

“Tense” /æ/ is still lax: A phonotactics study

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1 Introduction

The production of the lax vowel /æ/ is widely studied as a sociolinguistic variable in American English, as several dialects differ in the allophonic distribution of the vowel. In this paper, I ask whether the /æ/ used by Northern Cities Shift speakers, which is described as a raised and tensed [ɛə] in all environments, is still represented as a lax vowel in speakers’ grammars. The question asked of /æ/ could very well be asked of any phonetic variant in any language. Many variables are described in terms of feature differences between phonetic variants, yet their phonological representations are unknown. The variation between tense and lax /æ/ is particularly interesting because the tense/lax vowel classes are targeted by phonological patterns in English. Tense and lax vowels are subject to morphophonological rules and differ in phonotactic distribution. As such, the central question of this paper is determining whether the tense /æ/ used by Northern Cities Shift speakers belongs to the phonological class of tense or lax vowels.

The answer to this question has implications beyond the specification of this particular vowel. The phonetic properties of the vowel may suggest to learners that it should be classified as phonologically tense, but the distribution of the category in the lexicon of English may suggest to learners that it is lax. By way of showing whether speakers pay attention to phonetic properties or lexical distributions in generalizing features, this experiment can offer evidence in favor of phonetically- or phonologically-driven approaches to phonologically active classes (Chomsky and Halle 1968, Clements and Hume 1995, Mielke 2008).

I test the Northern Cities Shift specification through a forced-choice well-formedness judgment task, in which participants are asked to choose which of a pair of nonce words, constructed to include a lax-only environment /Vsk, Vsp/, as in *gasp*, *risk*, sounds more like a possible English word. I compare the performance of speakers of California English and Northern Cities Shift speakers. The key difference between the dialects is that California English has a nasal /æ/ system, in which /æ/ is primarily lax and only tensed pre-nasally (and thus lax in the experimental conditions presented), while the Northern Cities Shift tenses in all environments. As I will show, Northern Cities Shift speakers respond to trials such as [bɛəsp] vs. [bisp] in the same way that California English speakers respond to [bæsp] vs. [bisp], suggesting they keep the vowel in the phonologically active class usually considered to be lax vowels.

This paper proceeds as follows: in section 2, I discuss the phonetic features of /æ/ systems, the tense-lax distinction, and phonologically active classes. Section 3 outlines the methodology of the experiment. Section 4 details the experimental results and data analysis, while Section 5 discusses the phonological context of the results. I conclude and offer directions for future research in section 6.

2 Background

2.1 /æ/ As stated above, /æ/ is traditionally viewed as a lax vowel. The vowel has a high degree of variability among American English dialects, with several different systems attested. Most of these systems have allophones labeled tense ([ɛə]) and lax ([æ])¹. The tense [ɛə] is raised, lengthened, and diphthongized compared to [æ] (Boberg & Strassel 2000: 109). Both the lengthening and glide of a diphthong are phonetic properties associated with tenseness in English. There are relatively few studies of [ɛə] from an articulatory

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¹ The tense form can range in production from [ɪə] to [æə] (Green 2001), but here I use [ɛə] as a catch-all, following Boberg and Strassel (2000).

or phonological perspective (Labov 1994: 505). Although the vowel length gives the impression of tenseness, articulatory experiments are less conclusive, showing variation in production even within the same speaker (DeDecker & Nycz 2012: 811). Despite this, the variant is usually considered to be tense in the sociolinguistic literature.

The simplest and most widespread allophonic distribution of /æ/ is a nasal system (Dinkin 2011: 71). In many dialects, including California English, /æ/ diphthongizes and raises to [ɛə] when preceding nasal consonants (*cat* [kæt], but *hand* [hɛənd]). In contrast, cities participating in the Northern Cities Shift have a continuous /æ/ system in which it is always raised and diphthongized, regardless of environment. When speaking of the vowel in Northern Cities Shift speakers, then, we may generalize it as [ɛə]. Table 1 summarizes several /æ/ systems by word class. As seen in Table 1, while all dialects have some tensing before nasals (*tan*), only Northern Cities Shift tenses before voiceless stops (*bat*).

Word	Standard American English	California English	Mid-Atlantic English	Northern Cities Shift English
Bat	[bæt]	[bæt]	[bæt]	[bɛət]
Bad	[bæd]	[bæd]	[bɛəd]	[bɛəd]
Pass	[pæs]	[pæs]	[pɛəs]	[pɛəs]
Tan	[tæn]/[tɛən]	[tɛən]	[tɛən]	[tɛən]

Table 1: Surface Representations of /æ/ in various dialects

2.2 English Tense/Lax distinction Many languages make a distinction between vowels that is described as tense vs. lax, although the way these classes are defined differs from language to language. Some descriptions refer to tense vowels as having more muscular effort than lax vowels or an Advanced Tongue Root (Archangeli and Pulleyblank 1989), while others rely on a contrast between long and short vowels. Cross-linguistically, the tense/lax distinction is often evident through cases of vowel harmony (Telugu: Wilkinson 1974, Yoruba: Archangeli and Pulleyblank 1989, inter alia).

English, like many other Germanic languages (for example, Frisian, Dutch, German, and Swedish), displays a tense/lax distinction couched in terms of *long* and *short* (Löfstedt 2010) or *free* and *checked* vowels (Mees and Collins 1983). Free vowels may appear word-finally, while checked vowels cannot. Long vowels and diphthongs are usually considered to be free/tense in these languages, while short vowels are checked/lax. In the case of Standard American English, this roughly makes the following classes: /i, e, u, o, ɔ, ɔɪ, aɪ, aʊ/ are tense, while /ɪ, ɛ, ʊ, ʌ, ɑ, æ/ are lax². Note that while they are transcribed as monophthongs, the tense vowels all tend to be long, often diphthongal. Although low vowels are often seen as underspecified for [+/-tense], work on English has traditionally specified them for the feature (Hayes 2009).

These classes are phonologically active, meaning they are classes which display phonotactic restrictions or phonological processes (Mielke 2008). In the case of tense/lax vowels, this is seen in both morphophonological processes (Lee 1996) and phonotactic distribution (Green 2001). Of interest here is the distinction in phonotactic distribution, summarized in Table 2. In addition to being permitted word-finally, tense vowels may occur preceding word-final /ð/ and preceding a vowel. Lax vowels may not occur in these environments. On the other hand, lax vowels may occur preceding /ŋ/. In monomorphemes, lax vowels may precede consonant clusters that include at least one noncoronal consonant. Phonotactically legal clusters of this sort in English include stop-fricative (SF), fricative-stop (FS), and sonorant-obstruent (NO). Tense vowels are not found in these environments (Green, 2001, pp. 5-7). With the exception of a handful of function words (*with* [wið], etc.) and the low back vowels³, these patterns are largely exceptionless.

² This is a clear distinction for all vowels except /ɔ, a/, which generally pattern as stated above, but with many exceptions. The exceptions occur to an extent that Polgardi considers them a separate class of long lax vowels, rather than tense (2012: 113).

³ The diachronic merger of /a, ɒ/ resulted in several lexical items in the /V#/ environment (*spa*, etc.). Many American English dialects, including California English, also merge /a, ɔ/, yielding further exceptions regardless of the feature specifications of the merged vowel (i.e., if lax, there are /V#/ tokens; if tense, there are /Vsk/ tokens). For this reason, the present experiment avoided the issue by making use solely of front vowels.

Environment	Tense Vowels	Lax Vowels
/V#/	<i>she</i> [ʃi], <i>die</i> [daɪ]	*[dɪ]
/Vð#/	<i>bathe</i> [beð], <i>loathe</i> [loð]	*[bɪð]
/V.V/	<i>riot</i> [raɪ.ət], <i>react</i> [ri.ækt]	*[re.ət]
/Vŋ/	*[tɒŋ]	<i>hung</i> [hʌŋ], <i>sing</i> [sɪŋ]
/VFS/ (monomorphemes)	*[tesp]	<i>wisp</i> [wɪsp], <i>desk</i> [dɛsk]
/VSF/ (monomorphemes)	*[niks]	<i>axe</i> [æks], <i>X</i> [ɛks]
/VNO/ (monomorphemes)	*[bomp]	<i>rump</i> [rʌmp], <i>amp</i> [æmp]

Table 2: Phonotactic Distribution of Tense and Lax Vowels

In terms of attested words, /æ/ patterns as a lax vowel without exception in Standard American English. As such, there are no lexical items with /æ/ in a tense-only environment. In dialects with an allophonic distribution of tense and lax /æ/, the lax allophone often surfaces in lax-only environments. Similarly, because the Northern Cities Shift vowel arose directly from lax /æ/, the distribution of lexical items with the vowel is that of a lax vowel almost without exception⁴. Like in other American English dialects, it is unclear whether words have a short allophone or a different vowel entirely when preceding /ŋ/.

2.3 Phonotactics and phonologically active classes This paper focuses on the lax-only environments /Vsk, Vsp/, which fall into the category of fricative + noncoronal stop CC codas. Among the monomorphemic monosyllables in a modified Carnegie Mellon University Dictionary (Hayes 2011), there are only 32 English lexical items (of 3759 total) with these codas; they contain lax vowels without exception. This confirms there is a phonotactic restriction on tense vowels in these environments. The following table shows this in terms of Observed/Expected Ratios, calculated as $P(xy)/(P(x)*P(y))$, in which x is a vowel/class and y is the /Vsk, Vsp/ environment. A value around 1 indicates that the vowel/class occurs in the environment about as often as expected, a value well above 1 indicates the vowel/class is overattested, and a value well below 1 indicates the vowel/class is underattested. A value of 0 means the vowel/class is unattested. As seen in Table 3, the lax vowels vary individually in how well-attested they are, but in general are extremely overattested. In contrast, all tense vowels are unattested. Because the total number of /Vsk, Vsp/ monosyllables is so small, we cannot draw any strong conclusions from these figures; however, given the categorical absence of tense vowels, the figures do show a phonotactic restriction on tense vowels in this environment. As the results will show in section 4, despite the low expected values, speakers learn the restriction quite strongly.

Vowel	Lax Vowels					Low Back		Tense Vowels						
	æ	ʌ	ɛ	ɪ	ʊ	ɑ	ɔ	aʊ	aɪ	e	ɔɪ	o	i	u
Observed	11	8	1	10	0	2	0	0	0	0	0	0	0	0
Expected	3.15	2.52	2.77	3.74	0.36	2.83	2.46	1.00	2.08	2.82	0.33	2.01	2.56	1.99
O/E	3.49	3.18	0.36	2.68	0	.71	0	0	0	0	0	0	0	0
Class	Lax					Tense								
ΣO	32					0								
ΣE	15.36					15.25								
ΣO/ΣE	2.08					0								
Σ(O/E)/n	1.74					0								

Table 3: O/E for /Vsk, Vsp/, individual vowels and tense/lax classes

Thus, the restriction on tense vowels is a systematic gap; tense vowels are not permitted in /Vsk, Vsp/ environments. In contrast, the relative lack of /ɛ/ and absolute lack of /ʊ/ represent accidental gaps (and we may hypothesize the absolute lack of /ʊ/ to be a result of the relative infrequency of the vowel overall).

⁴ There are four lexical items that contain word-final /æ/ for Northern Cities Shift speakers: *yeah*, *nah*, *baa*, and *waa*. Only *yeah* and *nah* are actually words in my estimation, as *baa* and *waa* are onomatopoeic and rather performative. I am not sure of the geographic distribution of /næ/, so this may or may not be a Northern Cities Shift innovation.

Speakers have been found to distinguish between systematic and accidental gaps in experimental conditions. Both Hebrew and Arabic speakers, for example, rate nonce words that represent OCP-violations (phonotactically illicit, and thus a systematic gap) far worse than nonce words that are phonotactically licit (accidental gaps) (Berent and Shimron 1997, Frisch and Zawaydeh 2001). Likewise, Amharic, Chala, and Quechua speakers make fewer mistakes when producing phonotactically licit nonce words than when producing phonotactically illicit ones (Rose and King 2007, Gallagher 2013). We could reasonably expect, then, that English speakers would similarly disfavor systematic gaps in the case of the tense/lax distinction. There is cross-linguistic evidence that this particular distinction may be phonologized: Dutch, which also distinguishes tense/lax vowels, has a restriction on tense vowels appearing before a consonant cluster in which the second consonant is noncoronal (Kager and Pater 2012), in many ways similar to one of the English restrictions. In a nonce word judgment task similar to the present experiment, Kager and Pater find that Dutch speakers prefer lax vowels in these environments.

These findings mean phonotactic restrictions are grammaticalized for speakers, much like phonological and morphophonological rules. As such, a systematic phonotactic restriction on a group of sounds is enough to make them a phonologically active class. Because this means the English tense and lax classes are phonologically active, we can see that the tensing of Northern Cities Shift /æ/ poses a phonological problem, as it provides a case of phonetic variation in a phonologically active feature. To put it most simply, which class is Northern Cities Shift /æ/ in? This in effect is a question of whether speakers treat /æ/ as systematically tense, with lexical exceptions, or systematically lax.

There are reasons to believe that speakers could treat it as either phonologically tense or lax: it phonetically resembles other English tense vowels and has chain shifted like one (see Labov 1994), but on the other hand, many lexical items exist (*task*, *gasp*, etc.) to provide a learner evidence that it patterns with lax vowels and thus may be lax. In some ways, one's approach to how phonologically active classes are constructed would influence a hypothesis. If /æ/ is tense, it would support a phonetically-driven approach to feature classes, as its specification would be derived from its phonetic features. In contrast, if it is lax, it would support a phonologically-driven approach, as its specification would be derived from attested lexical items and phonological patterns. In a broader context then, this experiment may serve as a comparison of the two approaches to phonological classes.

2.4 Possible grammars for the tense/lax distinction The phonotactic grammar we would expect to find evidence of in this experiment depends on the specification of /æ/. It is simplest to envision the grammar we would find in non-tensing dialects. In these cases, /æ/ would be lax. As such, the tense/lax distinction would be robust, as shown above in Table 3. We would thus expect to find evidence of a constraint that only permits lax vowels in the experiment environments of /Vsk, Vsp/. Because the experiment only uses these codas, I will frame such a constraint in terms of those codas only; we may hypothesize that speakers will grammaticalize the distinction in other environments, but will have no evidence of it.

- (1) *_[+tense]sC_[-coronal]#—vowels with the [+tense] feature are not permitted preceding the word-final cluster /sC/, where C is a non-coronal

This is a similar constraint, albeit more specific, to those proposed for Dutch in Kager and Pater (2012). Note that this is a relatively arbitrary constraint, as it applies to a tetragram and somewhat questionably relies on the [-coronal] feature; however, it is descriptively adequate. Regardless of the actual formalization, a non-tensing dialect will require something that achieves the effect of separating attested from unattested structures achieved by (1). If Northern Cities Shift /æ/ is lax, this is also the grammar we would expect to find in that dialect.

In contrast to the case of lax /æ/, if Northern Cities Shift /æ/ is phonologically tense, there are two possible grammars that speakers could adopt. One possibility is that a restriction on tense vowels in /Vsk, Vsp/ could be developed based on natural classes, but with an exception for /æ/ built in. In this case, we would expect to find the same constraint as in (1); however, it would be weakened in comparison to non-tensing dialects because of the prevalence of lexical items containing /æ/. This is because while the constraint has the same broad scope as detailed for a lax /æ/, it is less accurate due to the attested words with /æ/. Rather than represent a categorical restriction, then, (1) would represent a gradient restriction, and a learner like the UCLA Phonotactic Learner (Hayes and Wilson 2008) would give it less weight as a result.

We might instead suppose that if /æ/ were phonologically tense, phonotactic restrictions based on natural classes would be impossible, as lexical items containing /æ/ are known to exist. In terms of the learner mentioned above, the broad constraint wouldn't meet the accuracy threshold to be included, and the distribution would instead be represented by a more narrow, but more accurate, set of constraints. As such, restrictions would instead be stated in terms of segments.

- (2) *isC_[-coronal]#, *esC_[-coronal]#, etc.— the vowels /i, e, etc./ are not permitted preceding the word-final cluster /sC/, where C is a non-coronal

In this case, /æ/ would be perfectly licit alongside the lax vowels. However, because the constraints in (2) are narrower and less generalizable than in (1), the restriction on tense vowels for the Northern Cities Shift should be weaker than the restriction in a non-tensing dialect. Note that in this case, non-/æ/ tense vowels are ruled out by violating the specific constraint against that particular segment, but do not violate the other specific constraints.

In sum, we should expect to find evidence supporting the categorical restriction captured in (1) among speakers of non-tensing dialects like California English. If Northern Cities Shift /æ/ is lax, we should find the same pattern as California English; if tense, we would expect evidence that supports either a gradient formulation of (1) or segment-based restrictions as in (2). In either case, such evidence would take the form of a comparatively weaker distinction between attested and unattested vowels.

3 Methodology

The data collected in this experiment consists of phonotactic well-formedness judgments. In order to obtain these, a forced-choice experiment was designed, in which nonce minimal pairs were presented to participants, who were then asked to indicate which of the pair sounded more like a possible word of English. This design was selected because while rating wordlikeness on a Likert scale does a good job of finding differences in rating between nonce words representing systematic vs. accidental gaps in the lexicon (Frisch and Zawaydeh 2001), forced-choice tasks have been shown to find these differences as well as more detailed differences (Berent and Shimron 1997, Daland et al. 2011, Kager and Pater 2012, *inter alia*). This is helpful, as speakers have been shown to accept nonce words gradually, reflecting patterns in the distribution of the sound or morpheme in question in the language (Albright and Hayes 2003). For example, the nonce words [sesk, sisk], as tense vowels in a lax-only environment, may both be individually rated poorly on a Likert scale. However, a forced-choice task allows us to see if one of the phonotactically illicit words is more illicit than the other. This methodology has been successfully used to show Dutch speakers' knowledge of the Dutch tense/lax distinction, which is similar to that in English in primarily appearing in phonotactic distribution rather than phonological rules (Kager and Pater 2012).

3.1 Experiment The forced-choice task was designed using Experigen (Becker and Levine 2014). Participants were presented with a minimal pair of monosyllabic nonce words and asked to indicate which sounded more like a possible word of English by clicking "First" or "Second." The nonce word pairs differed only in vowel, while the onset and coda were the same for each trial. Each test trial used the codas /sk, sp/, which are lax-only environments. All front vowels /i, ɪ, e, ε, æ/ were used in this experiment. Only frames which yielded nonce words for each front vowel were used (i.e., /dVsp/ could be used: none of /dæsp, dɛsp, dɪsp, disp, desp/ are attested words. However, /rVsk/ could not: /ræsk, rɛsk, risk, resk/ are unattested, but /risk/ is a lexical item). As test conditions, /æ/ was compared to each of /i, ɪ, e, ε/, while /i-e, i-ɛ, ɪ-e, ɪ-ε/ comparisons were used as controls. For each condition, a list of 15 pairs was created. I attempted to control for word probability by minimizing differences in lexical neighborhood density (LND), calculated by treating the nonce words as /onset, vowel, coda/. LND is calculated as the number of existing words that share two of these positions. The value was based on a corpus of monosyllables extracted from Hayes' modified CMU Dictionary (Hayes 2011). In practice, this was only possible for the /æ-ɪ, i-e/ conditions. This is both because in lax-only environments, only words with lax vowels have a nonzero LND value, and because as shown in Table 5, the majority of existing words in the chosen frames have the vowel /æ, ɪ/, with /ε/ underattested. Fillers were created using the same vowels and codas /b, g, p, k/, matched for LND using the same technique. For each comparison condition, 10 filler pairs were made. A representative sample of stimuli may be seen in Table 4.

Trial type	Test	Test	Filler
/æ-i/	/bæsp/-/bisp/	/plæsk/-/plisk/	/spæp/-/spip/
/æ-e/	/swæsk/-/swesk/	/fæsp/-/fesp/	/bræb/-/breb/
/æ-ɛ/	/næsk/-/nɛsk/	/hæsk/-/hɛsk/	/væb/-/vɛb/
/æ-ɪ/	/pæsp/-/pɪsp/	/gæsk/-/gɪsk/	/θæɡ/-/θɪɡ/
/i-e/	/brisp/-/brɛsp/	/tisp/-/tɛsp/	/mib/-/mɛb/
/ɪ-e/	/ʃɪsp/-/ʃɛsp/	/slɪsk/-/slɛsk/	/ɡɪk/-/ɡɛk/
/i-e/	/prisp/-/prɛsp/	/mɪsp/-/mɛsp/	/kɪɡ/-/kɛɡ/
/ɪ-ɛ/	/dʒɪsk/-/dʒɛsk/	/kɪsp/-/kɛsp/	/jɪɡ/-/jɛɡ/

Table 4: Sample stimuli

Participants were divided into a control group that did not engage in /æ/ tensing (California English speakers) and a test group that did (Northern Cities Shift speakers). Stimuli were recorded such that participants heard their variant of /æ/. This meant California English heard a lax [æ], while Northern Cities Shift speakers heard a tense variant. This was done in an effort to minimize any potential social evaluations of the nonce words. In order to keep the rest of the vowels constant, a linguist with phonetic training who was a native speaker of New York City English recorded each stimulus. As an NYCE speaker, she could and did produce both /æ/ variants in the same environment. It should be noted that this means that the phonetic realization of /æ/ heard by participants is confounded by region. We will not know from this experiment whether speakers would react in the same way to the phonetic realization other than the one they heard. In the case of Northern Cities Shift speakers in particular, the question of whether they react in the same way to both variants could prove to be an interesting line of further research.

Participants saw 120 trials in total: 80 test, 32 filler, and 8 practice. One example of each filler condition was used as practice to get participants accustomed to the task. Ten of each test condition and four of each filler condition were randomly selected to yield the rest of the trials; these 112 trials were presented in a randomized order. The experiment was conducted in person so that the experimenter explained the directions and was present throughout the practice items to answer any questions. In addition to the experiment, participants completed a short survey of their age, background, and history with other languages. Participants were paid \$10 for about 20 minutes of their time.

The primary goal of this design, of course, was to determine whether /æ/ is underlyingly tense or lax for Northern Cities Shift speakers. While the methodology is similar to that of other nonce word studies, there is a clear contrast: previous studies take as a given that an environment represents a systematic or accidental gap and test whether those are treated differently. This experiment builds off of these studies by taking as a given that systematic and accidental gaps are treated differently, thus testing whether Northern Cities Shift speakers treat tense vowels in /Vsk, Vsp/ environment as a systematic or accidental gap. Because we would expect tense vowels to be treated as a systematic gap if /æ/ is lax and potentially as an accidental gap if /æ/ is tense, we can determine whether Northern Cities Shift /æ/ is phonologically tense or lax from the treatment of the nonce words containing tense vowels. However, /æ/ may still be tense even in the case that tense vowels are treated as a systematic gap if a restriction is weakened compared to the restriction in the California English group. In this case, though, we would expect a difference between dialect groups, as well as /æ/ to be treated differently than other lax vowels. We are thus addressing several issues: whether there is a phonotactic restriction on tense vowels appearing in /Vsk, Vsp/ coda, whether /æ/ is in the same phonological class as other lax vowels, and whether the Northern Cities Shift group differs from the Californian group. These smaller issues serve to point to the specification of /æ/.

3.2 Participants Because /æ/ systems in North American English are tightly correlated to geography, geography was used as a proxy for dialect in recruiting participants. Much of the US does not engage in tensing, while those that do are for the most part grouped around the Great Lakes. The large population combined with the lack of tensing was the impetus for the use of California English speakers as a control. Subjects were initially recruited by email from undergraduate linguistics courses at NYU. Because the entire Lower Peninsula engages in /æ/ tensing, Michiganders were initially recruited as the test group of Northern Cities Shift speakers. In addition, college athletes with a hometown in a /æ/ tensing state or metropolitan area (roughly, Milwaukee, Chicago, St. Louis, Cleveland, Buffalo, Syracuse, and Rochester) were recruited from NYU and other nearby universities.

While 21 speakers participated in the experiment, the data from one African-American Northern Cities Shift-area participant was removed on the basis of not being a native Northern Cities Shift speaker; the Northern Cities Shift is well known for not making inroads in the African-American population of the cities in which it is found (Van Herk 2008). In total then, 11 Californians and 9 Northern Cities Shift speakers comprise the data reported here.

3.3 Predictions Because this is a forced-choice task, there are a clear set of predictions of possible outcomes and their interpretations. In the case of the control group of California English speakers, we would expect participants to phonologize a phonotactic restriction on tense vowels in /Vsk, Vsp/ environments. This entails choosing nonce words containing a lax vowel at a rate greater than chance in conditions comparing a nonce word with a tense vowel to one with a lax vowel (/æ-i, i-e/ etc.). At the same time, we would expect the decision to be close to chance, with possible effects of transitional probabilities or other factors if the pair of nonce words have vowels of the same tenseness (/æ-i, ε-i/ etc.). If Northern Cities Shift /æ/ is lax, those participants would behave in the same way: attested lexical items would exist to show that /æ/ is representative of the pattern; thus, nonce words containing it would be chosen at high rates compared to words containing tense vowels. However, if Northern Cities Shift /æ/ is tense, participants should respond differently. If this resulted in tense vowels being treated as an accidental gap, we would expect to see no evidence of a phonotactic restriction outside of effects of transitional probability; i.e., /æ-e/ might still be favor /æ/ because of attested lexical items containing /æ/, but /ε-i/ would not favor /ε/, as it is relatively unattested. If tense vowels remained a systematic gap but /æ/ was treated as an exceptional vowel to both classes, we would expect to find differences between the two dialects' treatment of /æ/, as unlike for California English speakers, the vowel would not be in the same phonological class as /ε, i/ for Northern Cities Shift speakers.

4 Results and Data Analysis

In order to determine if /æ/ is underlyingly tense or lax for Northern Cities Shift speakers, we are interested in three primary questions. As such, I first compare the results to chance to look for evidence of a phonotactic restriction on tense vowels. I then model the results as a logistic mixed effects regression using the *lme4* package in R (Bates et al. 2014, R Core Team 2013). This enables us to confirm the presence/absence of a phonotactic restriction on tense vowels, while testing whether /æ/ falls into the same natural class as other lax vowels. Additionally, these models show whether there is a difference between the two groups of participants. Post-hoc tests further show whether there is a difference between the groups.

4.1 Testing for a Phonotactic Restriction For a given pair of vowels, if there is a phonotactic restriction, we would expect the licit one to be chosen at a rate well above chance, that is, well above 50%. Because there are only two possible outcomes of each trial, the experiment resembles a glorified coin toss: if the coin is fair, there is no restriction, if it is an unfair coin, there is a restriction. After a large number of trials, a fair coin may not come up heads exactly 50% of the time, but it will more likely than not be close to this value, falling somewhere along the binomial distribution. As such, we may compare the experiment results to the binomial distribution; the further from 50% they are, the more unlikely it is that they are due to chance. This comparison is two-tailed: results could be either well above or well below chance levels. Binomial tests were conducted in R (R Core Team 2013). Because there are 16 conditions (eight conditions and two groups), I use a Bonferroni corrected standard of $p=0.0015625$ ($.05/2/16$) as a guideline for accepting results as significantly different from chance.

As seen in Table 5, the Californian group favors vowels as predicted. In conditions that pit a tense vowel against a lax vowel, where we would expect a phonotactic restriction to be visible, we find that the lax vowel is chosen at a rate significantly above chance. At the same time, one vowel is not favored at a rate significantly above chance in conditions that compare two vowels of the same tenseness, even when one is chosen at a relatively high rate. Turning to the Northern Cities Shift group, we find that /æ/ is favored over /e,i/, while /ε/ is favored over /i/. Each of these is a case of the vowel that is attested in the frame being chosen over the unattested vowel. However, there is no such effect for /ε-i/ even though /ε/ is unattested. At the same time, /æ/ is favored over /i/ significantly more than chance despite both being attested. Overall then, there appears to be a phonotactic restriction on tense vowels for the Northern Cities

Shift group, but things are not as straightforward as in the case of the Californian group. It is worth noting that both conditions that differ from the Californian group involve /ɪ/, suggesting that the difference is not due merely to chance.

Pair	California English		Northern Cities Shift	
<i>Predicted Restriction</i>				
/æ-e/ (choose /æ/)	69.1%	.00002	74.4%	<<.00001
/æ-i/ (choose /æ/)	82.7%	<<.00001	87.8%	<<.00001
/e-ɪ/ (choose /ɪ/)	63.6%	0.00147	47.8%	0.29921
/ε-i/ (choose /ε/)	71.8%	<<.00001	73.3%	<<.00001
<i>Predicted Non-Restriction</i>				
/æ-ε/ (choose /æ/)	60.9%	0.00837	60.0%	0.02230
/æ-ɪ/ (choose /æ/)	62.7%	0.00272	67.8%	0.00022
/e-i/ (choose /e/)	52.7%	0.25234	63.3%	0.00402
/ε-ɪ/ (choose /ɪ/)	60.9%	0.00837	54.4%	0.17142

Table 5: Comparison of participant responses to chance

Overall then, there appear to be phonotactic restrictions on tense vowels for both groups.

Due to the large number of conditions, the binomial test, while useful, is not an ideal diagnostic. As such, I model the results with a logistic mixed effects regression. Because the specification of /æ/ is in question, we cannot use every condition in a single regression; essentially, we know more about the other vowels than /æ/, so we can only combine conditions that let us not make assumptions about the features of /æ/. To look for evidence of a phonotactic restriction, I fit a regression model to the responses on conditions in which /æ/ is compared to another vowel (i.e., [Cæsk] vs. [CVsk]). This allows us to have a dependent variable of whether /æ/ was chosen or not. Alongside the random factor of participants, I use four fixed effects: the tenseness of the other vowel, the height of the other vowel, the coda of the trial frame, and the difference in transitional probability between the nonce word containing /æ/ and that of the nonce word containing the other vowel. Additionally, I test for either a main effect of dialect or an interaction with one of the fixed factors. Figure 1 shows the main effect of tenseness. Both groups responded roughly the same, favoring /æ/ much more compared to tense vowels (/e, i/) than lax vowels (/ε, ɪ/).

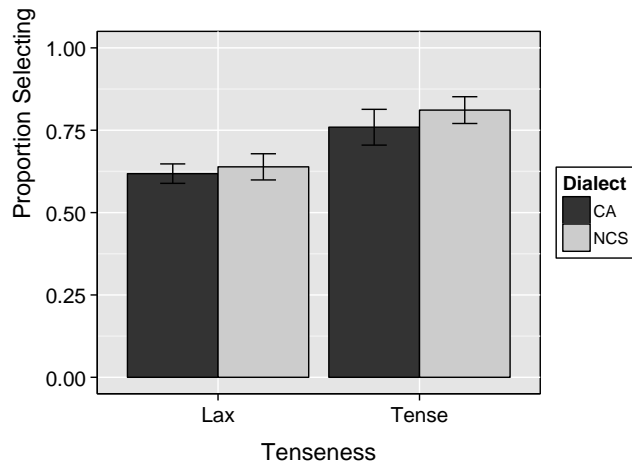


Figure 1: Proportion of responses selecting /æ/ by tenseness of other vowel.

As there is little evidence in the literature of height effects in English, height is included in the model more in case of potential effects than in expectation of them. Somewhat similarly, coda is included simply to confirm that it has no effect or unexpected interaction. The effect of transitional probability is encoded as

the difference in probability between the word containing /æ/ and the other word, that is, $P(/æ/) - P(\text{Other})$. Because the experiment is a forced-choice, the more likely nonce word would be the expected choice, with the rate of choice potentially increasing as the difference in probability is larger.

Table 6 summarizes the final model when using [-high] lax other vowels (essentially, /ɛ/) as a baseline. The only significant effects were those of height, tenseness, and transitional probability: /æ/ was more likely to be chosen when compared to a [+high] vowel or a tense vowel. Furthermore, the larger the difference in transitional probability between /æ/ and the other vowel, the more likely /æ/ was to be chosen. Coda did not have a significant effect, nor was there a main effect of dialect or interaction of dialect with any fixed factors. Note too that the intercept was not significantly different from zero. This means that /æ/ was not inherently favored over other vowels; it was not more likely to be chosen simply for being /æ/. Because there is no effect of dialect, this model applies to both groups in the same way.

Factor	Effect Size (β)	p-value
Intercept	.31451	.05711
[+high]	.63920	.00020
Tense	.66487	.00009
Transitional Probability Difference	.28549	.00178

Table 6: Results of logistic regression comparing /æ/ to other vowel

4.2 Testing for /æ/'s Class While the above model describes how speakers reacted to /æ/, it does not say whether /æ/ is treated as a member of a phonological class alongside the lax vowels /ɛ, ɪ/ or whether it is exceptional. To determine this, I combine the conditions comparing attested vowels (i.e., [CLsk]—including /æ/) to unattested vowels (i.e., [CTsk]). This model has a dependent variable of whether the attested vowel was chosen or not; as above, this makes no assumptions about /æ/'s features. I treat participants again as a random factor, alongside three other fixed factors: identity of the attested vowel, the coda of the trial frame, and the difference in transitional probability between the attested and unattested vowel. Figure 2 shows that the attested vowel, in this instance essentially a measure of vowel height, has an effect. Both groups select /æ/ and /ɛ/ at high rates compared to /ɪ/, and this difference is especially pronounced for Northern Cities Shift speakers.

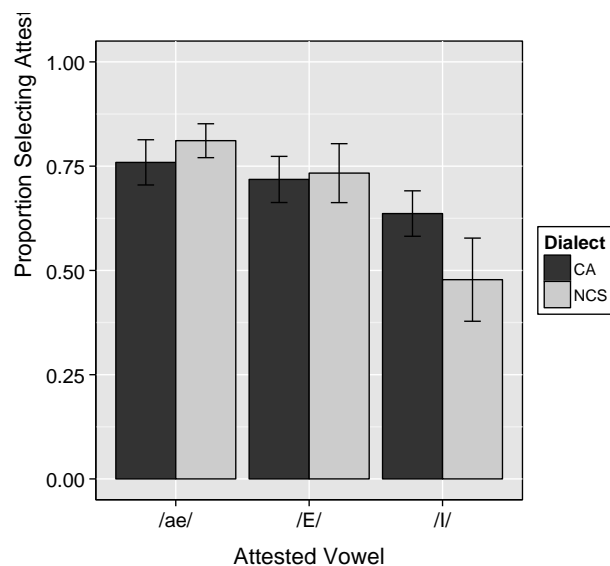


Figure 2: Proportion of responses selecting vowel attested in /Vsk, Vsp/ over unattested vowel.

Coda is again included as a double-check for the sake of completeness, as it could potentially have an unexpected interaction. Transitional probability is calculated in the same manner as above.

Table 7 summarizes the final model when using attested vowel as a factor and /æ/ as a baseline. As seen, coda (i.e., [sk] vs. [sp]) did not prove to be a significant effect. When the attested vowel is /ɪ/, there is both a main effect and an interaction with group. According to the model, while both groups significantly disprefer /ɪ/, this is especially the case for the Northern Cities Shift group. There is an additional main effect of the transitional probability difference, scaled to help the model converge. The larger the difference in probability between the attested vowel and unattested vowel, the more likely the attested vowel is to be chosen. Finally, the intercept is significantly different from zero. Because this model compares attested vowels to unattested, this indicates the phonotactic restriction on tense vowels; the attested vowels form a class that is more likely to be chosen. Neither group nor the vowel being /ɛ/ have a significant effect.

Factor	Effect Size (β)	p-value
Intercept	1.17871	<<.00001
Vowel=[ɛ]	.04782	.87295
Vowel=[ɪ]	-.64618	.01395
Transitional Probability	.21841	.03200
Group (Northern Cities Shift=1)	.33187	.37612
V=[ɛ]:Group	-.24589	.55302
V=[ɪ]:Group	-1.03726	.00903

Table 7: Results of logistic regression using attested vowel as fixed effect.

4.3 Testing for a Dialect Difference While the logistic regression model of conditions comparing /æ/ to another vowel suggests that there is no difference between the two dialects, the model comparing attested vowels to unattested vowels suggests there is an interaction between the identity of attested vowel and dialect. Post-hoc tests confirm that there is a difference between the dialects, showing that only the Northern Cities Shift group significantly disprefers /ɪ/ when compared to /æ, ɛ/. I split the data used in the logistic regressions into Northern Cities Shift and California English speakers, and ran an ANOVA on each using vowel as an independent variable and response as a dependent variable. This allowed me to use Tukey's HSD test to compare the vowels pairwise (Table 8). While there was no significant difference between attested vowels among California English speakers, Northern Cities Shift speakers show a significant difference between both /æ, ɪ/ and /ɛ, ɪ/, but not between /æ, ɛ/.

Pair	California English p-value	Northern Cities Shift p-value
/æ, ɛ/	.71497	.35028
/æ, ɪ/	.05114	.00000
/ɛ, ɪ/	.36697	.00029

Table 8: Results of Tukey's HSD post-hoc test comparing attested vowels

Taken with the logistic regression results, the post-hoc tests show the Northern Cities Shift preference for [-high] vowels to be much stronger than that of California English speakers. Alongside more strongly disfavoring [+high] vowels, seen in the group-/ɪ/ interaction, the Northern Cities Shift preference appears independently of other factors, while the California English preference only shows up in the logistic models. Note, however, that this difference does not bear on the feature specifications of /æ/.

5 Discussion

In order to determine whether /æ/ is phonologically tense or lax, we are interested in three issues: whether there is a phonotactic restriction on tense vowels appearing in /Vsk, Vsp/ coda, whether /æ/ is in the same phonological class as other lax vowels, and whether the Northern Cities Shift group differs from the Californian group. The answer to each of these questions points to /æ/ being lax. The logistic model comparing /æ/ to other vowels shows that California English and Northern Cities Shift treat /æ/ the same. Because it is especially favored compared to tense vowels, we can interpret the model as indicating that there is a phonotactic restriction on tense vowels in the /Vsk, Vsp/ environments. In the case of California English speakers, both the binomial tests and logistic regression model point to California English having a

restriction against tense vowels in /Vsk, Vsp/ environments as well. The only conditions in which California English participants choose one vowel significantly more than chance are ones which contrast lax vowels with tense vowels, and the intercept in the regression model comparing attested and unattested vowels points to attested vowels being favored regardless of other factors; that is, the attested vowels form a phonological class. The restriction in phonotactic distribution is grammaticalized, then, in a dialect with a more standard /æ/ system. We may reasonably claim that California English speakers have some constraint with the effect of *[+tense]sC_[-coronal]# in the experiment environments.

Because Northern Cities Shift speakers do not substantially differ from California English speakers in treatment of /æ/, the results also indicate that Northern Cities Shift /æ/ is phonologically lax, regardless of its phonetic characteristics. In the case of the binomial tests, participants chose the attested vowel in three of four conditions comparing a lax vowel to a tense vowel, including both conditions comparing /æ/ to a tense vowel. At the same time, they made no significant choice in three of four conditions in which a pair of vowels of the same tenseness were compared. This suggests that there is a phonotactic restriction on tense vowels appearing in the experiment environments.

Furthermore, the two conditions that are inconsistent with a tense/lax based phonotactic restriction both involve /ɪ/—it appears there is something more systematic going on. This is supported by the logistic model comparing attested vowels to unattested vowels. While the intercept indicates that the Northern Cities Shift speakers favor attested vowels regardless of other factors, the interaction points to /ɪ/ being disfavored among the vowels in its phonologically active class. /æ/ is, however, a member of that class, making it phonologically lax. In other words, because Northern Cities Shift speakers treat tense vowels as a systematic gap and at the same time treat /æ/ as a member of a phonological class including other lax vowels, we may conclude that the vowel is lax for those speakers. As in the case of California English, the experiment suggests that Northern Cities Shift speakers have some constraint with the effect of *[+tense]sC_[-coronal]# in their grammar. At the same time, there is no evidence of a weakened restriction on tense vowels that would permit /æ/ to be tense.

This result serves to answer the narrow research question set at the beginning of this paper: is tense /æ/ phonologically tense? It also serves, however, to support a phonologically-driven view of phonologically active classes. It appears Northern Cities Shift participants generalized their phonological classes referred to by the phonotactic grammar from attested lexical items, rather than from phonetic characteristics. That is, being long and a diphthong does not make /æ/ inherently tense, even though the other long vowels and diphthongs are tense. Instead, being attested in positions in which only lax vowels appear makes /æ/ lax.

The systematic dispreference of [+high] vowels is an unexpected result worthy of comment. This appears to be a novel restriction developing in the Northern Cities Shift phonology. Both California English and Northern Cities Shift participants disfavor high vowels, although the California English aversion does not play a large role. While the effect exists for California English speakers, it is not strong enough to affect the main tenseness restriction seen in the binomial tests. In other words, high tense/lax vowels are worse than non-high tense/lax vowels (/bɛsp/ is better than /bɪsp/; /bɛsp/ is better than /bɪsp/), but tense vowels are always worse than lax vowels regardless of height (/bɪsp/ is better than /bɛsp/). The Northern Cities Shift height restriction appears to have become phonologically active, as seen in the favoring of /æ/ over /ɪ/ and lack of favoring of /ɪ/ over /e/. This is rather surprising: if Northern Cities Shift /æ/ is in the lax class, there is apparently little reason for the phonology to change, and it is unclear why it would change in this particular way.

6 Conclusion

This paper investigates whether the tensed /æ/ described in sociolinguistic literature as in use by Northern Cities Shift speakers has been phonologized by Northern Cities Shift speakers as a tense or lax vowel. In doing so, I make use of the fact that the tense and lax vowel classes in English are phonologically active classes, particularly in phonotactic distribution. Thus, a forced-choice task designed to look for evidence of phonotactic restrictions in lax-only environments sheds light on the class /æ/ falls into. As this paper illustrates, the vowel is in a phonologically active class with /ɛ,ɪ/ for both Californians, who have a nasal system, and Northern Cities Shift speakers. That is, both groups grammaticalize the phonotactic restriction seen in the distribution of tense and lax vowels.

It is worth pointing out that it would be more accurate to characterize this experiment as indicating that Northern Cities Shift /æ/ behaves as lax *in lax-only environments*. That is, where it is attested as phonotactically licit, it is. While we may hypothesize that this may be generalized to tense-only

environments (with /æ/ phonotactically illicit in these cases), it is not necessarily the case that this will happen. This generalization, along with the apparent development of a height restriction for Northern Cities Shift speakers, is worth exploring further.

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