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The Weckud Wetch of the Wast: Lexical Adaptation to a Novel Accent

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Abstract

Two experiments investigated the mechanism by which listeners adjust their interpretation of accented speech that is similar to a regional dialect of American English. Only a subset of the vowels of English (the front vowels) were shifted during adaptation, which consisted of listening to a 20-min segment of the "Wizard of Oz." Compared to a baseline (unadapted) condition, listeners showed significant adaptation to the accented speech, as indexed by increased word judgments on a lexical decision task. Adaptation also generalized to test words that had not been presented in the accented passage but that contained the shifted vowels. A control experiment showed that the adaptation effect was specific to the direction of the shift in the vowel space and not to a general relaxation of the criterion for what constitutes a good exemplar of the accented vowel category. Taken together, these results provide evidence for a context-specific vowel adaptation mechanism that enables a listener to adjust to the dialect of a particular talker.

Keywords: Speech perception; Perceptual adaptation; Word recognition; Accent; Dialect

1. Introduction

Spoken language understanding is remarkably robust. Mature listeners are not only able to recognize words in noisy speech, but they do so despite variations in talker, speaking rate, and dialect. These variations cause catastrophic errors in automatic speech recognition (ASR) devices, yet are solved quite easily by young children. When a string of phonetic information is presented, the ASR algorithm must find the best match with stored lexical and sublexical templates. Although both ASR algorithms and human listeners can reduce the search space

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and fill in missing or degraded phonetic information by relying on the preceding lexical, semantic, and pragmatic context (i.e., top-down knowledge), human listeners can also quickly adapt their perceptual categories to accommodate variation among speakers. Thus, for mature listeners, lexical representations, the mapping between lexical items and their phonetic forms, or both may be constantly changing as the perceptual system adapts to new input. In this article, we demonstrate that passively listening to 20 min of running speech in a novel accent is sufficient to shift vowel categories. Phonetic forms that were initially heard as nonwords were subsequently judged to be words when they corresponded to English words in the new accent.

The focus of this investigation was on one particular type of variation in spoken language—dialectal differences—in an effort to assess the mechanism of adaptation to a novel accent. Vowel differences play an important role in differentiating regional dialects of American English (Clopper & Pisoni, 2004; Thomas, 2001). For example, the word *dead* is pronounced as "ded" in Midwestern American English, as "dayed" in some dialects of Southern American English, and as "dad" in some dialects of Northern American English (Labov, 1998). Although on initial exposure a sudden shift in dialect can lead to confusions (Ladefoged & Broadbent, 1957), most listeners rapidly adjust and are able to successfully recognize accented speech (Clarke & Garrett, 2004). However, the mechanism by which this vowel adaptation process operates is largely unknown.

Differences in vowel quality are captured, to a first approximation, by the center frequencies of the first two formants (F1 & F2). However, even within a dialect, these prototypical F1–F2 values vary considerably because of differences in vocal tract size (male, female, child), speaking rate (rapid speech leads to formant undershoot), and surrounding consonant context (Hillenbrand, Getty, Clark, & Wheeler, 1995; Peterson & Barney, 1952). Presumably, top-down knowledge is helpful for enabling a listener to quickly realize the lexical intent of a spoken utterance and to remap the vowel space (Davis, Johnsrude, Hervais-Adelman, Taylor, & McGettigan, 2005; Kraljic & Samuel, 2006; Norris, McQueen, & Cutler, 2003); that is, to alter the relation between a lexical item and its acoustic–phonetic instantiation. If the accent involves only a subphonemic deviation from the listener's own dialect, adaptation may be possible in the absence of top-down knowledge (Clarke, 2003; Maye & Gerken, 2000). However, if the native and novel accents differ to the extent that there is a phonemic mismatch between the two accents (as in *dead* → "dad"), top-down knowledge is necessary to avoid interpreting accented words as novel lexical items or familiar lexical items different from the ones intended by the talker.

Encountering systematic differences from one's own pronunciation is a common occurrence and rarely poses a significant problem for listeners. Rather, listeners routinely encounter individual talkers whose speech exhibits idiosyncratic phonetic characteristics, and listeners use these acoustic cues to identify a particular talker's voice (Allen & Miller, 2004). These idiosyncratic aspects of pronunciation are utilized in lexical processing as well. Performance on word recognition tasks is higher for familiar talkers than unfamiliar talkers (Bradlow & Pisoni, 1999; Nygaard, Sommers, & Pisoni, 1994), and experience with a particular talker can affect the perceptual boundary between two phonetic categories (Kraljic & Samuel, 2006; Norris et al., 2003). Similarly, a moderate amount of training with low-intelligibility speech results in improved recognition that generalizes to unfamiliarized words (Davis et al., 2005;

Greenspan, Nusbaum, & Pisoni, 1998; Schwab, Nusbaum, & Pisoni, 1985). These findings suggest that listeners encode the minute phonetic details of talkers with whom they are familiar and use this information to facilitate access of the appropriate lexical items.

Listeners are also adept at learning the characteristic phonetic signatures of various dialect communities, and can use these fine-grained phonetic details to identify a talker's dialect (Clopper & Pisoni, 2004; Evans & Iverson, 2004). Furthermore, experience listening to a particular dialectal or foreign accent results in improved word identification for words previously unheard in that same accent (Bradlow & Bent, 2003; Clarke, 2003; Clarke & Garrett, 2004; Scott & Cutler, 1984; Weil, 2001; Wingsted & Schulman, 1987), indicating that listeners are able to adapt to new mappings between lexical items and phonetic forms. Due to the similar nature of adaptation to a new talker and adaptation to a new accent, the perception of different accents has been characterized by some as an extreme case of talker normalization (e.g., Nygaard & Pisoni, 1998).

In addition to unfamiliar accents and talkers, listeners must adapt to global shifts in the phonetic characteristics of their own dialect community over time (Labov, 1994). Although some aspects of language change undoubtedly arise when children acquire a linguistic system that differs slightly from that of the previous generation (Senghas & Coppola, 2001; Singleton & Newport, 2004; Slobin, 1977), language change has also been documented within individual talkers, indicating that it is not strictly an intergenerational process (Bauer, 1985; Harrington, Palethorpe, & Watson, 2000; Yaeger-Dror, 1994). Furthermore, this change can be rapidly effected within a single talker on the basis of short-term exposure to phonetically different input: Sancier and Fowler (1997) found that a Portuguese-English bilingual's pronunciation in each language was altered after 6 months in a monolingual (Portuguese or English) setting.

The fact that the phonetic characteristics of language are in a constant state of flux requires that the language processing system be adaptive in nature. There is abundant evidence in the literature on lexical access to indicate that this is indeed the case within the lexicon. The speed of lexical access is well-known to be affected by word frequency, with frequently occurring words being accessed more quickly than low frequency words (for reviews, see Dahan, Magnuson, & Tanenhaus, 2001; Lively, Pisoni, & Goldinger, 1994). To encode frequency, the lexicon, the lexical processing system, or both must be updated each time a word occurs. The speed with which a word is accessed is also influenced by the local context in which the word occurs—a phenomenon known as *priming*. In particular, spoken words are accessed faster if they have been accessed recently or if they follow words that are similar in meaning (see reviews in Grosjean & Frauenfelder, 1996). The phenomena of priming and frequency effects highlight the fact that the language processing system is not static, but rather changes constantly as new input is encountered.

This study examines a case of adaptation in the language processing system induced in a controlled, laboratory setting. Listeners were exposed to a novel accent of English created by systematically altering the pronunciation of particular vowel sounds, and we tested the effects of this exposure on their lexical access. Three recent studies have explored similar issues and therefore it is worthwhile to note how they differ from this study. Clarke and Garrett (2004) presented listeners with English sentences spoken by native speakers of Spanish or Chinese who were late learners of English and thus spoke foreign-accented English. The final word in each sentence was not easily predicted from the preceding semantic or syntactic context. Listeners were asked to judge whether a probe word (presented orthographically on a computer screen) was the same or different from the final word in the sentence. Both error rates and reaction times (RTs) declined with exposure, but both reached control (unaccented) levels within 1 min of exposure. Davis and colleagues (2005) used noise-vocoded speech to determine whether listeners can understand multiword sentences that have been degraded. Over the course of listening to 30 sentences, listeners' word recognition accuracy dramatically improved (from 20%–70%). These effects were driven by lexical status (familiarization to nonwords did not result in the same level of improvement as familiarization to words), and they generalized to words that were not attested in the exposure materials. Floccia, Goslin, Gerard, and Konopczynski (2006), like Clarke and Garrett, measured RT, but the task was lexical decision rather than cross-modal matching, and the stimulus materials were spoken in various regional dialects of French (the listeners' native language) as well as by non-native speakers of French. RT was longer for words that were not produced in the native dialect, and the magnitude of this effect was greater for longer carrier sentences. However, this study found no improvement in performance on non-native dialect stimuli across a block of 32 trials. These results are inconsistent with Clarke and Garrett, and Floccia et al. speculated that this absence of rapid dialect adaptation is because they used multiple talkers, whereas Clarke and Garrett used only one.

The foregoing studies differed in two important ways from the present study. First, in Clarke and Garrett (2004) and Davis et al. (2005) all of the test items were, in fact, real words. Second, adaptation was evidenced by speeded RT, accuracy, or both. Because of these two factors participants in these studies may, in fact, have been performing a task analogous to an ASR system—that is, finding the best match between a degraded input item and stored lexical representations. In the present study, as in Floccia et al. (2006), we tested adaptation via a lexical decision task in which participants were required to judge whether the test items were words or nonwords. Because some of the test items were nonwords, participants could not simply determine which existing lexical item constituted the best match. Instead, they needed to determine whether the input item was sufficiently similar to an existing lexical item to constitute a lexical match. In contrast to all three of the previous studies, which did not isolate the particular phonetic cues that listeners adapted to, we constructed our stimulus set such that we would know precisely what sort of phonetic adaptation occurred in the participants' lexicons in response to exposure to the accent. Furthermore, unlike the previous three studies, we wanted to test for qualitative changes in listeners' acoustic–phonetic mapping. In particular, this study sought to test whether exposure to accented stimuli could actually alter the lexical status of certain stimuli; that is, whether listeners could adapt such that stimuli originally perceived to be nonwords would come to be perceived as words.

Although dialectal variations can involve wholesale shifts in the entire vowel space (i.e., all vowels are remapped to some extent, and the remapping is applied to all lexical items), this need not be the case. Adaptation could be applied only to specific regions of the vowel space, to a specific subset of vowels within or across different regions of the vowel space, or to specific lexical items that have been encountered by a listener exposed to the novel dialect. The goal of this study was to examine the specificity of adaptation to a novel dialect. To examine changes in how acoustic–phonetic information maps onto lexical items, we exposed listeners to a 20-min passage of speech produced with a novel accent. We then tested whether they subsequently judged phonetic forms to be words when these forms would be mapped to nonwords in their normal (unaccented) dialect. In Experiment 1, we shifted only some of the vowels and tested for the specificity of vowel adaptation, across both adapted and unadapted regions of the vowel space; and we tested for generalization to words that were not presented during adaptation. In Experiment 2, we performed the same vowel adaptation, but utilized test words with vowels shifted in the opposite direction within the vowel space to rule out the possibility that adaptation was simply a relaxation of the criterion for what constitutes a vowel category.

2. Experiment 1

This experiment was conducted in two sessions that occurred on different days. In Session 1, participants listened to a story (a modified version of the "Wizard of Oz") spoken in a standard American English accent (normal English [NE]) for approximately 20 min, and subsequently completed an auditory lexical decision task. In Session 2, they heard the same story spoken by the same voice, but the pronunciation was altered to simulate a different accent (lowered vowel accent [LVA]). They then completed an identical lexical decision task as in Session 1. Critically, some of the items in the lexical decision task were constructed such that the same phonetic form would be heard as a nonword in NE (e.g., *wetch*) but would correspond to a real word in LVA (i.e., *wetch* → "witch"). If exposure to 20 min of accented input enables listeners to learn a new mapping between phonetic forms and lexical items, participants' responses to these critical items should indicate that they are nonwords in Session 1, but words in Session 2.

2.1. Method

2.1.1. Participants

Fifteen undergraduate students at the University of Rochester participated in the study. They were paid $20 for their participation in two 45-min sessions.

2.1.2. Stimuli

The artificial accent was created by lowering front vowels in F1–F2 vowel space, such that the vowel /i/ was produced as [I], /I/, as [ɛ], /ɛ/ as [æ], and /æ/ as [a]. The diphthong /e^{i}/ was produced as [ɛ^{I}], and /a/ (a low central vowel) was unaltered, resulting in a merger with /æ/. Both the familiarization story and the test stimuli were produced by the MacinTalk speech synthesizer, using the text-to-speech application Speaker 1.14 (voice: Bruce), speaking in an Inland North accent. The LVA stimuli were spoken in the same voice, but the pronunciation was altered from NE by editing the program's custom dictionary such that the text entries for words containing front vowels were associated with phonetic representations in which the vowels were lowered (e.g., the phonetic representation for the word *witch* was changed from [witʃ] to [wɛtʃ], and likewise for all other words containing front vowels). Average changes in formant frequencies for test items that occurred in both NE and LVA are provided in Appendix A.

Five types of stimuli were included in the lexical decision task. The critical test-item comparison was between NE words with a non-lowered front vowel (e.g., *witch*; henceforth, “Witch” items) and items with a lowered front vowel (e.g., *wetch*; henceforth, “Wetch” items), which would correspond to nonwords in NE but words in LVA. We predicted that in Session 1 participants would indicate that Wetch items were nonwords, whereas in Session 2 there would be an increase in endorsement rate (i.e., “word” responses) for these items. For Witch (i.e., unshifted) items, there are two possible response patterns. If exposure to LVA results in a downward shift of participants’ entire front vowel space, then Witch items should become less word-like in Session 2, and we should see a reduction in “word” endorsement rates. Alternatively, listeners may expand their vowel space to include both normal and shifted phonetic forms. If this is the case, participants should indicate that Witch items are words in both Sessions 1 and 2. Words containing the vowels /e^{i}/ and /a/ were not included in the test items due to the fact that the first is a diphthong and the second was unshifted.

The remaining three item types were comprised of words containing no front vowels. One set included real words with no vowel shift (e.g., *girl*; henceforth, “Girl” items), another included items similar to NE words but with lowered non-front vowels (e.g., *loke*, cf. real word *look*; henceforth, “Loke” items), and the final set included items similar to NE words but with raised non-front vowels (e.g., *tuke*, cf. real word *took*; henceforth, “Tuke” items). Lowered and raised back-vowel items were created by adding words to the Speaker 1.14 dictionary with custom phonetic representations (e.g., the item *loke* was associated with the phonetic representation [lok]). Because these last three item types did not contain front vowels, we predicted that responses would not change between Sessions 1 and 2 for Girl and Tuke items in which vowels are unaltered or raised, respectively. We also predicted that if listeners shift their entire vowel space, rather than just the front vowels, there should be an increase in endorsement rate for Loke items from Session 1 to Session 2.

Stimulus sets were comprised of 48 items each. Witch, Wetch, and Girl items were each comprised of 24 words that occurred in the story (trained items) and 24 words that did not occur in the story (generalization items). For Witch and Wetch items, the trained items were phonetic forms that occurred in the story during only one of the two sessions. For example, the phonetic form *witch* occurred during Session 1 but not during Session 2 (because *witch* is not an appropriate phonetic form in LVA); and the phonetic form *wetch* occurred only during Session 2 (because it is a word in LVA but not in NE). Because Girl items did not include any front vowels, the pronunciation of these words did not change between Sessions 1 and 2. Generalization items never occurred during either session. Loke and Tuke items never occurred in either session because they constituted nonwords in both NE and LVA.

Because of constraints on the available set of trained items (i.e., needing to be words that actually occurred in the story), the trained items for Witch and Wetch item sets included many of the same lexical items (albeit with different pronunciations); for example, the Witch set included *witch,* whereas the Wetch set included *wetch*. This was true for 14 out of 24 items in each set. The full set of test stimuli is given in Appendix B.

Test items were also balanced for word frequency such that for each set of stimuli one half of the items were high-frequency words, and one half were low-frequency words. For trained items, frequency of occurrence was intentionally confounded between story occurrence and actual occurrence—that is, trained high-frequency words were words that occurred with a high frequency in English (>100 in the Kucera–Francis database), and also occurred several (7–10) times during the story. Trained low-frequency words were words with a low frequency of occurrence in English (<10 in the Kucera–Francis database), and occurred infrequently (1–2 times) during the story. Frequency was confounded in this manner because the set of possible trained front-vowel items was too small to counterbalance frequency of English versus story occurrence.[1]

2.1.3. Procedure

The experiment was conducted in two sessions. Session 2 took place 1 to 3 days following Session 1. Both sessions were conducted on a Macintosh G4 computer, with stimulus presentation controlled by Psyscope (Cohen, MacWhinney, Flatt, & Provost, 1993). Participants listened through Sennheiser HD580 headphones to a 20-min story spoken by a synthetic voice. Following the story, participants were given instructions spoken by the same voice to complete a lexical decision task in which they would hear auditory stimuli and press a button on a button box to indicate whether each stimulus was a word or a nonword. There was a 2-sec window for a response, after which the next test item was presented. Participants were instructed to respond quickly but without sacrificing accuracy. Both response type (word vs. nonword) and RT were recorded. Items from all five stimulus sets were presented in random order for a total of 240 test items.

Session 2 was virtually identical to Session 1. However, without informing participants, the synthetic voice now told the same 20-min story in LVA rather than NE.[2] Participants then completed a lexical decision task identical to that of Session 1.

2.2. Results

We analyzed endorsement rate (i.e., percentage of "word" responses) and RT for each item type.

2.2.1. Endorsement rates

Average endorsement rates are shown in Table 1. A repeated measures analysis of variance (ANOVA) conducted on endorsement rates revealed a significant effect of item type, both by subjects and by items: $F_s(4, 56) = 205.41$ and $F_i(4, 92) = 108.43$, ps $< .001$, respectively. The main effect of session was also significant by both subjects and items, $F_s(1, 14) = 117.57$ and $F_i(1, 23) = 133.532$, ps $< .001$, respectively; with overall endorsement rates increasing from 53% to 61% between Sessions 1 and 2. The finding of a significant interaction between item type and session, $F_s(4, 56) = 54.92$ and $F_i(4, 92) = 12.140$, ps $<.001$, respectively, was followed by paired comparisons within each item type across Sessions 1 and 2 (see difference scores in Fig. 1). Significant increases in endorsement were found for Wetch items, $t_s(14) = 11.51$, $p < .001$; as well as for Girl items, $t_s(14) = 2.36$, $p < .05$; and Loke items, $t_s(14) = 2.94$, $p < .05$, by subjects—and for all item sets when analyzed by items: $t_{\text{witch}}(23) = 2.12$, $p < .05$; $t_{\text{wetch}}(23) = 7.42$, $p < .001$; $t_{\text{girl}}(23) = 2.49$, $p < .05$; $t_{\text{loke}}(23) = 4.89$, $p < .001$; $t_{\text{tuke}}(23) = 2.57$, $p < .05$. To test whether the increase in endorsement rate was greater for Wetch items than for the other item types, we conducted separate ANOVAs comparing

Table 1
Experiment 1: Endorsement rates and reaction time for "word" responses (in milliseconds)

Variable	Witch items: Unaltered front vowel	Wetch items: Lowered front vowel	Girl items: Unaltered non-front vowel	Loke items: Lowered non-front vowel	Tuke items: Raised non-front vowel
Endorsement rate, Session 1	90.5% (2.6)	39.4% (4.6)	83.2% (4.1)	24.8% (3.9)	28.7% (4.7)
Endorsement rate, Session 2	93.0% (2.4)	59.0% (3.8)	87.3% (3.1)	34.0% (5.4)	30.9% (5.2)
Reaction time, Session 1	372 (22)	541 (51)	433 (25)	612 (44)	559 (34)
Reaction time, Session 2	304 (19)	423 (37)	356 (24)	555 (55)	490 (40)

Note. Standard errors are shown in parentheses.

the Wetch (shifted) and Loke (unshifted) item sets because the Loke set had the second largest increase in endorsement rate, and found a significant interaction between item type and session: $F_s(1, 14) = 11.513$, $p < .005$; $F_i(1, 23) = 6.825$, $p < .05$.

To confirm that the increase in endorsement rate for Wetch items was truly due to participants having learned a general fact about the accent (i.e., that front vowels were lowered), rather than simply having gained familiarity with unusual pronunciations for particular words, we conducted an additional paired comparison on just those Wetch items that had not occurred in the story (generalization items), for Session 1 versus Session 2, again finding a significant increase in endorsement rate in analyses both by subject and item: $t_s(14) = 4.452$, $p = .001$; $t_i(23) = 4.419$, $p < .001$.

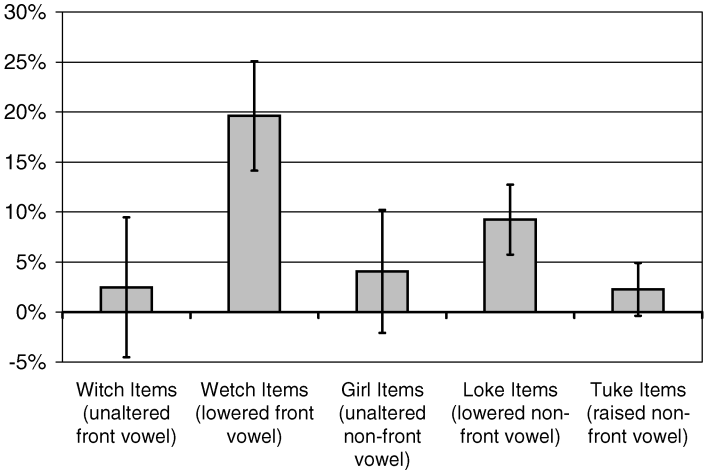

Fig. 1. Experiment 1: Difference in endorsement rates from Session 1 to Session 2. *Note*. Error bars represent one standard error.

To test the specificity of the effect of exposure to an accent in which only front vowels were lowered, we compared responses to the Loke and Tuke item sets, comprised of nonwords (in both NE and LVA) in which back vowels from real words had been lowered and raised, respectively. ANOVAs conducted over these two item sets (by subject and item) revealed a significant interaction between item type and session—$F_s(1, 14) = 5.714$ and $F_i(1, 23) = 4.574$, $ps < .05$, respectively—indicating that the 9.2% increase in endorsement rate for Loke (i.e., lowered) items exceeded the 2.2% increase for Tuke (i.e., raised) items.

2.2.2. RT data

Analyses of RT typically include only correct responses. Due to the nature of this experiment, and the fact that all potential nonword items differed from real words only by raising or lowering a vowel, there was no opportunity for unambiguously incorrect responses, making it impossible to determine which trials truly constituted response errors. Thus, we analyzed RTs for all "word" responses to each item type.

A repeated measures ANOVA conducted over RT data for "word" responses revealed a significant effect of session, $F_s(1, 14) = 12.387$, $p < .005$ and $F_i(1, 37) = 33.3$, $p < .001$; as well as an effect of item type, $F_s(4, 56) = 37.572$ and $F_i(4, 148) = 17.958$, $ps < .001$, respectively. RT decreased between Sessions 1 and 2, averaging 483 msec ($SE = 25$ msec) and 401 msec ($SE = 27$ msec), respectively. Average RTs for each item type are shown in Table 1, with generally higher RTs for Loke and Tuke items (lowered and raised back vowels), as well as for Wetch item responses during Session 1, which is likely a reflection of many of these responses being truly erroneous (i.e., accidental presses of the unintended button). There was, however, no interaction between session and item type, $F_s(4, 56) < 1$ and $F_i(4, 148) = 1.158$, *ns,* respectively; thus, no further pairwise comparisons were conducted. This failure to find evidence of accent adaptation in the RT data may be due to our inability to exclude erroneous trials.

2.3. Discussion

The significant increase in endorsement for lowered front-vowel items (i.e., Wetch items) indicates that listening to the accented story during Session 2 caused participants to admit certain phonetic forms as words that they had indicated were nonwords during Session 1. In particular, the items with the largest increase in endorsement rate were just those items that demonstrated the change in accent; namely, items that differed from NE in that their front vowel had been lowered, such as *wetch.*

The fact that these effects were significant even for items that had not occurred in the story indicates that participants learned the general phonetic characteristics of the accent (i.e., that front vowels are lowered), rather than simply memorizing those items they had heard pronounced with the accent. Of course, in Session 2, the participants *had* heard all of the test items before—namely, during the lexical decision task of Session 1. However, if this brief experience were responsible for driving the effect, we would have seen the same change in responses on the Loke and Tuke items (which differed from real NE words by a raised or lowered *back* vowel), which were also heard as nonwords in Session 1. Although all item sets showed some increase in endorsement, the fact that the increase in endorsement rate for

Wetch items significantly exceeded that of the other sets indicates that this change was driven by the participants' acquisition of the accent.

Although the largest effect was found for lowered front vowel (Wetch) items, we also found evidence for a smaller effect on lowered back vowel (Loke) items. This suggests that exposure to an accent with lowered vowels in one region of the vowel space may result in some small amount of general lowering across the entire vowel space.

An interesting aspect of our results is that participants did not fully alter their vowel system to create a new mapping between phonetic forms and lexical items after listening to LVA. If they had, the phonetic form *witch* should now correspond to the (non-existent) lexical item "weech," resulting in a nonword response. In fact, all Witch items were chosen such that raising the vowel would create a nonword (like *witch* $\sim$ weech). However, the lack of change in responses to such items from Session 1 to Session 2 indicates that participants did not completely remap their vowel space. Rather, after exposure to LVA, they simply accepted both accented and standard pronunciations. This finding raises the possibility that what participants learned was not that front vowels in LVA are lowered compared to NE, but rather that front vowels are pronounced oddly—that is, they may simply have allowed for more noise or a broadening in their front vowel categories. To test between these two possibilities, we conducted a second experiment in which the lexical decision task included raised, rather than lowered front vowel test items.

3. Experiment 2

This experiment was identical to Experiment 1, except that during the lexical decision task the Wetch (lowered front vowel) items were replaced with Weech items with raised front vowels (see Appendix A). That is, participants again listened to a story produced in NE during Session 1 and in LVA with lowered front vowels during Session 2. The post-exposure lexical decision task, however, contained test items with raised rather than lowered front vowels (with all other stimulus sets remaining identical to Experiment 1). If the effect of listening to the accented story is that participants simply relax their criterion for what constitutes an acceptable member of each front vowel category, then raised front-vowel items ought to become more word-like after listening to the lowered front vowel accent, just as lowered front-vowel items changed in Experiment 1. If, however, the effect is only in the specific direction of the accent, there should be no significant change in participant responses to raised vowel test items.

3.1. Method

3.1.1. Participants

Eighteen undergraduate students from the University of Rochester participated in this study, none of whom had participated in Experiment 1. They were paid $20 for their participation.

3.1.2. Stimuli

We used the same exposure stimuli from Experiment 1, but during the test replaced the lowered front vowel Wetch items with Weech items in which front vowels were raised (e.g., *weech* → "witch"). Twenty-four items were raised-vowel versions of words that occurred in the story (trained items),[3] and 24 were raised-vowel versions of words that did not occur in the story (generalization items). The new stimuli were created in the same manner as in Experiment 1.

3.1.3. Procedure

The procedure was identical to Experiment 1. Participants were exposed to NE in Session 1 and LVA (still with lowered front vowels) in Session 2. During each session, this exposure was followed by an auditory lexical decision task identical to Experiment 1, with the exception that Wetch items were replaced by Weech items.

3.2. Results

3.2.1. Endorsement rates

Data were analyzed in the same manner as Experiment 1. Average endorsement rates for Experiment 2 are shown in Table 2. A repeated measures ANOVA conducted on endorsement rates revealed a significant effect of item type, both by subjects and by items, $F_s(4, 68) = 331.53$ and $F_i(4, 92) = 95.91$, *p*s < .001, respectively; and a significant effect of session, $F_s(1, 17) = 9.08$, $p < .01$ and $F_i(1, 23) = 45.12$, $p < .001$; with overall endorsement increasing from 66% to 70% between Sessions 1 and 2. However, there was no interaction between item type and session—$F_s(4, 68) = 1.18$ and $F_i(4, 92) = 1.75$, *ns,* respectively—indicating that the item sets did not differ in the size of their endorsement rate increase (see difference scores in Fig. 2). Pairwise comparisons within each item type across Sessions 1 and 2 found significant increases in endorsement for Girl, Loke, and Weech item sets by subjects: $t_{\text{girl}}(17) = 2.46$; $t_{\text{loke}}(17) = 2.37$; $t_{\text{weech}}(17) = 2.26$, *p*s < .05, respectively—and for Witch, Loke, Tuke, and

Table 2
Experiment 2: Endorsement rates and reaction time for "word" responses (in milliseconds)

Variable	Witch items: Unaltered front vowel	Weech items: Raised front vowel	Girl items: Unaltered non-front vowel	Loke items: Lowered non-front vowel	Tuke items: Raised non-front vowel
Endorsement rate, Session 1	90.3% (1.7)	63.8% (2.5)	81.3% (2.2)	32.3% (2.8)	26.7% (3.1)
Endorsement rate, Session 2	91.9% (1.6)	68.6% (2.6)	84.7% (2.3)	39.1% (3.0)	30.4% (3.0)
Reaction time, Session 1	380 (18)	459 (20)	414 (17)	584 (29)	577 (36)
Reaction time, Session 2	322 (25)	418 (25)	352 (25)	494 (37)	493 (32)

Note. Standard errors are shown in parentheses.

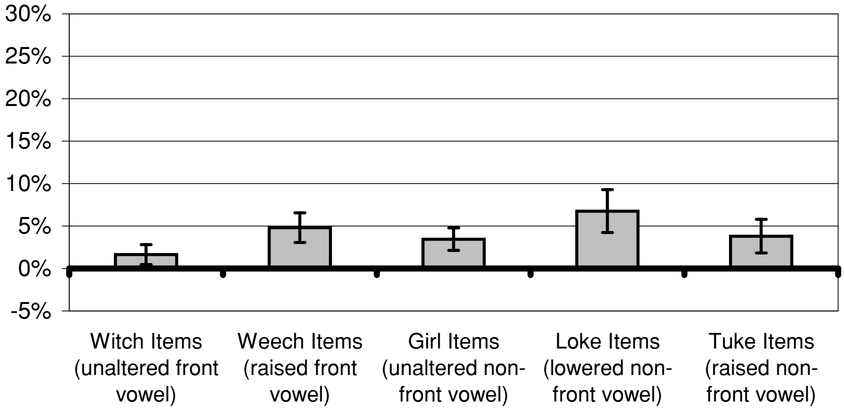

Fig. 2. Experiment 2: Difference in endorsement rates from Session 1 to Session 2. *Note*. Error bars represent one standard error.

Weech item sets by items: $t_{\text{witch}}(23) = 2.38$, $p < .05$; $t_{\text{loke}}(23) = 3.07$, $p = .005$; $t_{\text{tuke}}(23) = 4.49$, $p < .001$; $t_{\text{weech}}(23) = 2.38$, $p < .05$. An ANOVA comparing performance on Wetch and Weech item sets across the two experiments showed a significant interaction between experiment and session, $F_s(1, 31) = 19.20$ and $F_i(1, 46) = 27.81$, ps $< .001$, respectively; confirming that the adaptation effect was specific to the direction of the shift in the vowel space.

One surprising difference between Experiments 1 and 2 is that the baseline, Session 1 endorsement rate for Weech items in Experiment 2 was higher than for Wetch items in Experiment 1 (64% and 39%, respectively)—that is, the raised front-vowel items were heard as more word-like than the lowered front-vowel items prior to exposure to the accented story. This difference in the two item sets may have been due to the fact that all 24 of the trained Weech items were analogs of the 24 trained Witch items, whereas only 14 of the trained Wetch items were analogs of Witch items (see Footnote 3). This explanation is supported by the fact that Wetch items that *were* analogous to Witch items received Day-1 endorsement rates comparable to the Weech items (62%). Furthermore, the increase in endorsement for this subset of Wetch items (to 83%) was significant, $t(13) = 4.66$, $p < .001$; whereas for the same subset of Weech items endorsement rates actually decreased (from 75%—70%),$t(13) = 3.15$, $p < .01$.

To determine whether adaptation to the lowered front vowels of the accent generalized to back vowels at test, we again compared the Loke and Tuke item sets for Experiment 2 (lowered vs. raised back vowels), but found no interaction between item set and session: $F_s(1, 17) = 1.23$ and $F_i(1, 23) < 1$, *ns*, respectively. This result casts doubt on our finding from Experiment 1 that endorsement rates for Loke items showed a somewhat larger increase than those for Tuke items. The lack of a significant difference between raised and lowered back-vowel items in Experiment 2 suggests that the apparent generalization to back vowels seen in Experiment 1 was spurious—a conclusion that is further supported by the fact that the effect size for Wetch items was considerably larger than the effect size for Loke items.[4]

One possible explanation for this difference between the two experiments is that exposure to raised front-vowel items during the lexical decision task in Experiment 2 inflated the endorsement rates for raised back-vowel items, nullifying the difference between raised and lowered back-vowel items. However, if exposure to raised back-vowel items during the test phase did inflate the endorsement rate of these items, we would still expect that 20 min of exposure to lowered vowels in a meaningful story prior to the lexical decision task would have a larger effect than exposure during the test itself.

3.2.2. RT data

Again, we analyzed only RTs for "word" responses to each item type. A repeated measures ANOVA conducted over RT data for "word" responses revealed a significant effect of session, $F_s(1, 17) = 7.65$, $p < .05$ and $F_i(1, 23) = 52.04$, $p < .001$; as well as an effect of item type, $F_s(4, 68) = 45.77$, $p < .001$ and $F_i(4, 92) = 22.08$, $p < .001$. RT decreased between Sessions 1 and 2, averaging 458 msec ($SE = 22$ msec) and 396 msec ($SE = 19$ msec), respectively. Again, RTs were generally higher for Loke and Tuke items (lowered and raised back vowels). Once again, there was no interaction between session and item type (both $F\text{s} < 1$, *ns*); thus, no further pairwise comparisons were conducted.

3.3. Discussion

The results from Experiment 2 confirm that listening to the accented story results in a change in the specific direction of the accent, rather than simply relaxing the criterion for what constitutes a good exemplar for the front vowel categories. Exposure to an accent in which front vowels were systematically lowered did not increase endorsement rates for items with raised front vowels. In this experiment, we found no evidence for a generalization of the lowering effect to back vowels, suggesting that this result in Experiment 1 may have been spurious. In any case, the adaptation to lowered front vowels far exceeded the increases in endorsement rates for any of the other item sets, indicating that adaptation was driven by the specific properties of the accented input and not by a broadening of the criterion for what constitutes a vowel category.

4. General discussion

This pair of experiments demonstrates systematic changes in the mapping of acoustic–phonetic input to lexical representations. Under typical listening conditions, where dialects are largely uniform among a community of talkers, the lexicon appears static because most occurrences of words reinforce already established phonetic forms. However, common experience suggests that listeners can adjust their interpretation of altered phonetic forms when listening to a talker who speaks a different dialect. Here we document that these adjustments can be made within 20 min of listening experience, as assessed by performance on a lexical decision task. Our results are consistent with those of Clarke and Garrett (2004) and Davis et al. (2005); but, rather than a simple change in the speed of lexical access for accented English, we document that the altered phonetic forms were judged to be acceptable lexical items only after exposure to the accented story. In contrast to Floccia et al. (2006), we found clear evidence for adaptation.

Although this study involved only one voice, evidence suggests that adaptation can generalize to new talkers with a similar accent (Clarke, 2003; Kraljic & Samuel, 2006). Furthermore, the fact that listeners are able to comprehend multiple accents (Clopper & Bradlow, 2006; Labov & Ash, 1997; Mason, 1946), as well as our finding that participants accepted both standard and accented pronunciations of words, suggests that it is possible to develop and maintain more than one mapping (e.g., bilingual, bi-dialectal, native- vs. foreign-accented, etc.). However, Floccia et al. (2006) found little evidence of adaptation when the exposure consisted of more than a single talker, suggesting that learning two talker-specific accents simultaneously may be more difficult than learning a single talker's accent. The issue of whether and how these dual representations interact is a question for future research. In some instances there may be word-specific mappings, wherein a listener encodes multiple phonetic forms for a particular lexical item. In this study, the fact that adaptation generalized to novel lexical items is inconsistent with a purely lexical-based hypothesis, indicating that it is possible to shift the mapping between word meanings and their phonetic instantiation across the entire lexicon.

The vowel shift employed in this study affected the entire set of front vowel categories and was not specific to a particular phonological context. However, it is not uncommon for vowel shifts to be restricted to particular phonological contexts. For example, in certain Canadian and American dialects of English vowels are raised before voiceless consonants but not before voiced consonants (Clarke et al., 1995; Labov, Ash, & Boberg, 2006), a phenomenon known as "Canadian raising." In the South and Midland dialects of American English there is a merger of mid- and high front vowels before nasal consonants (sometimes referred to as the *pin–pen* merger; Labov et al., 2006). It would be interesting for future research to explore adaptation to context-specific vowel shifts of this sort because context-specific adaptation would suggest a change in the listener's phonological system rather than simply a shift in acoustic–phonetic mapping. Studies of artificial phonotactic learning have found that listeners can readily acquire novel phonotactic rules that are specific to a particular phonological context (Dell, Reed, Adams, & Meyer, 2000; Onishi, Chambers, & Fisher, 2002), which suggests that listeners might also readily adapt to a novel dialect employing context-specific shifts.

These results add to the body of research suggesting that the lexical processing system not only undergoes change when new words are added to the lexicon or new meanings and usages are added to existing lexical entries, but also when confronted with accented speech. Other evidence suggests that for each word in the lexicon the preferred meaning and syntactic frame are also malleable on the basis of relative frequency of occurrence (Garnsey, Pearlmutter, Myers, & Lotocky, 1997; Trueswell, Tanenhaus, & Kello, 1993). Taken together, these findings paint a picture of a lexical processing system that is constantly changing, being updated on the basis of new input.

Notes

1. Although both high- and low-frequency items were included in the stimulus set, frequency did not interact with the main effect of session, either across all Wetch items or within just the Wetch generalization items, computed over endorsement rates by both subjects and items (all Fs < 1, *ns*).

2. During debriefing, participants were asked if they noticed any difference between Sessions 1 and 2. None reported noticing any differences (in fact, several complained that the sessions were identical, resulting in participants' loss of interest). When informed that the synthetic voice spoke with different accents during the two sessions, several participants expressed surprise.
3. Because of constraints on stimulus construction, the trained front-vowel item sets (Witch, Wetch, and Weech items) contained as many analogous words as possible (e.g., the items *witch*, *wetch*, and *weech*). It was possible to match all 24 of the Weech items with analogous Witch items, but this was not possible for all of the Wetch items (e.g., lowering the vowel in the item *them* to create *tham* resulted in a phonetic form that was perceived as the real word *than*).
4. We cannot rule out the possibility that this difference in effect size reflects a difference in the perceptual salience of the respective vowel shifts; that is, perhaps the acoustic difference between the shifted back-vowel items and their real word (i.e., unshifted) counterparts (e.g., *look* → loke, *took* → tuke) is simply more perceptually salient than the difference between shifted front-vowel items and their normal English counterparts (e.g., *witch* → wetch). If this were the case, the back-vowel items might be more resistant to adaptation. To evaluate this possibility, we compared the formant frequencies and vowel durations of back-vowel items and found that lowered back-vowel items involved a numerically larger average formant shift than the other shifted item types, and both lowered and raised back-vowel items involved a numerically larger vowel duration change than the front-vowel item types. However, none of these differences between front and back vowels was statistically significant. Moreover, it is not possible to evaluate whether these numerical differences are meaningful, given that back-vowel items did not contain matched lexemes (i.e., lowered and non-lowered forms of the same word, such as *look* and *loke*), and thus contained coarticulatory effects on vowels that was not true of the matched front-vowel lexemes we compared (e.g., *witch* vs. *wetch*). We leave it to future research to examine this possibility more thoroughly.

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Appendix A

Average changes in vowel formant frequencies (Hz) and vowel durations (msec) for test stimuli that occurred with both normal and lowered front vowels (Experiment 1), and for stimuli that occurred with both normal and raised front vowels (Experiment 2).

Trained Hi-freq		Trained Lo-freq		Untrained Hi-freq		Untrained Lo-freq	
wɪtʃ	*witch*	sɛntɚ	*center*	lɛvəl	*level*	ʃɛlf	*shelf*
lɪtəl	*little*	sɪlvɚ	*silver*	tɛst	*test*	mɛnju	*menu*
ænt	*aunt*	yɛs	*yes*	fɪlm	*film*	læk	*lack*
wɪkəd	*wicked*	kɪs	*kiss*	mɛθəd	*method*	mɪnt	*mint*
hænd	*hand*	brɪk	*brick*	bɪl	*bill*	dɛnt	*dent*
ðɛm	*them*	dɛzɚt	*desert*	hæpi	*happy*	klæm	*clam*
ɛvɚ	*ever*	yɛlo	*yellow*	sɛvən	*seven*	lɛtəs	*lettuce*
nɛvɚ	*never*	ræn	*ran*	præktɪs	*practice*	rɪst	*wrist*
æsk	*ask*	træp	*trap*	hɛvi	*heavy*	kræft	*craft*
læf	*laugh*	græs	*grass*	fɪʃ	*fish*	fɪn	*fin*
ænsɚ	*answer*	mædʒɪk	*magic*	bætɛl	*battle*	pɛpɚ	*pepper*
æftɚ	*after*	stænd	*stand*	bɛst	*best*	gæp	*gap*

Trained Hi-freq		Trained Lo-freq		Untrained Hi-freq		Untrained Lo-freq	
wɛtʃ	cf. *witch*	kɪp	cf. *keep*	sɪd	cf. *seed*	bɪtəl	cf. *beetle*
lɛtəl	cf. *little*	sɛlvɚ	cf. *silver*	kɛŋ	cf. *king*	wɛg	cf. *wig*
pɪpəl	cf. *people*	stɛl	cf. *still*	bæntʃ	cf. *bench*	kæg	cf. *keg*
lɛv	cf. *live*	kɛs	cf. *kiss*	haf	cf. *half*	mat	cf. *mat*
sɛtɪ	cf. *city*	ræst	cf. *rest*	nɪd	cf. *need*	kælp	cf. *kelp*
gæt	cf. *get*	dæzɚt	cf. *desert*	ʃɛp	cf. *ship*	wæb	cf. *web*
ævɚ	cf. *ever*	yælo	cf. *yellow*	rɛvɚ	cf. *river*	dɛg	cf. *dib*
nævɚ	cf. *never*	fæns	cf. *fence*	dɛnɚ	cf. *dinner*	tʃat	cf. *chat*
ask	cf. *ask*	trap	cf. *trap*	bak	cf. *back*	bɛb	cf. *bib*
man	cf. *man*	gras	cf. *grass*	fast	cf. *fast*	tænt	cf. *tent*
ansɚ	cf. *answer*	madʒɛk	cf. *magic*	tʃɪf	cf. *chief*	damp	cf. *damp*
aftɚ	cf. *after*	past	cf. *past*	dɛmpəl	cf. *dimple*	pæbəl	cf. *pebble*

Appendix B

Stimuli used in lexical decision tasks in Experiments 1 and 2. Each stimulus is given both in the international phonetic alphabet (broadly transcribed) and English spelling (italics). For nonword items, English spelling is given for the English word that the item was matched to.

Trained Hi-freq		Trained Lo-freq		Untrained Hi-freq		Untrained Lo-freq	
gɚl	*girl*	kɔrn	*corn*	hop	*hope*	mɔnark	*monarch*
haʊs	*house*	but	*boot*	muv	*move*	nʌdʒ	*nudge*
dɔr	*door*	sʌn	*sun*	nɔrməl	*normal*	skaʊt	*scout*
wʊmən	*woman*	gro	*grow*	pʊl	*pull*	vaʊtʃ	*vouch*
lɔŋ	*long*	farmɚ	*farmer*	kɔld	*cold*	plajɚz	*pliers*
noz	*nose*	hol	*hole*	fjutʃɚ	*future*	pʌb	*pub*
wʌndɚ	*wonder*	skaj	*sky*	bɔi	*boy*	ʃʌvəl	*shovel*
aj	*eye*	blu	*blue*	sut	*suit*	kʊʃən	*cushion*
ʌŋkəl	*uncle*	rod	*road*	art	*art*	kənu	*canoe*
nɔrθ	*north*	tap	*top*	totəl	*total*	bʌmp	*bump*
ɔld	*old*	to	*toe*	sun	*soon*	stok	*stoke*
no	*no*	najt	*night*	tuθ	*tooth*	wɔrt	*wort*

Hi-freq		Hi-freq		Lo-freq		Lo-freq	
lok	cf. *look*	nʊz	cf. *news*	stʊl	cf. *stool*	swʊn	cf. *swoon*
tʊl	cf. *tool*	ɔpən	cf. *open*	podɪŋ	cf. *pudding*	plʊm	cf. *plume*
tʃʊz	cf. *choose*	prʊv	cf. *prove*	sot	cf. *soot*	rʊʒ	cf. *rouge*
flɔr	cf. *floor*	pot	cf. *put*	skʊtɚ	cf. *scooter*	kwɔt	cf. *quote*
fʊd	cf. *food*	rɔl	cf. *role*	hof	cf. *hoof*	prɔz	cf. *prose*
hɔm	cf. *home*	tʊθ	cf. *tooth*	lɔnɚ	cf. *loner*	pɔtʃ	cf. *poach*
nʊn	cf. *noon*	ʃɔrt	cf. *short*	brʊz	cf. *bruise*	ɔvəl	cf. *oval*
lʊz	cf. *lose*	bʊt	cf. *boot*	krɔm	cf. *chrome*	spʊf	cf. *spoof*
lɔkəl	cf. *local*	sʊn	cf. *soon*	klɔvɚ	cf. *clover*	mʊd	cf. *mood*
bɔk	cf. *book*	ʃʊz	cf. *shoes*	kʊp	cf. *coop*	lʊp	cf. *loop*
frʊt	cf. *fruit*	θrɔ	cf. *throw*	grʊm	cf. *groom*	lɔkəs	cf. *locus*
mɔst	cf. *most*	mɔment	cf. *moment*	dʒʊs	cf. *juice*	lʊm	cf. *loom*

Hi-freq		Hi-freq		Lo-freq		Lo-freq	
tuk	cf. *took*	lost	cf. *lost*	stop	cf. *stop*	lul	cf. *lull*
wotɚ	cf. *water*	lot	cf. *lot*	bruk	cf. *brook*	morvəl	cf. *marvel*
stroŋ	cf. *strong*	modɚn	cf. *modern*	dok	cf. *dock*	rʊb	cf. *robe*
wotʃ	cf. *watch*	mʊst	cf. *most*	blond	cf. *blonde*	moθ	cf. *moth*
bom	cf. *bomb*	ʊvɚ	cf. *over*	dʊs	cf. *dose*	pond	cf. *pond*
klʊz	cf. *close*	rʊd	cf. *road*	foks	cf. *fox*	notʃ	cf. *notch*
drop	cf. *drop*	rok	cf. *rock*	hʊz	cf. *hose*	nozəl	cf. *nozzle*
fut	cf. *foot*	ʃop	cf. *shop*	lodʒ	cf. *lodge*	nul	cf. *null*
gud	cf. *good*	ðʊz	cf. *those*	dʒʊk	cf. *joke*	porsəl	cf. *parcel*
hʊp	cf. *hope*	tʊld	cf. *told*	nob	cf. *knob*	pod	cf. *pod*
hot	cf. *hot*	sʊrs	cf. *source*	lʊfɚ	cf. *loafer*	prʊb	cf. *probe*
loŋ	cf. *long*	sʊʃəl	cf. *social*	mok	cf. *mock*	puls	cf. *pulse*

Trained Hi-freq		Trained Lo-freq		Untrained Hi-freq		Untrained Lo-freq	
witʃ	cf. *witch*	sɪntɚ	cf. *center*	lɪvəl	cf. *level*	ʃɪlf	cf. *shelf*
litəl	cf. *little*	silvɚ	cf. *silver*	tɪst	cf. *test*	mɪnju	cf. *menu*
ɛnt	cf. *ant*	yɪs	cf. *yes*	film	cf. *film*	mint	cf. *mint*
wikəd	cf. *wicked*	kis	cf. *kiss*	mɪθəd	cf. *method*	dɪnt	cf. *dent*
hɛnd	cf. *hand*	brik	cf. *brick*	bil	cf. *bill*	klɛm	cf. *clam*
ðɪm	cf. *them*	dɪzɚt	cf. *desert*	hɛpi	cf. *happy*	lɪtəs	cf. *lettuce*
ɪvɚ	cf. *ever*	yɪlo	cf. *yellow*	sɪvən	cf. *seven*	rist	cf. *wrist*
nɪvɚ	cf. *never*	rɛn	cf. *ran*	prɛktis	cf. *practice*	krɛft	cf. *craft*
ɛsk	cf. *ask*	trɛp	cf. *trap*	hɪvi	cf. *heavy*	fin	cf. *fin*
lɛf	cf. *laugh*	grɛs	cf. *grass*	fiʃ	cf. *fish*	pɪpɚ	cf. *pepper*
ɛnsɚ	cf. *answer*	mɛdʒik	cf. *magic*	bɛtəl	cf. *beetle*	gɛp	cf. *gap*
ɛftɚ	cf. *after*	stɛnd	cf. *stand*	giv	cf. *give*	kilt	cf. *kilt*