization in vowels following ambisyllabic nasals was significantly greater at vowel onset than that observed following onset nasals, suggesting that the following vowel is produced with sustained velum lowering as a consequence of the ambisyllabic nasal articulation. Overall, these anticipatory and carryover patterns indicate that ambisyllabic nasals do not consistently align with either onset or coda nasals with respect to the nasality of adjacent vowels. Rather than exhibiting hybrid properties that interpolate between onset and coda categories, ambisyllabic nasals appear to display a distinct constellation of coarticulatory behaviors. These findings therefore support the view that ambisyllabic nasals constitute a separate phonetic category, characterized by asymmetric temporal coordination of velum lowering relative to oral articulatory gestures.

Comparisons between ambisyllabic nasals and the two non-ambisyllabic

intervocalic nasal types (non-A and non-B) revealed a systematic asymmetry. In terms of anticipatory coarticulation, ambisyllabic nasals patterned together with non-A nasals across all measurement points (the midpoint, the two-thirds point, and the vowel-final point), whereas significant differences were observed between ambisyllabic nasals and non-B nasals. A parallel pattern emerged for carryover coarticulation: ambisyllabic nasals again patterned with non-A nasals, but diverged from non-B nasals at the measurement points. That is, these vowel-nasality results indicate that ambisyllabic nasals pattern more consistently with non-A nasals than with non-B nasals.

Crucially, this pattern does not support Giegerich's view of ambisyllabicity, under which ambisyllabic consonants are predicted to exhibit phonological and phonetic properties distinct from both non-ambisyllabic nasals A and B. Instead, the present findings suggest that ambisyllabic nasals share substantial phonetic commonalities with non-A nasals. Notably, both ambisyllabic and non-A nasals occur in environments characterized by a stressed preceding vowel and an unstressed following vowel. This stress-asymmetric configuration closely accords with Kahn's definition of ambisyllabicity, according to which ambisyllabic affiliation arises specifically in contexts where the following vowel is unstressed.

What is worth noting in the current work is the asymmetry between anticipatory and carryover nasalization of intervocalic nasal consonants. A1-P0 values are all positive in anticipatory nasalization while they are negative in carryover nasalization as shown in Figure 3. This means that the preceding vowels are not likely nasalized but that the following vowels are nasalized, even more than preceded by a word initial onset. This is opposite to vowel nasalization of word-initial onset and word-final coda nasals; the A1-P0 value of coda is -0.86 and that of onset is -0.33. The velum lowers earlier than the movement of oral gestures in case of coda nasals, giving rise to high degrees of nasalization of preceding vowels. However, both nasal and oral gestures move concomitantly in case of onset nasals, with weak or little nasality carrying over to the following vowels. What might induce the differences in nasalization directionality between intervocalic nasals and onset or coda nasals?

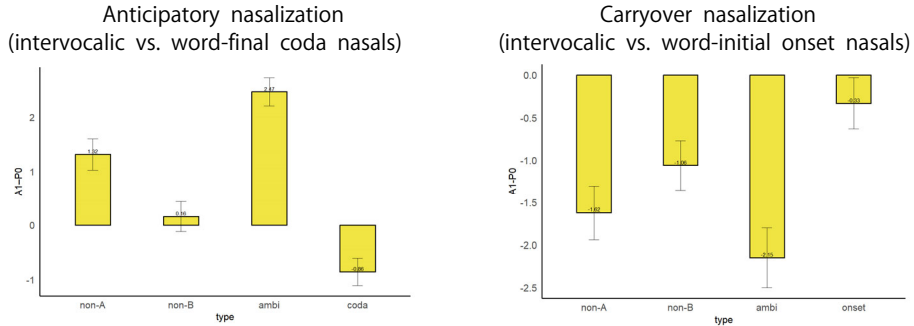


Figure 3. Mean A1-P0 values of preceding and following vowels at intervocalic nasal boundaries, compared with vowels adjacent to word-initial onset and word-final coda nasals

We propose that the directionality of vowel nasalization is governed by prosodic edge effects on the temporal coordination between velic and oral gestures. Previous work in articulatory phonology has demonstrated that prosodic boundaries systematically shape gestural timing through boundary-related anchoring as well as temporal expansion and compression effects (Byrd 2000; Byrd and Saltzman 2003; Cho 2005). Importantly, although gestures adjacent to prosodic boundaries often undergo lengthening, such lengthening is applied in a highly regular manner, resulting in reduced variability in their temporal alignment with the boundary (Byrd and Saltzman 2003).

In word-initial onset position, the oral closure gesture is anchored to the left prosodic edge, which promotes tight coordination with velic gestures and facilitates early velic raising following oral release. This boundary-driven coordination limits the temporal extent of nasal airflow into the following vowel, resulting in relatively weak carryover nasalization. In contrast, word-final coda nasals are shaped by constraints at the right prosodic edge, where temporal compression and truncation restrict the available space for gestural realization (Byrd 2000). Under such conditions, velic raising cannot be delayed beyond oral release, forcing velic lowering to be realized earlier and increasing its temporal overlap with the preceding vowel, thereby giving rise to robust anticipatory nasalization.

In contrast to these edge-aligned cases, intervocalic nasals are not aligned with prosodic edges and thus are not subject to the same boundary-driven anchoring or truncation pressures. In a V-N-V sequence, the nasal must be coordinated with both the preceding and the following vowel, which imposes competing demands on the

timing of velic movement. Advancing velic raising to minimize carryover nasalization would require the velum to be raised early and then lowered again to produce the nasal consonant, necessitating additional velic re-timing and increasing articulatory cost. By contrast, delaying velic raising until after oral release allows the preceding vowel to remain largely oral while permitting nasal airflow to persist briefly into the following vowel, a coordination pattern that minimizes reconfiguration of the velic gesture relative to the oral constriction.

This tendency toward delayed velic raising may be further reinforced for intervocalic nasals, whose syllabic affiliation is distributed across the V_1 -N- V_2 interval rather than anchored to a single syllable edge. Under such gestural sharing, the nasal constriction can be robustly coordinated with the following vowel while the velic gesture lags behind oral release, yielding precisely the pattern observed in the present study: weak anticipatory nasalization on the preceding vowel but substantial carryover nasalization on the following vowel. In this way, the reversed directionality of nasalization in intervocalic contexts follows naturally from the combined effects of prosodic non-edge status and vowel-to-vowel coordination pressures on velic-oral timing.

4. Conclusion

This study has provided a comprehensive acoustic examination of intervocalic nasal consonants in American English, offering new insight into the phonetic status of ambisyllabic nasals. Using A1-P0 as a validated acoustic measure of vowel nasality and systematically sampling all logically relevant intervocalic configurations, the results demonstrate that ambisyllabic nasals pattern neither with canonical onset nor with coda nasals. Instead, they exhibit acoustic properties closely resembling those of non-ambisyllabic intervocalic nasals preceded by stressed tense vowels, supporting Kahn's notion of ambisyllabicity. In addition, the observed asymmetry between anticipatory and carryover nasalization - characterized by minimal nasalization on preceding vowels but robust carryover effects on following vowels - reveals a reversed directionality of nasalization unique to intervocalic contexts. We argue that this pattern follows naturally from prosodic edge effects on the temporal coordination of velic and oral gestures: while onset and coda nasals are constrained by boundary-driven

anchoring and truncation, intervocalic nasals occupy a prosodic non-edge position that allows delayed velic raising and favors carryover nasalization. Together, these findings provide acoustically grounded phonetic evidence for ambisyllabicity and suggest that its phonetic realization is best understood as an emergent property of edge-governed gestural timing, rather than as an intermediate or hybrid representation between onset and coda.

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Received: 2026. 02. 02.

Revised: 2026. 02. 23.

Accepted: 2026. 03. 10.