WHAT'S REALLY HAPPENING TO SHORT-*A* BEFORE *L* IN PHILADELPHIA?

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ABSTRACT: The phonemic split of short-*a* into low, lax /æ/ and raised, tense /æh/ is one of the distinctive phonological features of the Philadelphia dialect. Studies over the past 25 years have argued that /æ/ is in the process of being replaced by /æh/ in words in which it appears before /l/, such as *alley* and *personality*, via a process of lexical diffusion. However, this article argues that the foregoing is a misinterpretation of the changes affecting /æ/ before /l/. A quantitative analysis of phonetic data in the Philadelphia Neighborhood Corpus, containing sociolinguistic interviews covering 40 years in real time and 100 years in apparent time, shows that /æ/ before /l/ is better described as having merged with /aw/; the raising of /aw/ toward the phonetic vicinity of /æh/ then creates the illusion that /æ/ is being replaced by /æh/ in these words. This can be taken as evidence against the proposition that lexical diffusion is a common mechanism by which regular sound changes go to completion, since a regular sound change that was thought to be an example of lexical diffusion is shown not to be.

THE distinctive phonemic split in /æ/ in the Philadelphia dialect is a frequent topic of research into language variation and change. First described in detail by Ferguson (1972), the Philadelphia short-*a* system has been a focus of studies on such topics as dialect geography (Ash 2002), child language acquisition (Payne 1980; Brody 2009), lexical phonology (Kiparsky 1995), the relationship between the individual and the speech community (Labov 1989), and the social evaluation of local features (e.g., Labov 2001; Prichard and Tamminga 2011) among many others. In this article, we focus on a change reportedly affecting this system regarding short-*a* before /l/, as in *pal*, and argue that short-*a* in this environment is undergoing a merger with /aw/ as in *Powell*.

The Philadelphia short-*a* system is typically described as a split of the reflex of the Middle English short /a/ phoneme into a so-called lax phoneme /æ/, roughly corresponding to the Wells (1982) lexical set TRAP, and a so-called tense phoneme symbolized here as /æh/ (following the notation of Labov 1994, among others), roughly corresponding to the lexical set BATH and phonetically generally a raised, ingliding diphthong in the neighborhood

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of [eə]. A host of phonological and morphophonological regularities, subregularities, and sub-subregularities in most cases can predict the incidence of /æ/ or /æh/ in any given word. However, it is still necessary to regard /æ/ and /æh/ as separate phonemes because in some words these regular principles predict the wrong version of short-*a* and at least one minimal pair is distinguished by the /æ/~/æh/ contrast (namely the noun *can*, containing /æh/, and the stressed pronunciation of the auxiliary *can*, containing /æ/). Following Ferguson (1972) and Labov (1994), the classic description of the conditioning environments for /æ/ and /æh/ is as follows:

1. /æh/ occurs before syllable-coda /f/, /θ/, /s/, /m/, and /n/: *laugh*, *path*, *class*, *ham*, *man*.
2. /æ/ occurs before all other coda consonants and any onset consonants: *flat*, *bang*, *jazz*, *mash*; *taffy*, *placid*, *hammer*, *manage*.
3. Consonants preceding inflectional suffixes and other stem-level affixes, such as *-er*, are not considered to be syllable onsets under the preceding rules: /æh/ in *passing*, *passes*, *manning*, but /æ/ in *passive*, *manage*.
4. Similarly, truncations of /æ/ words retain /æ/ regardless of syllable structure: /æ/ in *math*, *exam*.
5. Function words that can be reduced to schwa contain /æ/, not /æh/: *and*, *am*, *has*, *had*, auxiliary *can* (but /æh/ in *can't*).
6. Ablaut past tenses use /æ/, not /æh/: *ran*, *swam*, *began*.
7. Rare and late-learned words use /æ/: *asp*, *daft*, *gaffe*, etc.
8. *Mad*, *bad*, and *glad* (but not *sad*) are lexical exceptions to these rules, using /æh/.

Since the original description in Ferguson (1972), however, a number of studies (Labov 1989, 1994; Roberts and Labov 1995; Banuazizi and Lipson 1998; Brody 2009) have reported changes in progress to this system and added two environments to the set of conditioning environments for /æh/: following intervocalic nasals and following /l/. Thus, for example, *planet* and *pal* are beginning to contain /æh/, instead of /æ/ as predicted by Ferguson's outline. These changes are frequently described as taking place through lexical diffusion—that is, the process of phonological change that, as Wang and Cheng (1977) describe it, is "lexically gradual," not affecting all eligible words simultaneously, but "phonetically abrupt," moving words discretely from one phonemic category to another. Thus, words containing /æ/ before /l/ and intervocalic nasals are claimed to be switching directly from /æ/ to /æh/ one at a time on a word-by-word basis, rather than all such words moving together gradually across phonetic space. For example, Labov (1989) finds *planet*, *alley*, *personality*, and *nationality* to be leading the pack in switching from /æ/ to /æh/.

Roberts and Labov (1995) studied the acquisition of the Philadelphia short-*a* system among 3- and 4-year-olds in 1990 and found that the children were participating in the incrementation of these changes in progress, in that they had a higher rate of tensing before /l/ and intervocalic nasals than did the adults studied by Labov (1989) in the 1970s. However, Brody (2009), carrying out a similar study on adults and 3–5-year-old children 18 years later, found that the intervocalic-nasal and /l/ environments had substantially diverged. On one hand, the movement toward tensing before /l/ had continued to increase: according to Brody, the children interviewed in 2008 tensed before /l/ 83% of the time (as compared to 65% for the children in 1990); the adults in 2008 showed 54% tensing before /l/ (as compared to 22% for the adults in the 1970s). This constitutes both real-time and apparent-time evidence for change toward tensing before /l/. On the other hand, the behavior of the intervocalic-nasal environment was completely different: while the word *planet* in Brody's data achieved 100% tensing in both children and adults, tensing of short-*a* before intervocalic nasals in all other words had declined to 4% in children (from 39% in Roberts and Labov 1995) and remained at 0% in adults. In other words, while tensing before /l/ has continued apace, tensing before intervocalic nasals has, as Brody (2009, 19) puts it, "crystallized at one word, *planet*," and essentially disappeared in all other lexical items.

Banuazizi and Lipson (1998), studying the tensing of short-*a* before /l/ among adults in the Port Richmond neighborhood of Philadelphia, note further anomalous differences between tensing before /l/ and other short-*a* tensing environments. They point out that /l/ differs from all other tensing environments in the Philadelphia short-*a* system in that short-*a* before /l/—which we can refer to symbolically as (æl)—is no less likely to be tense if the /l/ is intervocalic than if it is syllable-final: thus *Alice* is as likely to contain /æh/ as is *Al*. The single word *planet* notwithstanding, this is not found for any other tensing-conditioning consonants. Moreover, Banuazizi and Lipson find that in their data /æh/ before /l/ actually tended (impressionistically) to sound phonetically intermediate between typical /æ/ and /æh/—although it is possible to attribute this merely to the tendency for tokens of any front vowel before /l/ to be somewhat backer and/or lower than those in other environments. Finally, although they look for lexical diffusion at work in the tensing of (æl), they find no convincing evidence of it and argue that (æl) is "probably not as subject to lexical specialization" as Labov (1989) suggested it to be.

The differences between the change in *planet* and the change in (ael) suggest the presence of different processes at work in the two changes to the Philadelphia short-*a* system. *Planet* appears to have joined *mad*, *bad*, and *glad* as merely a singular lexical exception to short-*a*'s overall phonological pattern, albeit after a period of flirtation, on the part of the children studied by Roberts and Labov (1995), with the idea of extending that status to other words as well. Although this is striking, it is not altogether unreasonable as a linguistic change. As Labov (1994, 542) reminds us, "lexical diffusion is the result of the abrupt substitution of one phoneme for another in words that contain that phoneme." Since /æ/ and /æh/ are different phonemes in Philadelphia English, it is exactly in the form of lexical diffusion that we would expect to see changes in the conditioning environments of tensing to take place; and since lexical diffusion is by its very nature a process that affects individual lexical items one at a time, it is not beyond the realm of probability that one such lexical item might get singled out for special treatment and others ultimately ignored.

From this perspective, the tensing of (æl) seems arguably even more anomalous. If /l/ is joining the set of environments that trigger tensing, then in words containing (æl), /æ/ is being abruptly replaced by /æh/. Thus, we should expect to find lexical diffusion, and although Labov (1989) claims that lexical diffusion is taking place, Banuazizi and Lipson (1998) find no evidence of it. If lexical diffusion is taking place, it is of a very different sort than what is happening before intervocalic nasals, where one lexical item was transferred to /æh/ and then the process halted; before /l/, according to Brody's (2009) data, the process seems to be going to completion as a regular sound change. Wang and Cheng (1977) characterize lexical diffusion as fully compatible with regular "Neogrammarian" sound change, though only retrospectively—regular sound change is merely the result once all words eligible for a given lexical diffusion have undergone it—but the difference in behavior between (æl) and *planet* is nonetheless striking. Moreover, Banuazizi and Lipson's finding that the result of tensing before /l/ is phonetically intermediate between canonical /æ/ and /æh/, rather than jumping directly to /æh/, is more directly incompatible with a lexical-diffusion model; this finding suggests "phonetically gradual and lexically abrupt" sound change (in Wang and Cheng's terms), which according to Labov (1994, 542) is the predicted pattern of regular Neogrammarian sound change without lexical diffusion. In addition, if /l/ is joining the set of environments that trigger tensing, it is exceptional among the set of tensing environments, the only one that does not distinguish between closed and open syllables. So, is lexical diffusion taking place, or is (æl) being raised through regular gradual sound change? And is /l/ joining the set of Philadelphia short-*a* tensing consonants, along with /f θ s m n/, or is the nature of the phonological process causing the raising of (æl) better described in some other terms?

Banuazizi and Lipson (1998) link the raising of (æl) to /l/-vocalization, another "high-profile variable" in the Philadelphia speech community, rather than to /l/ merely joining the set of tensing environments. They find that (æl) is more likely to be raised when the /l/ is followed by /ə/ or /ʌ/ and less likely to be raised when it is followed by a high vowel. These effects are parallel to the effects found by Ash (1982) on /l/-vocalization in Philadelphia: following /ə/ and /ʌ/ favor vocalization, and following high vowels disfavor it. Thus, (æl)-raising is more frequent in /l/-vocalization environments. Banuazizi and Lipson (1998, 50–51) hypothesize that vocalized /l/ "attaches to the nucleus of the preceding syllable, thereby lengthening it"—in effect creating a diphthong—and "because in English, length is associated with tense vowels, the short-*a* of *Hallahan* would be realized as tense." They conclude that "instead of considering this purely as an extension of the conditioning environment for short-*a* raising, the most plausible explanation is that the separate /l/-vocalization rule is having some sort of effect on the increased tendency of Philadelphians to tense pre-/l/ short *a*."

A further clue to the behavior of (æl) in Philadelphia English can be found in an early discussion of Philadelphia dialect by Tucker (1944). Although Tucker makes no mention of Ferguson's (1972) distinctive short-*a* tensing pattern, he refers to (æl) in the context of some discussion of the /aw/ phoneme. Tucker (1944, 41–42) writes, "The diphthong written *ou* or *ow* has [æ] instead of [ɑ] as its first element," and several paragraphs later goes on to add, "When *ou*, pronounced [æʊ], loses its second element, the result is simply 'flat *a*': *hour* [æ:r], *owl* [æ:l], *Powell* [pæ:l], the latter two hardly to be distinguished from *Al* and *pal*." In other words, Tucker reports, if not incipient phonemic merger, then at least close phonetic similarity between /æ/ and /aw/ in the pre-/l/ environment. Ash (1982, 12) also specifically refers to the possibility of such a merger as a result of /l/-vocalization, since "the [vocalized] /l/ merges or nearly merges with the glide following the nucleus of … /aw/." That is, if the nucleus of /aw/ is fronted so as to be phonetically [æ] and /l/ is vocalized so as to be phonetically similar to the offglide of /aw/, the result is that /aw/ and (æl) (and /awl/) begin to be phonetically indistinguishable. Veatch (1991) likewise describes this merger as a possible consequence of /l/-vocalization. Now, Ash does not find frequent /l/-vocalization among speakers born before about 1920, meaning that at the time of Tucker's article, /l/-vocalization was a relatively new feature in Philadelphia; however, there may have been phonetic precursors to what Ash considers to be full /l/-vocalization that were sufficient to cause the offglide of /aw/ to coalesce into a following /l/.

The final piece of the puzzle is the phonetic change in Philadelphians' /aw/ over the decades after Tucker's (1944) description of the dialect. Labov

(2001, 187) describes the raising and fronting of the nucleus of /aw/ as having been one of the "new and vigorous" sound changes that were underway in Philadelphia in the 1970s, in the most advanced cases having a nucleus as raised as [e]. Labov, Ash, and Boberg (2006, 106–7, 159), using data collected in the 1990s, confirm that the nucleus of the Philadelphia /aw/ is among the highest and frontest in any dialect of North American English.

Thus we have the following sequence of events:

1. As early as 1944, (æl) was described as "hardly to be distinguished" from /awl/.
2. By the 1970s, the raising of the nucleus of /aw/ toward [e] was identifiable as a "new and vigorous change."
3. Also by the 1970s, (æl) was detectably raising, and considered to be identified with /æh/—a phoneme whose typical nucleus is also in the vicinity of [e].

The best explanation for this sequence of events, therefore, is not that /l/ has joined /f θ s m n/ as a regular tensing environment for short-*a*, but rather that /æ/ at some point underwent a conditioned phonemic merger with /aw/ in the pre-/l/ environment and that the raising of (æl) is simply a special case of the new and vigorous raising of /aw/. Thus, the identification of (æl) with /æh/ is an illusion, a misinterpretation on the part of linguists who observed that (æl) was being raised to the same phonetic vicinity as /æh/ but overlooked its identification with /aw/ and thus jumped to the conclusion that /æ/ was being replaced with /æh/ in (æl) words just as it was in *planet*.

We test the hypothesis that the raising of (æl) in Philadelphia is due to its identification with /aw/, not with /æh/, in a newly compiled corpus of Philadelphia speech data, the Philadelphia Neighborhood Corpus (PNC; Labov and Rosenfelder 2011). Since this is one of the first published studies based on this corpus, a brief description of it is in order; a more thorough description can be found in Labov, Rosenfelder, and Fruehwald (2013). The PNC is a corpus of sociolinguistic interviews conducted by students at the University of Pennsylvania as part of Linguistics 560: The Study of the Speech Community, an introductory class on sociolinguistic fieldwork taught by William Labov and occasionally by Gillian Sankoff at least once every two years since 1972. In this class, the students are divided into two or more groups, and each group is assigned a neighborhood in or around Philadelphia in which to conduct sociolinguistic interviews. As of this writing, 61 such neighborhood group studies have been completed by Linguistics 560 students, producing 1,107 recorded interviews. These recordings constitute the largest collection of sociolinguistic data on any speech community and form the basis of the PNC.

At the time of this study, 292 of these 1,107 interviews had been transcribed, representing 49 of the total 61 neighborhood studies. This comprises over 1.6 million words of sociolinguistic data, averaging 29 minutes per speaker for a total of approximately 140 hours of speech. Of these, 284 interviews, focusing chiefly on those with European American speakers, have been phonetically analyzed using the Forced Alignment and Vowel Extraction program suite (FAVE; Rosenfelder et al. 2011). This consists of two programs: FAVE-align and FAVE-extract. The FAVE-align program takes as its input an audio recording of speech data together with an orthographic transcript of the recording and outputs a TextGrid file for use in Praat (Boersma and Weenink 2011), aligning each word and each phoneme of the speech data with exact timestamps indicating their locations in the sound file. The FAVE-extract program, taking as its input the sound file and the TextGrid output by FAVE-align, measures the first and second formants of each measurable vowel nucleus present in the FAVE-align output. The 284 PNC interviews that have undergone this process have yielded a total of 638,599 vowel tokens, for an average of 2,401 F1/F2 measurements per speaker.

Normalization of the vowel measurements in the corpus is calculated according to Lobanov's (1971) normalization procedure, which transforms a speaker's vowel space into *z*-scores. These *z*-scores are then rescaled to hertz values with an overall mean of 650 Hz and a standard deviation of 150 Hz for F1 and an overall mean of 1700 Hz and a standard deviation of 420 Hz for F2. We make use of the normalized vowel measurements in this study.

The volume and depth of the PNC make it ideal for studying such a change in progress in Philadelphia English as (æl). The sheer number of interviews and number of vowel tokens measured per interview ensures data on (æl) sufficient to track its behavior in relatively fine detail. The average phonetically analyzed PNC speaker produced less than one token of (æl) per five minutes of speech. In a single sociolinguistic research project, this might not be a sufficient amount of data to draw conclusions from; but in a corpus the size of the PNC, it amounts to over 1,000 tokens of (æl), easily enough for rigorous statistical analysis. Moreover, the PNC data spans almost 40 years of data collection in real time and over 100 years in apparent time, with interview subjects born as late as 1990 and as early as 1888, meaning it is possible to track in detail a long-term phonological change such as this over nearly its entire history.

All told, the PNC at the time of this study contained 1,308 apparent tokens of (æl). Eleven of these tokens were the word *Halloween*, which was in all cases pronounced with the vowel of *hollow*, not (æl) as in *hallow*; these 11 tokens will therefore be removed from the data, leaving 1,297 tokens of (æl) in all, of which 1,207 have primary stress and 90 secondary or tertiary stress. There are 225 individual speakers who produced at least one token of (æl) and 41 speakers who produced at least ten tokens. Not counting *Halloween*, there are 20 lexical items containing (æl) instantiated ten or more times in the data: *Al*, *Albert*, *Alex*, *algebra*, *Alice*, *alcohol*, *alley*, *balance*, *California*, *gallon*, *Hallahan*, *Italian*, *nationality*, *pal*, *personality*, *Ralph*, *salad*, *salary*, *valley*, and *value*. This set of 1,297 tokens is the subject of the analysis below.

Since the hypothesis at issue here is that short-*a* is merged with /aw/ before /l/, we first look for direct evidence of this merger. Unfortunately, there are only 46 tokens of /aw/ before /l/ in the corpus, so it is difficult to find enough data to establish a direct comparison. However, there is a striking case of a natural misunderstanding between one interview subject, Sam Y., and one of two other speakers who were present at his interview (given as "A" and "B" in the extract below):

A: Yeah, that owl's gonna be on TV tonight.	[æɤ]
SAM: Who, Al? … Yeah, who, Al?	[æo]
B: The owl.	[æɤ]
SAM: Oh, the owl.	[æwɫ̩]
B: The owl.	[æo]

[Interview PH79-3-6: Sam Y., 48 years old in 1979, Bottom Street]

Speaker A pronounces *owl* with a fronted /aw/ and fully vocalized /l/, so the entire word is a diphthong gliding from a low front nucleus to a back offglide; Sam interprets this as *Al* and echoes it with his own fully vocalized (if somewhat rounder) /l/. Speaker B repeats the word *owl*, pronouncing it the same way speaker A did; this time Sam understands and echoes the word *owl*, with a more clearly distinct diphthongal /aw/ and vocalized /l/, making for a more bisyllabic pronunciation. So, on first glance, it is clearly not the case that Sam has a full phonemic merger between short-*a* and /aw/ before /l/; in this short dialogue he pronounces *Al* and *owl* differently.

However, a few seconds later—having now begun telling the story about the owl that, according to speaker A, is going to be on TV—Sam pronounces the word *owl* again. This time he says [æɤ], pronouncing *owl* exactly the same way speaker A did, the way he had just misunderstood as *Al*. So it seems perhaps as if the distinctive pronunciation of *owl*, with a differentiated diphthong and /l/, may be a pronunciation available for Sam in careful speech when it is necessary to distinguish between two near-homophones; but in less reflective speech, the distinction between *Al* and *owl* is not maintained.

A similar pattern is found in another speaker, interviewed 27 years later. Jean (interview PH06-2-6, Sherwin Street), who was interviewed at the age of 61 in 2006, pronounces *towel* as [teo] in spontaneous speech; but in her recitation of the word list she was asked to read at the end of the interview, she pronounces *towel* seemingly bisyllabically as [tɛwɫ̩]. Thus, like Sam Y. in 1979, in spontaneous speech she has the entire /awl/ sequence compressed into a single diphthong, but in a careful speech style, she has a full diphthong for the /aw/ followed by a distinct /l/. Her word-list style is variable in this respect, however: Jean's word-list pronunciations of *pal* and *Powell* are nearly indistinguishable, with *pal* slightly higher: [peɤ] and [pɛɤ], perhaps, respectively.

So it is more or less clear that neither Jean nor Sam has a FULL merger of (æl) with /awl/, but they both may be subject to a merger in progress, where the contrast can be maintained in careful speech but falls together in less careful styles. It is worth noting that this characterization applies to both of them, even though the merging phonemes are to be found at different locations in the vowel space. Figure 1 shows the nuclei of all of Sam's (æl) and /awl/ tokens as measured by the FAVE-extract program and shows that they occupy the same area of phonetic space—a low position, more characteristic of lax /æ/ than tense /æh/. Figure 2 shows the same for Jean, but her (æl) and /awl/ occupy a raised position, about midway between /æh/ and /æ/. According to the traditional description of the raising of Philadelphia (æl), we would say that Sam's (æl) is low because it is phonologically identified

FIGURE 1
(æl), /awl/, and Mean /æ/ and /æh/ of Sam Y., PNC Speaker PH79-3-6

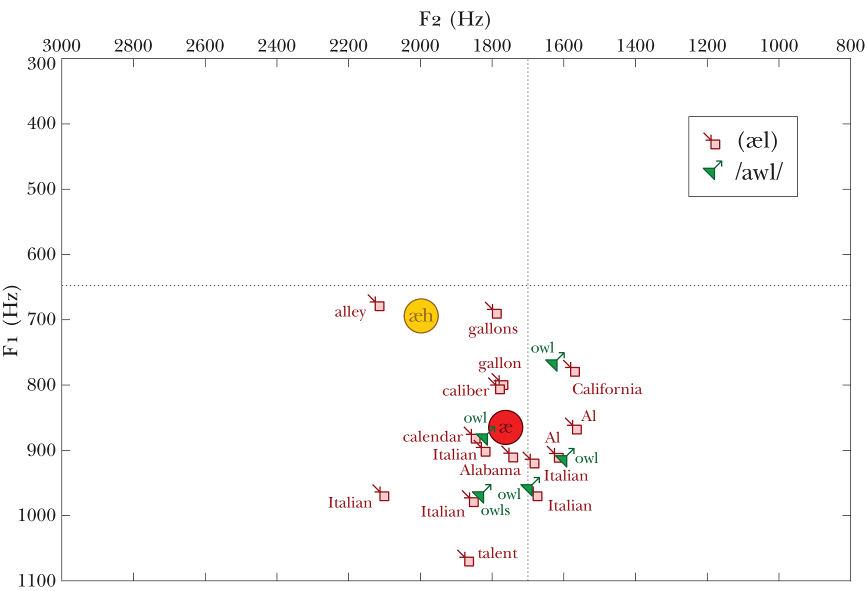
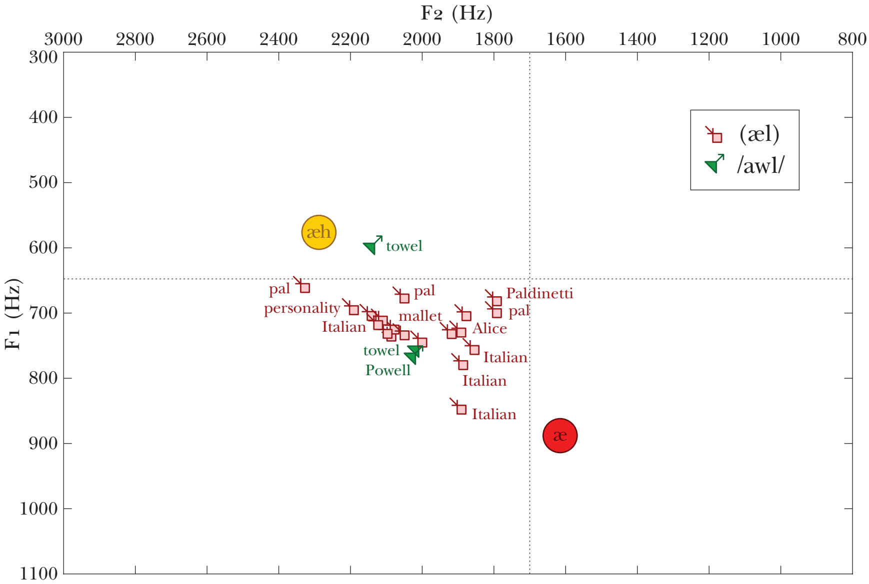


FIGURE 2
(æl), /awl/, and Mean /æ/ and /æh/ of Jean, PNC Speaker PH06-2-1



NOTE: Some labels are omitted for the sake of legibility.

with /æ/ and that Jean's is high, perhaps identified with /æh/; but that account leaves unexplained the fact that both of their (æl)s overlap phonetically with /awl/. The explanation of the raising of (æl) being put forward in this article, that (æl) is phonologically identified with /aw/, would account for this seeming coincidence.

As an anonymous reviewer notes, first and second formants are not the complete picture of a vowel's phonetic characteristics. That (æl) overlaps with /aw/ in nuclear F1 and F2 does not itself entail that they are phonologically identical; /æ/ and /aw/ before /l/ may differ in terms of length, formant contour, or even fundamental-frequency contour. Our analysis in this article focuses on nuclear formant values because those are the measurements most readily provided in the PNC data; and, as we will see below, an analysis based on F1 and F2 will prove sufficient to provide strong evidence for a phonological identification of (æl) with /aw/.

Of course, not all speakers in the corpus have convenient tokens of /awl/ with which their (æl) can be compared. To examine the status of (æl) in detail, we broaden our comparison of it to the /aw/ phoneme at large, rather than just its relatively infrequent pre-/l/ allophone. For example, above we observed that Banuazizi and Lipson (1998) found (æl) typically sounding phonetically intermediate between canonical /æ/ and /æh/. Since Banuazizi and Lipson's interviews were conducted as part of the Study of the Speech Community class, their data is in the PNC, and we can check the status of (æl) for their speakers acoustically and compare it to /aw/. Figure 3 shows the /æ/, /æh/, and (æl) of Kay, one of Banuazizi and Lipson's speakers, demonstrating that (æl) sits between the phonetic ranges of /æ/ and /æh/. Figure 4 displays the distribution of Kay's /aw/, showing that (æl) sits right in the middle of /aw/. Her mean F1 and F2 of (æl) differ from her mean F1 and F2 of /aw/ by 33 Hz and 150 Hz, respectively; on the other hand, they differ from /æ/ by 117 Hz and 286 Hz and from /æh/ by 133 Hz and 304 Hz. So at least we can say, both quantitatively and impressionistically, that Kay's (æl) resembles her /aw/ more closely in F1 and F2 than it does either her /æ/ or her /æh/.

Our aim, then, will be to investigate to what degree this description of (æl) as more similar to /aw/ than to /æ/ or /æh/ holds for the corpus as a whole. One simple way to approach this is merely to measure the distance in phonetic space between any given token of (æl) and the same speaker's mean F1 and F2 of /aw/, /æ/, or /æh/. If the hypothesis that (æl) is to some degree phonologically identified with /aw/ is correct, then we might expect to find most tokens of (æl) to be overall nearer to mean /aw/ than to mean /æ/ or /æh/.

FIGURE 3
/æh/, /æ/, and (æl) of Kay, PNC Speaker PH96-3-2

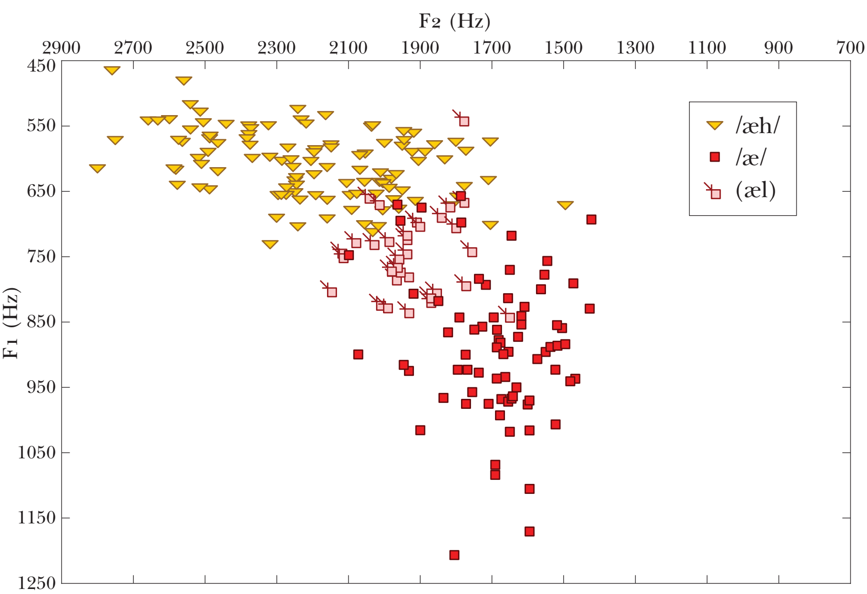
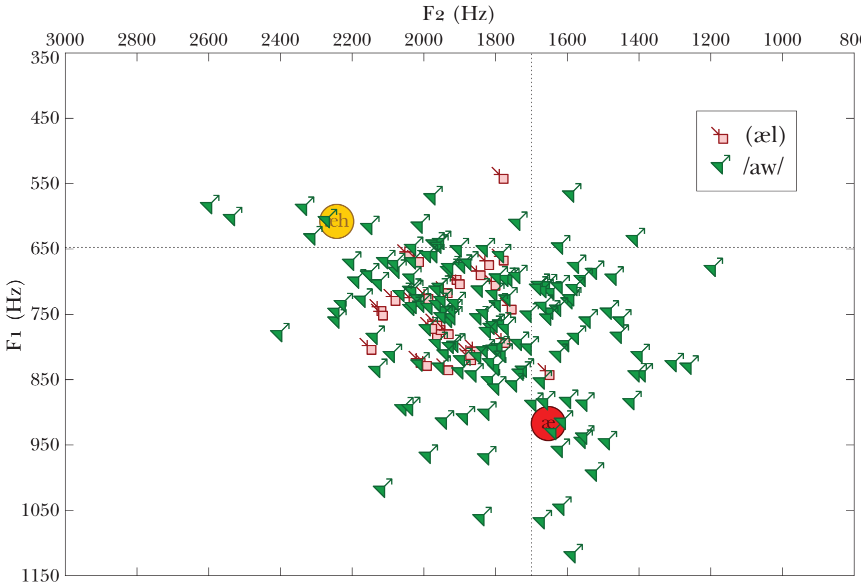


FIGURE 4
/aw/ and (æl) and Mean /æ/ and /æh/ of Kay, PNC Speaker PH96-3-2



We could measure this simply in terms of the Cartesian distance in F1/F2 space between (æl) tokens and the various phoneme means. However, unmodified Cartesian distance would be less than fully satisfactory in this respect for at least two reasons. First, F1 and F2, although both measured in hertz, do not have the same scale: a token of (æl) that differs from mean /aw/ by 100 Hz in F1 is not necessarily the same distance away from it in phonetic terms as one that differs from /aw/ by 100 Hz in F2. Moreover, each phoneme occupies a range of phonetic space about its mean, and not all phonemes occupy the same amount of phonetic space; if a given speaker's /aw/ occupies a wide range and their /æ/ occupies a narrow range, it is quite possible that any given token of /aw/ might be closer to mean /æ/ than to mean /aw/ but still within the phonetic range of /aw/ rather than /æ/. For this reason, instead of calculating the straight Cartesian distance, we normalize each distance in Hertz by the standard deviations of the phoneme means in order to calculate what we might call the *z*-DISTANCE.

We define *z*-distance as follows. If F1(æ) and F2(æ) are a speaker's mean formant values for /æ/ and σ_{F1}(æ) and σ_{F2}(æ) are the corresponding standard deviations, the *z*-distance from /æ/ of a given token of (æl) from that speaker will be:

$$\sqrt{\left(\frac{F1(æl) - F1(æ)}{\sigma_{F1}(æ)}\right)^2 + \left(\frac{F2(æl) - F2(æ)}{\sigma_{F2}(æ)}\right)^2}$$

For example, figure 5 displays Jean's /æ/ distribution and a token of *personality*. This token is 197 Hz higher and 586 Hz fronter than the mean /æ/. The standard deviations of the /æ/ distribution are 61 Hz in F1 and 117 Hz in F2; this means that *personality* is 3.23 standard deviations higher than mean /æ/ and 5.01 standard deviations fronter. Then we apply the Pythagorean theorem to the quantities 3.23 and 5.01 to calculate the *z*-distance and find that *personality* is 5.96 standard deviations away from /æ/ in F1/F2 space. Thus, the *z*-distance normalizes F1 and F2 to the standard deviations of /æ/ (in this case) in order to judge to what degree the token being compared is within the expected range for typical tokens of the phoneme.

Table 1 demonstrates the overall trends for the *z*-distances of (æl) from /æ/, /æh/, and /aw/ in the PNC corpus; they support the hypothesis that (æl) is phonologically more associated with /aw/ than with either of the short-*a* phonemes: the average (æl) token in the corpus is closer in *z*-distance to the same speaker's /aw/ than to /æ/ or /æh/, and similarly a greater percentage of (æl) tokens are within 1 or 2 standard deviations of /aw/ than of /æh/

FIGURE 5
Jean's *personality* in Comparison to /æ/, PNC Speaker PH06-2-6

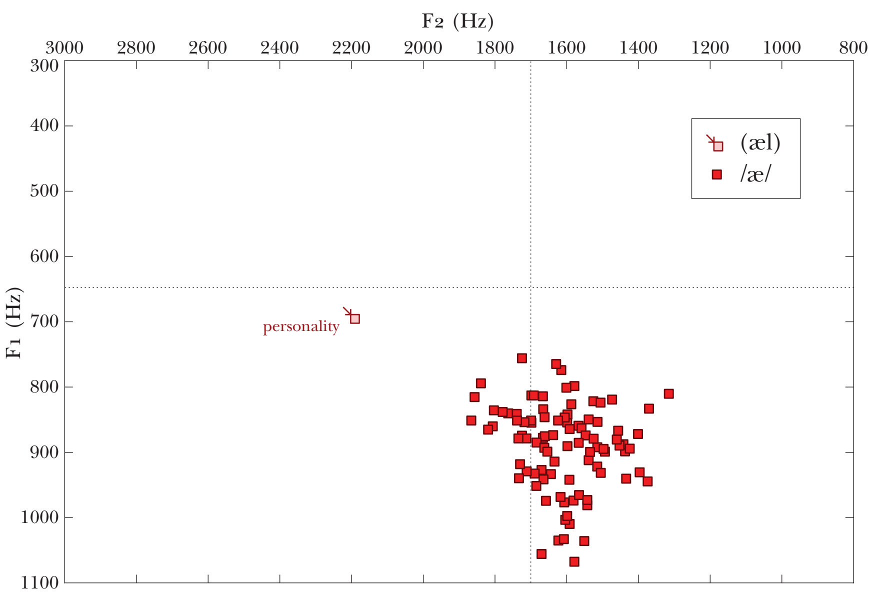


TABLE 1
Overall z-Distance of (æl) Tokens from /æ/, /æh/, and /aw/ (n = 1,297)

	/æ/	/æh/	/aw/
Mean z-distance of (æl) from	1.85	3.03	1.46
Std. deviation of z-distance from	1.30	1.76	0.90
Percentage of z-distance less than 1	29%	7%	35%
Percentage of z-distance less than 2	66%	29%	79%
Percentage of speakers with (æl) closest to	32%	11%	57%

or /æh/. A majority of speakers have their mean (æl) closer in z-distance to mean /aw/ than to either /æ/ or /æh/.

Now, (æl) does not display the behavior in table 1 that we expect of fully canonical tokens of /aw/, to be sure. Only 79% of tokens of (æl) are within two standard deviations of mean /aw/, while we would expect 95% of tokens of /aw/ to be in that range. Also, although the difference between the mean z-distances from /aw/ and /æ/ is statistically significant ($p < 10^{-25}$ in a paired t-test), supporting the hypothesis that (æl) tokens are overall closer to /aw/ than to /æ/, the overlap between the z-distance ranges from /aw/ and /æ/ is quite large—the standard deviations of these z-distances are large in comparison to the difference between the means. This means that many tokens of (æl) that are quite close to mean /aw/ are equally close to mean /æ/, and thus it cannot necessarily be determined from this data which phoneme they are phonologically identified with. It's not too surprising, of course, that (æl) is not as close to /aw/ overall as we would expect canonical /aw/ to be; what we believe we are documenting, after all, is the result of a phonological change, apparently incomplete, consisting of (æl) being reanalyzed as part of the /aw/ phoneme rather than the /æ/ phoneme. Presumably for at least some speakers in the corpus this change will be more or less incomplete, and thus have (æl) still identified with /æ/ or somehow intermediate between the two; speakers for whom it is less complete may contribute tokens of (æl) that increase its mean z-distance from /aw/. Moreover, of course, as an anonymous reviewer points out, there are many reasons not to take mere distances to vowel means as the best diagnostic for phonological identity. Neighboring consonants often exert some influence on the phonetic quality of the vowels they are adjacent to at the infra-phonological level; for instance, Labov, Ash, and Boberg (2006) report that in some dialect regions, /æ/ is consistently somewhat higher before /d/ than before /g/ (and in other regions, the pattern is reversed). It is certainly possible, therefore, that, for example, (æl) is phonologically identified with /æh/, but /æh/ is regularly lowered by a following /l/, which leads (æl) to be consistently some distance away from the mean /æh/. The conclusion from table 1, therefore, is merely loose evidence in favor of the proposition that (æl) is identified with /aw/, on the grounds that over the corpus as a whole (æl) tokens are closer to mean /aw/ than to /æ/ or /æh/.

How then shall we get a stronger indicator of the status of (æl)? If (æl) is phonologically identified with /aw/, then perhaps (æl) tokens are closer to /aw/ for any given speaker, but more importantly, across speakers /aw/ will be a better predictor than /æ/ or /æh/ of where in the vowel space (æl) appears. We saw this above in comparing Sam Y. and Jean: Sam has low /aw/ and low (æl), while Jean has raised /aw/ and raised (æl). Thus, instead of how close (æl) is to /aw/, what we should investigate is how well correlated (æl) is with /aw/.

Figure 6 demonstrates a clear and significant correlation in F1 between (æl) and mean /aw/: as a speaker's mean /aw/ is higher, their tokens of (æl) are likely to be higher as well. By contrast, figure 7 shows that there is no correlation in F1 between (æl) and mean /æ/. The top row of table 2 shows all six correlations of (æl) with F1 and F2 of /æ/, /æh/, and /aw/. Although the correlations with both /aw/ and /æh/ are all significant at the $p < .001$ level, it is clear that overall, /aw/ explains the distribution of (æl) tokens better than /æh/ does.

Since the phenomenon under investigation here is a change in progress—conventionally described as a transfer of (æl) from /æ/ to /æh/—it might be inappropriate to look at correlations between (æl) and phoneme means across the entire sample; we do not expect older and younger speakers to

FIGURE 6

Correlation of (æl) Tokens with Speaker /aw/ Means in F1 ($p < 10^{-34}$)

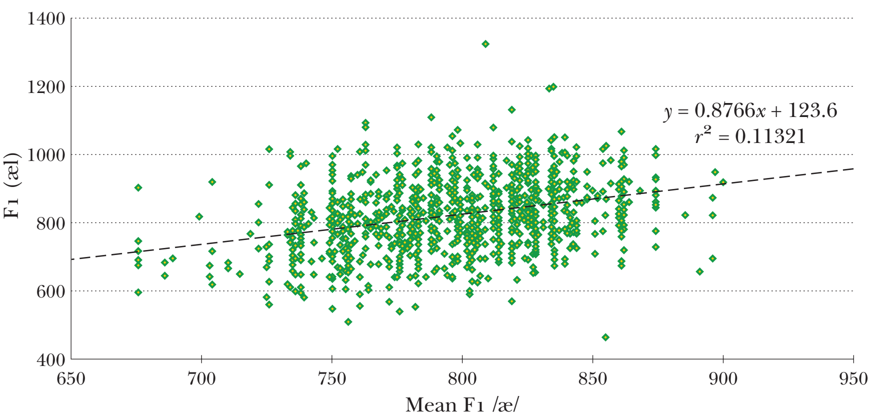
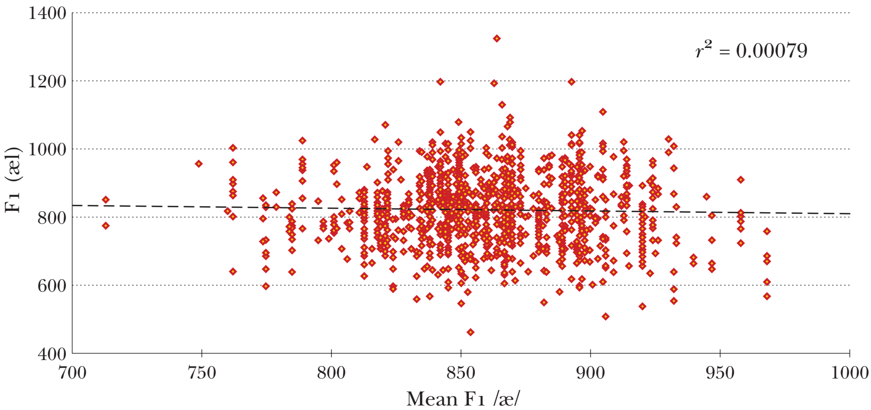


FIGURE 7
Lack of Correlation of (æl) Tokens with Speaker /æ/ Means in F1 ($p \approx .3$)



behave the same way with respect to (æl). So, perhaps older speakers show a stronger correlation between (æl) and /æ/, and younger speakers show a stronger correlation between (æl) and /æh/. We can test this by dividing the data in half in apparent time or in real time: since the corpus contains speakers born between 1888 and 1991 and interviewed between 1972 and 2010, we can compare speakers born before 1940 to speakers born later and speakers interviewed before 1992 to those interviewed later.

Table 2 shows that in both halves of the data, in both apparent time and real time and in both F1 and F2, (æl) is more strongly correlated with /aw/ than with either /æ/ or /æh/. Younger speakers (and speakers interviewed later) have stronger correlations with /æh/ than do older/earlier speakers, as predicted, but the correlations are still not as strong as the correlations with /aw/, especially in F1.

TABLE 2
Pearson-r Correlations between F1 and F2 of (æl) and Speaker Phoneme Means

	n	/æ/		/æh/		/aw/	
		F1	*F2*	*F1*	*F2*	*F1*	*F2*
All (æl)	1,297	−0.028	0.067*	0.11**	0.18**	0.34**	0.27**
Born before 1940	593	0.13*	0.11*	0.088*	0.15**	0.25**	0.18**
Born since 1940	704	−0.11*	0.051	0.16**	0.21**	0.33**	0.33**
Interviewed before 1992	803	0.042	0.093*	0.046	0.14**	0.32**	0.24**
Interviewed since 1992	494	−0.17**	0.029	0.20**	0.25**	0.37**	0.34**

*$p < .05$; **$p < .001$

There are multiple statistically significant correlations in table 2 for all subdivisions of the data. This may be because, for example, /æh/ and /aw/ each independently exert some influence on the speech community's realization of (æl), or it may be merely because /aw/ and /æh/ are themselves correlated by virtue of the fact that they are both involved in sound change in the same direction (see Labov 2001, 143). Therefore, the next step is to see whether the correlations of (æl) with say /æh/ will remain significant when the correlation with /aw/ is taken into account. In other words, the next step is to perform multiple-regression analyses.

The direction of movement of (æl) is up the front diagonal of the vowel space, from the region of /æ/ to that of /æh/. This direction of movement involves change in both the F1 and F2 dimensions, and so rather than running separate regressions for F1 and F2, which would merely give us projections of the diagonal direction of change onto the height and frontness dimensions, we use the linear combination F2 − 2F1. Since the slope of the front diagonal of the vowel space with respect to F2 and F1 is approximately −½, this formula[1] measures distance moved along the front diagonal in the same way F1 and F2 measure distance moved straight down and straight forward, respectively, as schematized in figure 8.

FIGURE 8

F2 − 2F1 as a Measure of Distance Up the Front Diagonal of the Vowel Space

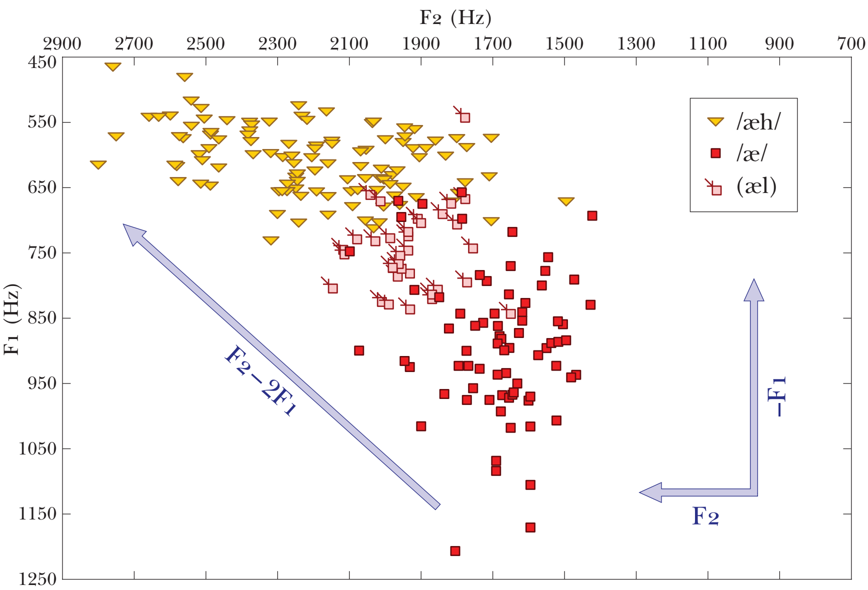


TABLE 3
Multiple Regression of F2 – 2F1 of (æl) Tokens versus Phoneme Means ($r^2 \approx 0.121$)

	Coefficient	*t*	*p*
/aw/ mean F2 – 2F1	0.612	11.8	≤ .0001
/æ/ mean F2 – 2F1	0.108	1.66	.0962
/æh/ mean F2 – 2F1	-3.37×10^{-4}	0.008	.9936

TABLE 4
Multiple Regression of F2 – 2F1 of /æl/ by Apparent-Time Halves

	Born before 1940 ($r^2 \approx 0.070$)			*Born since 1940 ($r^2 \approx 0.133$)*		
	Coefficient	*t*	*p*	*Coefficient*	*t*	*p*
/aw/ mean F2 – 2F1	0.399	5.79	≤ .0001	0.749	8.72	≤ .0001
/æ/ mean F2 – 2F1	0.280	2.35	.0189	0.0857	1.10	.271
/æh/ mean F2 – 2F1	–0.0712	1.06	.292	–0.0233	–0.386	.700

Table 3 shows the results of running a linear regression of F2 – 2F1 of (æl) tokens against just the speaker means for /aw/, /æ/, and /æh/. Only /aw/ has a significant effect on (æl). In other words, once the correlation with /aw/ is accounted for, /æ/ and /æh/ add no information in predicting the degree of raisedness of (æl). If we divide the corpus in half in apparent time, as shown in table 4, for the older speakers we find that /aw/ and /æ/ both have significant effects on (æl). This is not too surprising, inasmuch as we are describing a change in progress; some of these older speakers may, in fact, predate the start of the change and simply have (æl) as /æ/. However, for the younger speakers, only /aw/ has an effect; /æh/ isn't even close. So to the extent that the regression for older speakers indicates that (æl) used to be phonologically associated with /æ/, the regression for younger speakers does not support the conventional claim that (æl) has come to be associated with /æh/; rather, it strongly supports our hypothesis that (æl) is associated with /aw/ and has no particular connection to /æh/.

Finally, to cover all our bases, we carry out a "kitchen-sink regression"—that is, a multiple linear regression of F2 – 2F1 of (æl) against not only /aw/, /æ/, and /æh/, but also every other potentially relevant feature for which the data is coded or can be easily extracted. These factors are the following:

Year of birth of speaker
Year of interview
Gender of speaker
Word frequency in corpus
Duration of vowel

Lexical syllable stress
Syllable onset
- Labial obstruent
- /m/
- Apical obstruent
- /n/
- Postalveolar
- Velar
- /r/
- Obstruent-liquid cluster

/l/ part of coda cluster
/l/ word-final
Nasal following /l/[2]

In addition, since lexical diffusion has been implicated in past research on (æl) in Philadelphia, we add to the kitchen-sink regression the 20 individual lexical items appearing 10 or more times in the data; if any of these words tends to be leading or lagging the change as a whole, then the regression might catch it. The 20 high-frequency (æl) words are *Al*, *Albert*, *Alex*, *algebra*, *Alice*, *alcohol*, *alley*, *balance*, *California*, *gallon*, *Hallahan*, *Italian*, *nationality*, *pal*, *personality*, *Ralph*, *salad*, *salary*, *valley*, and *value*.

Altogether this constitutes a multiple regression on 40 potential factors. Because of the large number of independent variables in the regression, we apply a Bonferroni correction and use $p < .00125$ as our cutoff for statistical significance. Only four factors are found to have a significant effect on F2 – 2F1 of (æl); as shown on table 5, /aw/ is still substantially the strongest.

One lexical item does appear on table 5 as having significantly distinctive behavior: *gallon* substantially favors raising. An anonymous reviewer, however, suggests that this might not be a lexical effect, but merely a consequence of the fact that the onset of (æl) in *gallon* is /g/; although velar onset is included as a factor in the regression above, it may be the case that the voiced and voiceless velars have different effects on the height of (æl), and *gallon* is selected merely as a proxy for the effect of onset /g/, which was not

TABLE 5
Factors Having an Effect on F2 – 2F1 of (æl) at the $p < .00125$ Level

	Coefficient	*t*
/aw/ mean F2 – 2F1	0.565	13.2
Coda cluster	–140	–9.03
gallon	360	5.52
Year of birth	1.42	4.37

itself a factor included in the regression. And indeed, if onset /g/ is added as a factor to the regression above (coding positively those tokens containing orthographic <gal>, such as *gal* and *galley* as well as *gallon*, and negatively all others), it replaces *gallon* in the final result, as shown in table 6. This leaves no word-specific conditioning effects; the specific lexical items Labov (1989) identified as leading the change, such as *alley*, *personality*, and *nationality*, do not even approach statistical significance in either regression. Thus, this study, like Banuazizi and Lipson (1998), is unable to reproduce Labov's finding of lexical diffusion in (æl).

Table 6 shows that younger speakers favor raising of (æl), even once the correlation with /aw/ is taken into account. Since /aw/ and year of birth are themselves highly correlated for most of the apparent-time span of the data, the place to look for an explanation of the year-of-birth effect may be where the correlation of year of birth with /aw/ breaks down. Labov, Rosenfelder, and Fruehwald (2013) demonstrate that the long-term trend toward raising of /aw/ has undergone a sharp reversal; the raising of /aw/ seems to have reached its peak among speakers born in 1940, and since then /aw/ has moved back down the vowel space. So if younger speakers tend to have (æl) higher relative to the correlation with /aw/ than older speakers do, might this mean that, as /aw/ has moved back down for younger speakers, (æl) has remained high?

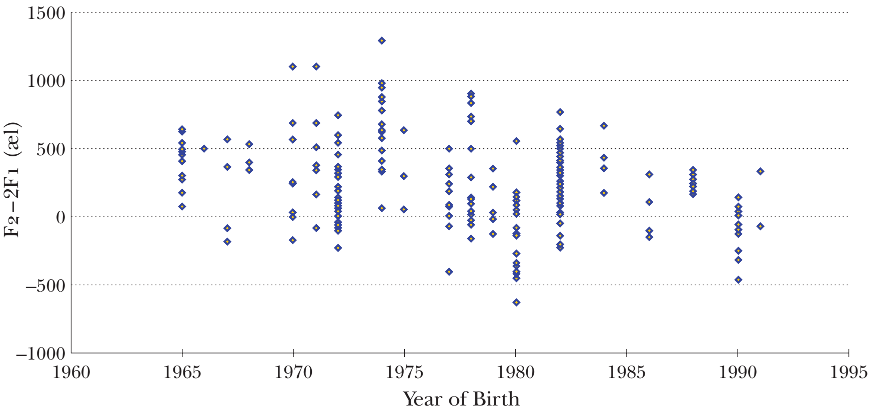
On the whole, the data does not seem to support this hypothesis. Figure 9 shows the distribution of F2 – 2F1 of (æl) tokens for the speakers born in 1965 or later; from this chart, it appears that (æl) has undergone a decline in the most recent generation just as /aw/ has (although it appears to have peaked a bit later). The statistics bear this out: after 1965, F2 – 2F1 of (æl) tokens is negatively correlated with year of birth ($r \approx -0.26$; $n = 234$; $p < .001$); and in a kitchen-sink regression restricted to this youngest quarter of the corpus, /aw/ is the only factor with which (æl) is significantly correlated, with a regression coefficient of approximately 1.14, very close to 1. So the retreat from raising of /aw/ apparently includes (æl); but this does not explain the

TABLE 6
Factors Having an Effect on F2 – 2F1 of (æl) at the $p < .00125$ Level, Including Onset /g/ in Regression

	Coefficient	*t*
/aw/ mean F2 – 2F1	0.567	13.4
Coda cluster	–135	–8.69
Onset /g/	353	6.92
Year of birth	1.47	4.55

FIGURE 9

F2 – 2F1 of (æl) Tokens for Speakers Born Later than 1965



significance of year of birth as a factor in the kitchen-sink regression on the whole corpus.

To sum up, this article presents fairly convincing quantitative evidence that (æl) has undergone raising in Philadelphia English because it is phonologically identified with /aw/, which has itself undergone raising, rather than (as has previously been proposed) because its phonological affiliation is changing from /æ/ to /æh/. The raising of /aw/, and therefore the raising of (æl) with it, is a gradient phonetic change, a type that Labov (1994) argues should not be subject to lexical diffusion; at the same time, we find no statistically significant evidence to support the claims of lexical diffusion that have been made for this change in the past. Furthermore, identification with /aw/ explains some of the observed features of (æl) that have been hard to account for otherwise. The raising of (æl), as Brody (2009) found, is going to completion across all lexical items, whereas the raising of short-*a* before intervocalic nasals has stalled after one word, *planet*; this is because the latter is an authentic case of lexical diffusion, while the former is a gradient sound change affecting /aw/. Banuazizi and Lipson (1998) noted that raised tokens of (æl) were not as raised as typical /æh/ tokens and that the raising of (æl) does not conform to the usual morphophonological constraints on the distribution of /æh/; this again is easily explained if (æl) has no particular relationship with /æh/ at all.

Although the evidence that (æl) is phonologically identified with /aw/ is compelling, to the extent that phonetic change in /aw/ drives (æl) along with it, it is striking that there does not seem to be COMPLETE phonological merger: speakers can still distinguish between (æl) and /awl/ in sufficiently careful speech, as Sam Y. in 1979 did explicitly, and Jean in 2006 did in pronouncing *towel* differently in word-list style than in spontaneous speech. Given that total phonemic merger has not apparently taken place, this leaves us with an interesting question: what is the nature of the type of phonological identification sufficiently close to allow movements in one phoneme to drag along an entity apparently still sufficiently phonologically separate from it to be distinguished in careful speech styles? We can see a potential answer to this question in the LOCATION of the difference between careful and casual styles: when these speakers distinguish between (æl) and /awl/ in careful speech, they do so by altering the pronuncation of /awl/: Sam's careful *owl* and Jean's careful *towel* are essentially disyllabic, with a clearly diphthongal /aw/ and a separate syllabic /l/. On the other hand, we don't, for example, find Jean in word-list style lowering *pal*, *alley*, or *personality* to [æ], though we do find her giving /l/ a separate syllable in word-list *towel*. So perhaps the vowels themselves are fully merged, and the proper synchronic description of the distinction that can still be made resides in the /l/ instead.

Veatch (1991, 67–69) discusses the syllabification of /l/ as one of a few possible phonological consequences of /l/-vocalization adjacent to diphthongs; merger of the vocalized /l/ into the offglide of the diphthong is another. This suggests that we can reconstruct the history of this merger in the following way. When /l/-vocalization was incipient, apparently in the early twentieth century, the /awl/ words, such as *owl* and *towel*, developed variation between disyllabic and monosyllabic pronunciations. When the nucleus of (æl) came to be identified with /aw/, the monosyllabic variant of /awl/ merged with (æl), but the disyllabic variant remained distinct, since (æl) never had a disyllabic pronunciation. The upshot of this is that, for speakers like Sam Y. and Jean, there are in effect two phonological classes of words with /aw/ before /l/—the historical /awl/ words, in which the /l/ is optionally syllabic, and the (æl) words, in which it is not—and the syllabicity of the /l/ can be exploited when necessary to distinguish between two words. So the two categories of words apparently remain distinct even though the vowel in (æl) is fully identified with /aw/. In effect, therefore, the phonological identification of /æ/ with /aw/ in the pre-/l/ environment has created a secondary split in /l/, in that the syllabicity of /l/ is now apparently phonemically contrastive after /aw/ in Philadelphia English—but the contrast between syllabic and nonsyllabic /l/ is realized only in careful speech and even then only variably. Therefore, the phonological consequence of the merger is a VARIABLE split, leading to full neutralization the majority of the time.

One more general methodological conclusion and one theoretical conclusion remain to be drawn. Conditioned merger leads to neutralization of a contrast in one environment between two phonemes that remain contrastive in other environments; and in such cases, it may sometimes seem to be a question without an answer to ask which of the two phonemes is present in words in which the merger has taken place, or whether the result of the merger is underspecification—for instance, in dialects in which the PIN-PEN merger is complete, is it meaningful to ask whether *been* contains the KIT phoneme or the DRESS phoneme? We put forward a methodology by which, in some cases, it may be possible to answer that question: by analyzing the relationship of the merged environment to sound changes in progress that involve the merged phoneme. Although /æ/ and /aw/ are merged in the pre-/l/ environment, it is clear from the PNC data that the result of the merger is phonologically identified with /aw/, and not /æ/, because (æl) is dragged along with the ongoing phonetic change in /aw/.

Finally, these results, in resolving a misconception in the literature about the nature of (æl), clarify somewhat the relative roles of lexical diffusion and gradual sound change. Labov (1994, 542) says that lexical diffusion is to be expected in cases of "abrupt substitution of one phoneme for another," and this is what we see in the case of the word *planet*, as Brody (2009) finds: *planet* has leapt from /æ/ to /æh/ as a single word, without bringing along other words containing /æ/ in the same environment. When the raising of (æl) was considered another case of abrupt replacement of /æ/ with /æh/, then Brody's finding that the replacement was going to completion in all words could be taken as evidence in favor of Wang and Cheng's (1977) contention that Neogrammarian-like regularity is a common eventual result of lexical diffusion. The finding of this study is therefore evidence against that proposition: a phonological change that had been thought, based on Brody's data, to be a case of lexical diffusion going to Neogrammarian completion turns out after all, on closer examination, to be phonetically gradual and, as far as we can tell, lexically simultaneous. Thus, our findings strengthen a model of phonological change in which lexical diffusion and regular Neogrammarian sound change are different processes with different consequences.

NOTES

Thanks are due to William Labov and Ingrid Rosenfelder for their substantial assistance in assembling an earlier version of this article.

1. We follow Labov (1994, 104) in estimating the slope as −½, although the exact formula Labov uses for calculating distance along the front diagonal—namely $\sqrt{F2^2-(2F1)^2}$—is based on a misapplication of the Pythagorean theorem and does not necessarily even produce a real number. For measuring distance trav-

eled in a given direction in a vector space, one merely needs to rotate and scale the coordinate system; and the correct formula for that is a linear combination of the original axes.

2. Nasal following /l/ was not a factor for which the data were already coded but was included in response to a suggestion from Josef Fruehwald (pers. comm., Oct. 18, 2011) that it might be relevant. It was coded automatically according to an orthographic criterion: those tokens where <al> or <all> was followed by a single vowel and then <n>, such as *balance* or *Allen*, were coded positively, and all others negatively.

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