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A Quantitative Study of Philadelphia /æ/-tensing

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ABSTRACT

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The study aims to provide acoustic evidence of Philadelphia /æ/-tensing based on the data collected in fast colloquial speech from 13 native speakers of English residing in Philadelphia. Specifically, the study compares word pairs that contain tense [æ̟] in a closed syllable and non-tense [æ] in an open syllable before a nasal and a voiceless fricative consonant (e.g., *pl*a̲*nt* vs. *pl*a̲*net*, *p*a̲*ss* vs. *p*a̲*ssive*) to investigate /æ/-tensing in terms of the F1, F2, and duration dimensions in fast colloquial speech. The results show that the properties of the conditioning coda consonant (i.e., nasal stops vs. voiceless fricatives) have a great impact on the realizations of /æ/-tensing; tense [æ̟] in the pre-nasal words was significantly different from non-tense [æ] mainly in F1, while tense [æ̟] in the pre-oral words was significantly different from non-tense [æ] only in vowel duration. Thus, the results indicate that the realizations of /æ/-tensing in Philadelphia are not manifested in a uniform way across the acoustic measures of F1, F2, and vowel duration. Moreover, pre-nasal words were significantly different from pre-oral words in terms of the F1 and F2 dimensions but not the vowel duration measure. The results also show that /æ/-tensing varied according to the lexical items investigated. Further, participants' age affected /æ/-tensing in that older people tended to have lower F2 but show a greater F2 difference between tense [æ̟] and non-tense [æ] than younger people, which seems to suggest that F2 is more closely related to a social factor of age.

KEYWORDS

Philadelphia /æ/-tensing, conditioning coda consonants (nasals vs. voiceless fricatives), acoustic dimensions (F1, F2, vowel duration), lexical variation, age effect

1. Introduction

Speakers of North American English, in particular, the Mid-Atlantic area of the United States tend to show variation in producing a low front non-tense vowel /æ/ due to its less quantal nature whereby speakers' articulation of /æ/ is not likely to reach the target /æ/ uniformly and perfectly whenever they produce it (Lindblom 1983). By contrast, more quantal vowels such as /i/, /u/, and /ɑ/ are likely to be insensitive to such articulatory changes (Stevens 1989). Consequently, it is not uncommon that the realization of /æ/ shows much variation. Diachronically, the variation of /æ/ in Old English with a low back vowel /a/ was witnessed in Middle English (e.g., *glæd>glad*) and Middle English /a/ again alternated with /æ/ in Early Modern English (Algeo 2010). Synchronically, much variation in producing /æ/ has been reported in the Mid-Atlantic regions of Delaware, New Jersey, New York, and Pennsylvania in the U. S. Specifically, a low front non-tense vowel /æ/ shows an alternation with tense [æ̞] in closed syllables in the Mid-Atlantic area of the U. S. (Labov 1989, Labov et al. 2006).

The occurrence of /æ/-tensing, however, diverges depending on dialects. According to Nie (2017), /æ/-tensing occurs in all closed syllables in Belfast except syllables closed with voiceless stops (e.g., *pal, pan, jazz, mass, cab*). In New York City the occurrence of /æ/-tensing is restricted to syllables closed with anterior nasals, voiced stops, and voiceless fricatives (e.g., *pan, cab, mass*) while in Philadelphia it is restricted to syllables closed with anterior nasals and voiceless fricatives (e.g., *pan, mass, calf*).

Tense [æ̞] has been generally described as being produced with tongue raised, fronted, and diphthongized relative to non-tense [æ] (Labov 1989 among others). The nature of tense [æ̞] in closed syllables, however, is not without controversy. That is, while most scholars agree that tense [æ̞] is produced with tongue higher than non-tense [æ], other differences such as tongue position and vowel length between tense [æ̞] and non-tense [æ] are not clear (Benua 1997: 181). For example, De Decker and Nycz (2012) reported in their ultrasound study that the degree of /æ/-tensing varies among their participants. Specifically, nasal codas (e.g., *pan*) tend to trigger higher and more advanced tongue position than obstruent codas do (e.g., *pad, pat, pass*), which shows the more stability of nasal codas than obstruent codas. However, this pattern shows individual variation; pre-nasal [æ̞] did not always exhibit higher and fronter tongue position than pre-obstruent [æ̞]. Labov et al. (2006) also reported lexical variation concerning the degree of /æ/-tensing in pre-nasal position. Further, while many scholars describe tense [æ̞] as diphthongized, Morén (1997) describes tense [æ̞] as shorter than its non-tense counterpart, claiming that the tense/non-tense differences are due to phonological length differences.

This suggests that /æ/-tensing may not be manifested uniformly in terms of the target vowel's tongue height (first formant frequency, F1), tongue position (second formant frequency, F2), or duration depending on the following conditioning coda consonants, lexical items, and speakers. However, not many studies have investigated whether the conditioning coda consonants, anterior nasals (/n/ and m) and voiceless fricatives (/s/ and /f/), affect /æ/-tensing differently in terms of the acoustic dimensions. Importantly, not many studies have looked at /æ/-tensing using pairs of words that contain tense [æ̞] in a closed syllable and non-tense [æ] in an open syllable (e.g., *man* vs. *manage*, *class* vs. *classic*), which can provide more robust contexts for /æ/-tensing vs. no /æ/-tensing. Thus, the present study aims to provide acoustic evidence of Philadelphia /æ/-tensing for adult speakers' fast colloquial speech collected from native speakers of English in Philadelphia taking into account the effects of conditioning coda consonants, and lexical and speaker variation. This study focuses on fast colloquial speech because there might be some differences in /æ/-tensing between articulated speech produced in laboratory settings and fast colloquial speech.

2. Previous Studies

Previous studies on /æ/-tensing have somewhat mixed results concerning the characterization of tense [æ̣]. For instance, Nie (2017: 181) considers tense [æ̣] being longer, tensed, raised, and diphthongal compared to low front non-tense [æ], involving tongue root advancement and/or tongue body raising. Benua (1995: 9) also describes tense [æ̣] as a diphthong that starts with a front vowel higher than non-tense [æ] and ends in a centralized glide when it occurs in closed syllables. Specifically, tense [æ̣] occurs only in tautosyllabic contexts so that words such as *m**a**n* and *m**a**ss* undergo /æ/-tensing whereas words such as *m**a**nage* and *M**a**ssachusetts* do not. Labov et al. (2016: 275) differentiate tense [æ̣] from non-tense [æ] as follows; while non-tense [æ] is short and low front non-peripheral, tense [æ̣] undergoes fronting, lengthening, raising, and ingliding. Labov et al. further claim that the occurrence of /æ/-tensing is more stable in a pre-nasal context than a pre-oral context based on two databases, IHELP(The project on the Impact of Higher Education on Local Phonology) whose data were collected from interviews with Philadelphia college students and their friends and families from 2012 to 2014 and PNC (The Philadelphia Neighborhood Corpus).

Nie (2017) accounts for the stability of tense [æ̣] in a pre-nasal context by adopting a phonetic enhancement approach. That is, nasal sounds are made by lowering the velum and the velum must lower further to produce the target low vowel in the pre-nasal context, which is accomplished by raising the tongue body when producing the target vowel to facilitate nasal articulation. De Decker and Nycz (2012) conducted acoustic and articulatory analyses of tense [æ̣] based on the four New Jerseyans' data collected in the Phonetics/Phonology Laboratory at New York University. The results of the acoustic analyses show that tense [æ̣] in pre-nasal position is realized with tongue higher and frontier than tense [æ̣] in pre-oral position. In the articulatory analyses using ultrasound, however, variations are attested among the speakers. In particular, one speaker's data show that tense [æ̣] in pre-nasal contexts does not have more advanced tongue position contours than tense [æ̣] in pre-oral contexts and the contours of tense [æ̣] in pre-nasal contexts hardly indicate a higher tongue body than the contours in pre-oral contexts. Although the authors did an articulatory analysis using ultrasound coupled with an acoustic analysis of /æ/-tensing, the number of the participants in De Decker and Nycz' study was only four and the participants produced the target /æ/ embedded in 4 stimulus words (*pan, pad, pat, pass*) in a laboratory environment. They also focused on F1 and F2 frequencies without looking at vowel duration.

Moreover, several studies have reported that the magnitude of /æ/-tensing varies even across words in pre-nasal position. For example, Labov et al. (2006: 175) showed that the degree of the target vowel's tongue body raising (i.e., F1) in pre-nasal contexts varies with words; tense [æ̣] in *pants* is produced with tongue higher than the vowel in *can't,* which is in turn produced with tongue higher than the vowel in *pan*. Likewise, F1 and/or F2 differences in pre-nasal contexts (e.g., *ham, aunt, can, can't, began, ambulance, damn*) spoken by one speaker in the New York City dialect are attested in Labov (2007: 358). Specifically, tense [æ̣] in *h**a**m* is produced with the tongue lowest but most fronted whereas tense [æ̣]s in *d**a**mn* and *beg**a**n* are produced with tongue much higher but not fronter than the vowel in *h**a**m*. Tense [æ̣]s in ***a**mbulance* and *c**a**n't* are among the highest vowels but least fronted in terms of tongue height and tongue position. The tongue height of tense [æ̣] in ***a**unt* and *c**a**n* (noun) is lower than that in *d**a**mn* and *beg**a**n*.

Labov (2001) reported that F2 (i.e., advanced tongue position) is most sensitive to social variables based on the PNC database (data from 112 speakers) and that /æ/-tensing is more salient in pre-nasal contexts than pre-/s/ contexts. He further noted that the younger the speakers are, the higher the mean values of F2 (p. 143). For instance, the mean F2 value of the speakers under 20 years old is about 2400 Hz while that of the speakers over 50 years old is about 2250 Hz for the words with tense [æ̣] in pre-nasal contexts. For the words with tense [æ̣] in pre-/s/

contexts, the mean F2 value of the speakers under 20 years old is about 2250 Hz while that of the speakers over 50 years old is about 2100 Hz. Thus, tense [æ̣] produced by the younger speakers shows fronter tongue position than tense [æ̣] produced by the older speakers.

Additionally, Morén (1997) describes tense [æ̣] as being shorter than its non-tense variant. He ascribes tense/non-tense differences to phonological length differences. That is, the underlying length of the low front vowel that undergoes /æ/-tensing has one mora, while the vowel that does not undergo /æ/-tensing has two moras (p. 54). For example, according to him, the short vowel before a nasal in *man* is realized as [mæ̣n], whereas the long vowel before a voiceless stop in *cat* is realized as [kæ:t] without /æ/-tensing. Thus, Morén's description of tense [æ̣] is in conflict with the description of other previous studies.

Given the somewhat mixed results of the previous studies on /æ/-tensing, the present study investigates /æ/-tensing to enhance our understanding of the nature of tense [æ̣]. The study focuses on /æ/-tensing in Philadelphia whose occurrence is restricted to before anterior nasals and voiceless fricatives. Specifically, the study explores the following research questions by conducting acoustic analyses of /æ/-tensing data collected in fast colloquial speech from native speakers of English residing in Philadelphia: 1) whether /æ/-tensing is differently manifested in terms of the F1, F2, and duration dimensions in fast colloquial speech according to the following conditioning coda consonants (i.e., nasal stops vs. voiceless fricatives). Related to this question, whether /æ/-tensing shows more stability in pre-nasal words than in pre-oral words; 2) whether /æ/-tensing shows lexical variation; 3) whether the realization of /æ/-tensing varies according to participants' age.

3. Method

3.1 Participants

Thirteen native speakers of English from Philadelphia participated in the experiment (8 females and 5 males). They were born and raised in Philadelphia with some were away from their hometown during college years. One participant was born in New York but was recruited for the experiment because she lived in Philadelphia for more than 6 years and because New York City shows /æ/-tensing. The participants ranged in age from 17 to 74 and their mean age was 35. They were paid $5 for their participation.

3.2 Stimulus Words

The stimuli consisted of 20 target words divided into two classes depending on the consonant following the low front vowel /æ/; /æ/ in a pre-nasal context (i.e., before nasals /n/ and /m/) and /æ/ in a pre-oral context (i.e., before voiceless fricatives /s/ and /f/). The stimuli occurred in the pre-nasal and pre-oral contexts because previous studies have documented that nasals are stronger triggers of /æ/-tensing relative to voiceless fricatives (Decker and Nycz 2012, Labov et al. 2016). The present study used several pairs of words that contain tense [æ̣] in a closed syllable and non-tense [æ] in an open syllable to compare /æ/-tensing vs. no /æ/-tensing in a straightforward way. Importantly, /æ/ in (1a) and (2a) is 'exclusively tautosyllabic' with the following coda consonant, which typically conditions /æ/-tensing. By contrast, /æ/ in (1b) and (2b) is 'not exclusively tautosyllabic' with the following consonant, which does not condition /æ/-tensing. /æ/ in (3a) is also closed with voiceless fricative /f/ which triggers /æ/-tensing unlike its voiced counterpart in (3b) (Kahn 1976, Labov 1981, Dunlap 1987, Benua 1995, Decker and Nycz 2012). Eleven filler words that do not condition /æ/-tensing in the dialects spoken in Philadelphia (e.g., *tap,*

tag, etc.) were also presented along with the target words:

(1) Pre-nasal context (/n/, /m/)
  a. /æ/-tensing:
    man jam plant candid
  b. No /æ/-tensing:
    manage janitor planet cannibal
(2) Pre-oral context (voiceless /s/)
  a. /æ/-tensing:
    class mass pass master
  b. No /æ/-tensing:
    classic massive passive Massachusetts
(3) Pre-oral context (voiceless /f/)
  a. /æ/-tensing: calf half
  b. No /æ/-tensing: calve have

3.3 Procedure

The participants produced the target words in the structure of "Say _____ again" three times. They were requested to read the sentences with the target words embedded in fast colloquial speech as if they were talking to their friends or family members. The recordings of vowel productions were done using an IPhone and the recordings were saved as mp3 files and converted to wave files using Zamzar at a laptop computer for acoustic analyses. The recordings were done in a slightly sound-attenuated room (but not a soundproof booth) in Philadelphia to create a somewhat causal speech environment.

4. Results

The program Praat (Boersma and Weenink 2015) was used for acoustic analyses; the first and second formants of each vowel token were measured at the midpoint of the vowel and the duration of each vowel token was measured excluding consonant transitions (Watson and Harrington 1999). A research assistant with phonetic training first did acoustic analyses of the data and then the authors examined all the data again. The inter-rater reliability was .92. The mean values of F1, F2, and duration of the target items are provided in Table 1.

Table 1. Acoustic Measurement Results

		F1	F2	Duration
pre-nasal context	tense [æ̰]	694	2087	0.155
	non-tense [æ]	810	1954	0.128
pre-oral context	tense [æ̰]	836	1880	0.148
	non-tense [æ]	856	1829	0.139

To determine whether each pair of the words provided in (1), (2), and (3) exhibits significant differences in F1, F2, and vowel duration, paired *t*-tests were performed using R (6.3.1, R Core Team 2019). The results are provided

in Table 2. Tense [æ̰] in the pre-nasal context showed significant differences mainly in F1, whereas tense [æ̰] in the pre-oral context exclusively in vowel duration, which is somewhat different from the findings of the previous studies. The results thus showed that the realizations of /æ/-tensing are not manifested uniformly across the acoustic dimensions of F1, F2, and vowel duration. Rather, the properties of the conditioning coda consonant (i.e., nasal vs. voiceless fricative) much affect the realizations of /æ/-tensing. When the word pairs are further considered, only the word pair *man* and *manage* were significantly different from each other in terms of the three acoustic measures ($p < .05$ or $p < .001$). The word pair *candid* and *cannibal* showed significant differences in F1 and F2 while the pair *plant* and *planet* in F1 and duration (all $p < .05$ or $p < .001$). Further, *calf* and *half* also exhibit /æ/-tensing in that the target vowel's duration is comparable to that of tense [æ̰] in words such as *master* and *plant.* But note that the vowel in *calve* and *have* is lengthened before a voiced obstruent in English (Ladefoged 2006) so that the vowel duration in these words is much longer than that of *calf* and *half.* Also, F2 differences between *calf* and *calve* and *half* and *have* are marginally significant ($p = .056$, $p = .098$, respectively), which indicates that *calf* and *half* tend to be produced in fronter position of the vowel space than *calve* and *have*, respectively. The overall results thus showed that /æ/-tensing occurs when the target vowel and the following coda consonant are exclusively tautosyllabic, as documented by previous studies (Benua 1995, Decker and Nycz 2012, Dunlap 1987, Kahn 1976, Labov 1981).

Table 2. Results of Paired *t*-tests

	F1			F2			duration		
	t	df	*p*	*t*	df	*p*	*t*	df	*p*
a. Pre-nasal									
man vs. manage	-2.028	73.837	0.046	2.606	73.485	0.011	5.509	55.617	0.000
jam vs. janitor	-3.223	73.189	0.002	1.881	71.740	0.064	1.420	50.361	0.162
plant vs. planet	2.156	71.702	0.034	-1.526	76.000	0.131	-3.590	63.462	0.001
candid vs. cannibal	-4.412	69.589	0.000	6.411	70.034	0.000	0.172	42.023	0.864
b. Pre-oral									
class vs. classic	-1.441	69.142	0.154	1.858	75.709	0.067	7.002	72.601	0.000
mass vs. massive	-0.381	75.729	0.705	0.439	74.423	0.662	4.765	59.527	0.000
pass vs. passive	-1.308	73.304	0.195	1.367	74.175	0.176	6.730	64.701	0.000
master vs. Massachusetts	0.434	73.943	0.665	-1.366	72.328	0.176	-7.250	74.683	0.000
calf vs. calve	0.215	73.119	0.831	1.943	71.935	0.056	-5.245	71.434	0.000
half vs. have	0.747	67.402	0.458	1.676	73.853	0.098	-5.718	63.271	0.000

Figure 1 shows the distribution of tense [æ̰] and non-tense [æ] for the 13 participants along the F1 and F2 measures and Figure 2 shows vowel durations for the two classes of the target words (i.e., /æ/-tensing words vs. no /æ/-tensing words). For pre-nasal tokens, a clear division is observed for the two classes (i.e., tense [æ̰] vs. non-tense [æ]) along the F1 and F2 dimensions; the [æ̰] of the pre-nasal tokens occupies significantly higher and fronter position of the vowel space than non-tense [æ]. Tense [æ̰] of the pre-oral tokens (i.e., tense [æ̰] before /s/ and /f/), however, tends to occupy only a slightly higher and/or fronter position of the vowel space than non-tense [æ]. Further, the difference in vowel duration between /æ/-tensing words and no /æ/-tensing words is more obvious for pre-oral tokens.

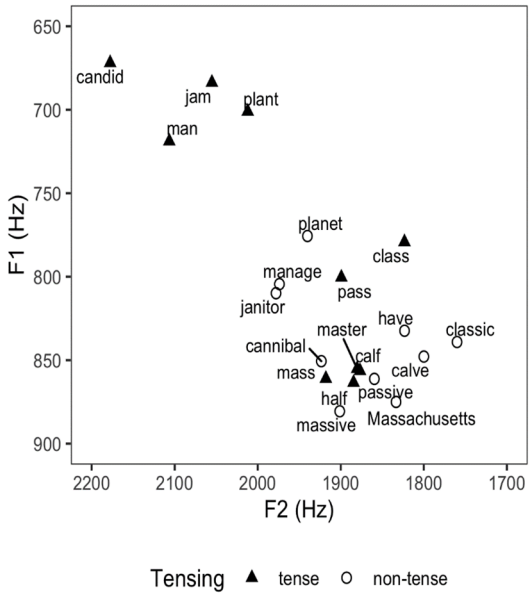

Figure 1. Distribution of Tense [æ̣] and Non-tense [æ] along the F1 and F2 Measures

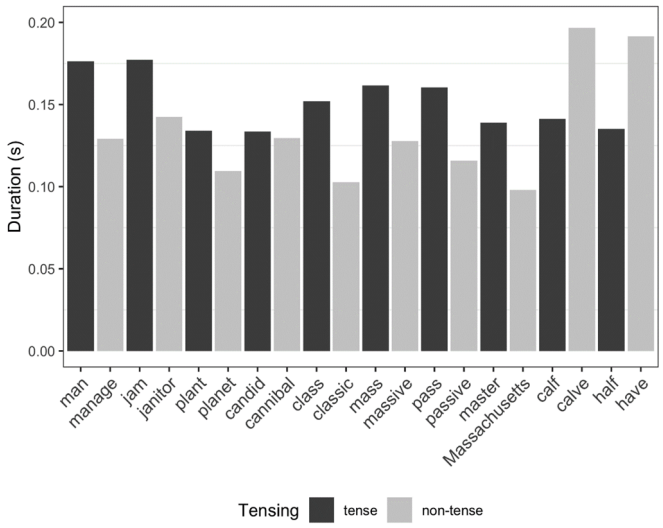

Figure 2. Vowel Durations of Tense [æ̣] and Non-tense [æ]

As discussed earlier, /æ/-tensing tends to occur more saliently in a pre-nasal context than a pre-oral context (Decker and Nycz 2012, Labov 2001). The results from the present study also indicate that there is a clear division between pre-nasal tokens and pre-oral tokens in terms of the acoustic realizations of /æ/-tensing. We thus analyzed /æ/-tensing words with respect to the pre-nasal vs. pre-oral contexts and paired samples *t*-tests showed that pre-nasal tokens were significantly different from pre-oral tokens along the F1 and F2 measures but not the duration dimension, as shown in Table 3 and Figures 3 and 4. That is, the plot in Figure 3 shows that the [æ̣] of pre-nasal tokens appears in significantly higher and fronter position in the vowel space than the [æ̣] of pre-oral tokens, while Figure 4 shows that pre-nasal tokens are not clearly separated from pre-oral tokens in vowel duration. Thus, the

results show that the more stability of /æ/-tensing in pre-nasal contexts than in pre-oral contexts is manifested only in terms of the F1 and F2 dimensions.

Table 3. Results of Paired *t*-tests of Pre-nasal vs. Pre-oral Tokens

	t	df	*p*
F1	-7.964	378.490	0.000
F2	11.495	271.870	0.000
duration	1.559	260.060	0.120

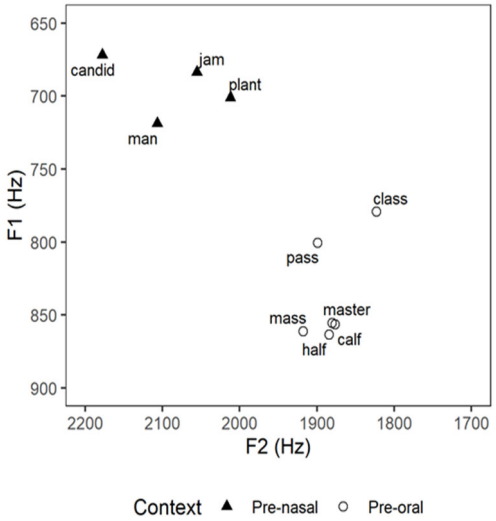

Figure 3. Distribution of Pre-nasal and Pre-oral Tokens along the F1 and F2 Measures

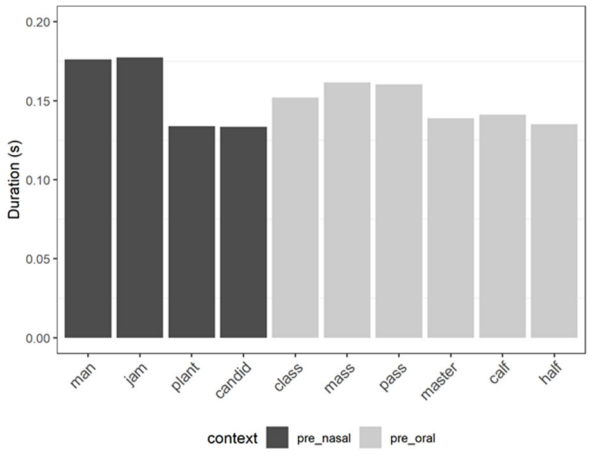

Figure 4. Vowel Durations of Pre-nasal and Pre-oral Tokens

The results presented above, however, indicate that there were variations in terms of the acoustic measures (F1, F2, and duration) among the words which show /æ/-tensing. Thus, one-way ANOVAs were performed to

determine whether Word was a significant factor of F1, F2, and duration for these tokens. Statistical results showed that Word was a significant factor of F1, F2, and duration as shown in Table 4 (all $p < .001$).

Table 4. One-way ANOVA Results on the Effect of Word on F1, F2, and Duration

	Df	Sum Sq	Mean Sq	*F*	*p*	
F1	9	2179629	242181.000	7.411	0.000	***
F2	9	4767541	529727.000	20.590	0.000	***
Duration	9	0.1018	0.011	7.441	0.000	***

Since the effect of word was significant for all three measures, pairwise t-tests with Bonferroni correction were performed to identify significant differences in F1, F2, and duration among the target words and the results are given in Tables 5, 6, and 7. As can be seen, there is a two-way split between pre-nasal tokens and pre-oral tokens along the F1 dimension and the same pattern was observed along the F2 dimension with some exceptions (*man* vs. *candid*, *plant* vs. *mass*, *plant* vs. *pass*). As for vowel duration, the length of *man* and *jam* was significantly longer than that of several words. Accordingly, the results showed that the magnitude of /æ/-tensing is not uniform across the pairs of words investigated.

Table 5. Results of Pairwise Comparisons of F1 (*p* values)

	man	jam	plant	candid
mass	0.026	0.001	0.005	0.000
master	0.046	0.002	0.010	0.001
calf	0.039	0.001	0.008	0.000
half	0.021	0.001	0.004	0.000

Table 6. Results of Pairwise Comparisons of F2 (*p* values)

	man	jam	plant	candid
candid	1.000	0.040	0.000	-
class	0.000	0.000	0.000	0.000
mass	0.000	0.008	0.449	0.000
pass	0.000	0.001	0.093	0.000
master	0.000	0.000	0.016	0.000
calf	0.000	0.000	0.010	0.000
half	0.000	0.000	0.023	0.000

Table 7. Results of Pairwise Comparisons of Duration (*p* values)

	man	jam
plant	0.000	0.000
candid	0.000	0.000
master	0.002	0.001
calf	0.004	0.002
half	0.000	0.000

Further, the participants' age of the present study ranged from 17 to 74 and thus linear mixed-effect regression models analyses were performed to determine whether the effects of /æ/-tensing on F1, F2, and duration differed depending on the participants' age. Fixed effects were Tensing (treatment-coded with non-tense [æ] vowels as the reference level) and participants' Age, and Word pairs were included in the model as a random intercept. The results are summarized in Table 8. The results show that tense [æ̞] had lower F1, higher F2, and longer duration measures than non-tense [æ]. The significant effect of age on F2 indicates that older people tended to have lower F2 than younger people. The significant interaction between tensing and age on F2 shows that older people tended to have a greater F2 difference between tense [æ̞] and non-tense [æ] compared to younger people. Figure 5 visualizes the effect of age on F2 of tense [æ̞] and non-tense [æ] vowels.

Table 8. Results of Linear Mixed-effect Regression Models with Tensing and Age as Fixed Effects and Word Pairs as a Random Intercept

		Estimate	SE	df	*t*	*p*	
F1	(Intercept)	908.138	98.392	11.851	9.230	0.000	***
	non-tense vs. tense	-73.304	14.427	715.166	-5.081	0.000	***
	Age	-1.839	2.411	11.137	-0.763	0.462	
	non-tense vs. tense : Age	0.211	0.359	713.935	0.587	0.557	
F2	(Intercept)	2066.055	60.086	17.746	34.385	0.000	***
	non-tense vs. tense	43.720	17.833	714.725	2.452	0.015	*
	Age	-5.387	1.309	11.737	-4.114	0.002	**
	non-tense vs. tense : Age	1.158	0.443	714.014	2.612	0.009	**
duration	(Intercept)	0.127	0.017	14.760	7.670	0.000	***
	non-tense vs. tense	0.021	0.008	717.700	2.684	0.007	**
	Age	0.000	0.000	12.700	-0.030	0.976	
	non-tense vs. tense : Age	0.000	0.000	714.200	0.502	0.616	

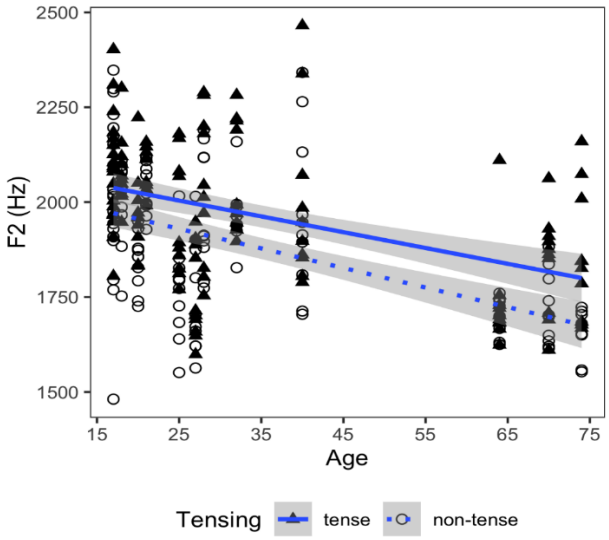

Figure 5. The Effects of Age on F2 of Tense [æ̞] and Non-tense [æ] Vowels

5. Discussion and Conclusion

The study explored /æ/-tensing in Philadelphia based on the data collected in fast colloquial speech from 13 native speakers of English residing in Philadelphia. The data collected were acoustically analyzed in terms of F1, F2, and vowel duration dimensions. Concerning the first research question, the results from the study reveal that the properties of the conditioning coda consonant (i.e., nasal stops vs. voiceless fricatives) affects the realizations of /æ/-tensing to a great extent; tense [æ̰] in the pre-nasal words was significantly different from non-tense [æ] mainly in F1, while tense [æ̰] in the pre-oral words was significantly different from non-tense [æ] only in vowel duration. The results are somewhat different from the findings of the previous studies in that tense [æ̰] has been generally described as being produced with tongue raised, fronted, and diphthongized compared to non-tense [æ] (Labov 1989, Labov et al. 2006 among others). Therefore, the results indicate that the realizations of /æ/-tensing in Philadelphia are not manifested in a uniform way across the acoustic measures of F1, F2, and vowel duration. One question regards why pre-nasal words prefer lower F1 (i.e., higher tongue height) than pre-oral words. It seems to be related to the fact that tense [æ̰] before nasals may sound differently from tense [æ̰] before oral consonants due to co-articulatory effects of nasality. It is well-known that the effects of co-articulatory nasality have the primary impact on the F1 (Wright 1975, Beddor 1982, Chen 1997). The movement of the velum that results in vowel nasalization changes vowel height, which results in the lowering of F1 in the vowel spectrum acoustically. Thus, the effects of co-articulatory nasality seem to make a difference between pre-nasal words and pre-oral words.

Moreover, when we analyzed /æ/-tensing in terms of pre-nasal vs. pre-oral contexts, pre-nasal words were significantly different from pre-oral words along the F1and F2 dimensions but not the duration measure. That is, the more stability of /æ/-tensing in pre-nasal words relative to pre-oral words was not manifested across the three acoustic measures investigated. The results of the study, nonetheless, corroborate the findings of previous studies concerning more stronger effects of /æ/-tensing in the pre-nasal context than the pre-oral context (De Decker and Nycz 2012, Labov 2006, 2007, Nie 2017) in that the [æ̰] of the pre-nasal words appears in significantly higher and fronter position in the vowel space than the [æ̰] of pre-oral words, even though pre-nasal words are not clearly separated from pre-oral words in vowel duration. According to Nie (2017), nasals show greater tongue advancement than fricatives and moreover nasals in the coda position trigger significant raising of the tongue body, thus facilitating /æ/-tensing. The enhancement of nasality and tongue body raising is also witnessed in vowel neutralization. Two front vowels /ɪ/ and /ɛ/ are neutralized before nasals (e.g., [pɪn] for both *pin* and *pen*) in some Southern dialects in the U. S. (Wolfram and Johnson 1982, Yavas 2005). The neutralization of /ɛ/ with /ɪ/ can also be accounted for by raising the tongue body of the vowel to facilitate nasal articulation.

As for why /æ/-tensing occurs in several dialects including Philadelphia despite different degrees of /æ/-tensing depending on the conditioning coda consonants, Nie (2017) maintained that the raising of the tongue body and the advancement of the tongue root, which leads to tensing of the previous vowel, facilitate frication and nasality in coda position. That is, the advancement of tongue root increases the size of the oral cavity and this in turn reduces supraglottal pressure and promotes air flow. Consequently, frication can be sustained relatively longer. Nasality is also enhanced by the raising of tongue body. Namely, low vowels require more lowering of the velum so that nasalization can more easily be perceived and this can be accomplished by the raising of the tongue body, thus reducing the distance that the velum must be lowered (House and Stevens 1956, Nie 2017).

The results further indicate that the magnitude of /æ/-tensing varies with lexical items; the effect of word was significant for all three acoustic measures (F1, F2, and vowel duration). As discussed earlier, there is a clear division between pre-nasal words and pre-oral words along the F1 dimension and the same trend was observed

along the F2 dimension. The duration of vowel in *man* and *jam* was significantly longer than that of several words compared. Previous studies have also documented lexical variation for /æ/-tensing. For example, Labov (2006, 2007) and De Decker and Nycz (2012) noticed that /æ/-tensing shows variation among speakers and words. Accordingly, the results of the present study are in line with the findings of previous studies.

The present study also found that the effects of /æ/ tensing on F1, F2, and duration varied according to the participants' age. More specifically, the results of the linear mixed-effect regression models analyses showed that older people tended to have lower F2 than younger people, which supports the findings of Labov (2001); he showed that younger people produced tense [æ̟] in fronter position in the vowel space than did older people. The present study further found that older people tended to have a greater F2 difference between tense [æ̟] and non-tense [æ] compared to younger people, which seems to suggest that F2 plays a more important role in the distinction between tense [æ̟] and non-tense [æ] for older people. The variability of F2 may be due to the fact that it is more closely connected to a social factor of age.

The present study adds a fragment to previous studies of /æ/-tensing by providing some acoustic evidence for the phenomenon in fast colloquial speech with an experimental design unlike previous studies which examined /æ/-tensing mostly in a laboratory setting or in databases. More specifically, the present study examined several pairs of words such as *plant* vs. *planet*, *man* vs. *manage*, *pass* vs. *passive, class* vs. *classic* so that we can more directly compare /æ/-tensing in a closed syllable (i.e., the target vowel is 'exclusively tautosyllabic' with the following coda consonant) with no /æ/-tensing in an open syllable (i.e., the target vowel is 'not exclusively tautosyllabic' with the following coda consonant) (Benua 1995, Kahn 1976). Importantly, the study found that /æ/-tensing is not manifested uniformly across the three acoustic measures of F1, F2, and vowel duration. Rather the properties of the conditioning coda consonant (i.e., nasal stops vs. voiceless fricatives) have a great impact on Philadelphia /æ/-tensing, and lexical variation and participants' age also play a role in /æ/-tensing. The study has some limitations, however, in that the number of participants was rather small and future study thus needs to explore /æ/-tensing with more diverse populations to deepen our understanding of Philadelphia /æ/-tensing.

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Examples in: English
Applicable Languages: English
Applicable Level: Advanced

