# A PERCEPTUAL STUDY OF VOWELS BEFORE /r/

Joshua Guenter, Julie A. Lewis, and Margaret Urban
*University of California, Berkeley, USA*

**ABSTRACT**

Phonemic categorization of the "R-colored vowels" has been approached in many different ways. This experiment provides comprehensive data from vowel similarity judgments made by California English speakers. The results of this experiment support the classification of these vowels as monophonemic diphthongs akin to /aj aw/. In the same experiment, we also investigate the phonological status of vowels before /l/ and /ŋ/.

## 1. INTRODUCTION

The status of the vowels found before /r/ in American English has been difficult for linguists to describe. Research by Lehiste shows that the formant frequencies of these vowels (usually called the "R-colored vowels"), as in the words *steer, your, lair, lore* and *bar*, are different from those of vowels found before other consonants [1]. For example, the vowel in *steer* is between /i/ and /ɪ/, the vowel in *your* is between /u/ and /ʊ/, the vowel in *lair* is between /ej/ and /ɛ/, and the vowel in *lore* is between /ow/ and /ɔ/. However, that in *bar* is similar to /ɑ/.

Subsequently, the phonological categorization of these vowels is not clear, and multiple analyses have been proposed. Lehiste categorizes them with the lax vowels /ɪ ɛ ʊ ɔ ɑ/ because their production involves a short target position and long final transition, as opposed to the tense vowels like /i ej u ow/ whose production involves a long target position and short final transition. Akmajian *et al.* also categorize them with the lax vowels, reasoning that the tense vowels are better exemplified with those in words such as *seer, player, doer, mower* [2]. On the other hand, Kreidler considers the vowels in the words *ear, chair, door, star* to have the same nuclei as the tense vowels in *tree, day, toe, spa* [3]. Harris considers the problem a matter of open-syllable neutralization, which could be interpreted as archiphonemic neutralization, or as categorizing the R-colored vowels with the tense vowels, which are the only ones found in open syllables in English [4]. De Camp considers /Vr/ sequences in words like *far, ear* to be monophonemic diphthongs akin to /aj aw/ on the grounds that the first elements in these sequences are similar in having variable phonetic realizations, and in not being readily assignable to the monophthongal phonemes of English [5].

In order to shed light on this debate, it would be useful to have experimental data in order to show how native speakers of American English psychologically categorize these sounds with respect to other vowel phonemes which are less difficult to categorize. We believe that that the data gathered from such an experiment will support De Camp's claim, that /Vr/ sequences in words such as *ear, far* are best analyzed as monophthongal diphthongs akin to /aj aw/.

## 2. PROCEDURE

Eighteen subjects were played a list of 130 pairs of common monosyllabic English words. The words were spoken by a 26-year-old female native speaker of California English. Between the words in each pair was a gap of 0.5 seconds.

A characteristic of the modern California dialect of American English is the lack of contrast between the /ɑ/ and /ɔ/ phonemes of General American. Hence, words like *tot* and *taught* are homonyms. This dialect only contrasts four vowels before /r/, as exemplified in the words *ear, air, are,* and *ore*. We will transcribe these vowels as [Ir Er Ar Or]. This dialect makes no distinction between the vowels /ʊ o ɔ/ before /r/, hence *boor, bore,* and *boar* are homonyms.

All subjects in this experiment were native speakers of California English between the ages of 18 and 25. Some had some basic training in linguistics, but none had extensive classroom exposure to phonetics or to any discussion of the problem at hand.

Subjects indicated, by pressing appropriate keys on a computer keyboard, whether they thought the vowels in the two words in the pair were the same or different. They were told explicitly to make this determination on the basis of the sound, not the spelling, and to decide only if the vowels were the same, not whether the words rhymed. Subjects' *Yes/No* responses (*Yes* meaning that the words were judged to have the same vowel, *No* meaning that the words have different vowels) and response times were recorded. Response times were measured from a tag 0.2 seconds from the end of the second word in each pair. Subjects were first given a training set of 30 pairs in order to familiarize them with the procedure, and to determine if there was any strong orthographic bias.

Responses were put into four categories: *Yes, No, Delayed Yes,* and *Delayed No*. A *Delayed* response was defined as one having a response time greater than two standard deviations from that subject's mean.

The word pairs fell into several different categories. One set (set SS) contained words with the same vowel phoneme and same coda consonant, such as *freight/gate*. Another set (set SD) contained words with the same vowel phoneme and a different coda consonant, such as *pup/bud*. A third set (set D) had words with different vowel phonemes such as *bite/gate*. There was also a set (set M) containing words with the same vowel phoneme, with the first word having the coda consonant /m/ in all situations.

The test set (set R) consisted of words with similar vowel nuclei, but with the first word containing the coda consonant /r/. The following sounds were matched within the pairs: [Ir] with /i/ and /ɪ/, [Er] with /ej/ and /ɛ/, [Ar] with /ɑ/, and [Or] with /ow/ and /ɑ/ (as mentioned above, California English lacks a contrast between /ɑ/ and /ɔ/). We also tested the vowel [ɚ] as in *bird* with /ʌ/, /ɛ/, and /ʊ/. The pairs were chosen in order to compare the R-colored vowels with their nearest non-rhotic counterparts, based on acoustic data from Lehiste [1]. Hence, the test set consisted of pairs split into ten groups: {Ir-i}, {Ir-ɪ}, {Er-ej}, {Er-ɛ}, {Ar-ɑ}, {Or-ow}, {Or-o}, {ɚ-ʌ}, {ɚ-ɛ}, and {ɚ-ʊ}.

## 3. RESULTS

### 3.1. Vowels before /r/

The results (these results and all results discussed in this paper are presented in Table 1) are as follows: The word pairs in set SS had 96% *Yes* responses. The word pairs in set SD had 90% *Yes* responses, showing that there is a slight effect of different coda consonants on categorization. Those in set D had 94% *No* responses. None of these groups had higher than 2% *Total Delayed* responses. Thus, the results are consistent with a phonemic framework. Word pairs

having the same vowel phoneme were strongly identified with a *Yes*. Words with different vowel phonemes were strongly identified with a *No*.

Some of the words in set R showed a similar categorization pattern with the clearly different-vowel phonemes in set D. The {Ir-ɪ} group (*beer/bit, beer/bid*) had 97% *No* responses. Likewise, the {Er-ej} group (*bear/gate, bear/spade*) had 100% *No* responses. All pairs involving /ɚ/ also patterned with set D.

| Set | Group | *Yes* | *No* | *Delayed Yes* | *Delayed No* | *Total Yes* | *Total No* | *Total Delayed* |
|---|---|---|---|---|---|---|---|---|
| SS | all | 96 | 3 | 1 | 0 | 97 | 3 | 1 |
| SD | all | 90 | 9 | 1 | 0 | 91 | 9 | 1 |
| D | all | 3 | 94 | 1 | 2 | 4 | 96 | 3 |
| R | {Ir-i} | 59 | 34 | 3 | 6 | 62 | 39 | 9 |
| " | {Ir-ɪ} | 3 | 97 | 0 | 0 | 3 | 97 | 0 |
| " | {Er-ej} | 0 | 100 | 0 | 0 | 0 | 100 | 0 |
| " | {Er-ɛ} | 23 | 56 | 9 | 14 | 31 | 70 | 22 |
| " | {Or-ow} | 28 | 50 | 14 | 9 | 42 | 58 | 22 |
| " | {Or-ɑ} | 0 | 92 | 3 | 6 | 3 | 97 | 9 |
| " | {Ar-ɑ} | 17 | 78 | 6 | 0 | 23 | 78 | 6 |
| " | {ɚ-ʌ} | 9 | 83 | 0 | 9 | 9 | 92 | 9 |
| " | {ɚ-ʊ} | 6 | 94 | 0 | 0 | 6 | 94 | 0 |
| " | {ɚ-ɛ} | 0 | 97 | 0 | 3 | 0 | 100 | 3 |
| L | {il-i} | 64 | 20 | 9 | 9 | 72 | 28 | 17 |
| " | {ɪl-ɪ} | 56 | 31 | 9 | 6 | 64 | 36 | 14 |
| " | {ejl-ej} | 62 | 36 | 3 | 0 | 64 | 36 | 3 |
| " | {ɛl-ɛ} | 30 | 65 | 4 | 2 | 33 | 67 | 6 |
| " | {owl-ow} | 61 | 17 | 17 | 6 | 78 | 22 | 22 |
| " | {ɑl-ɑ} | 44 | 56 | 0 | 0 | 44 | 56 | 0 |
| " | {ʊl-ʊ} | 20 | 72 | 3 | 6 | 23 | 78 | 9 |
| " | {ʌl-ʌ} | 42 | 45 | 3 | 11 | 45 | 56 | 14 |
| NG | {ing-i} | 17 | 83 | 0 | 0 | 17 | 83 | 0 |
| " | {ing-ɪ} | 28 | 67 | 6 | 0 | 33 | 67 | 6 |
| " | {eng-ej} | 25 | 70 | 3 | 3 | 28 | 72 | 6 |
| " | {eng-ɛ} | 20 | 67 | 6 | 9 | 25 | 75 | 14 |
| " | {ang-ej} | 39 | 61 | 0 | 0 | 39 | 61 | 0 |
| " | {ang-ɛ} | 6 | 94 | 0 | 0 | 6 | 94 | 0 |
| " | {ang-æ} | 17 | 78 | 6 | 0 | 22 | 78 | 6 |
| " | {ong-ɑ} | 72 | 28 | 0 | 0 | 72 | 28 | 0 |
| " | {ung-ʌ} | 56 | 39 | 6 | 0 | 61 | 39 | 6 |
| M | all | 75 | 21 | 4 | 0 | 79 | 21 | 5 |
| M' | all | 80 | 15 | 5 | 0 | 85 | 15 | 5 |
| Pairs: | *buy/pod* | 17 | 78 | 6 | 0 | 22 | 78 | 6 |
| " | *cow/pod* | 11 | 89 | 0 | 0 | 11 | 89 | 0 |
| " | *car/dock* | 22 | 72 | 6 | 0 | 28 | 72 | 6 |
| " | *car/pod* | 11 | 83 | 6 | 0 | 17 | 83 | 6 |
| " | *beer/bead* | 67 | 28 | 0 | 6 | 67 | 33 | 6 |
| " | *bee/bead* | 100 | 0 | 0 | 0 | 100 | 0 | 0 |

Table 1. Percentage of *Yes/No* and *Delayed* responses by vowel-pair category. Totals may not equal 100% due to rounding.

Other pairs showed more anomalous results. Comparison of [Ir] with /i/, as in *beer/beet* and *beer/bead*, had a 59% *Yes* response rate, lower than the rate for set SD, but much higher than the rate for set D, with 9% *Total Delayed* responses, which is significantly higher than the rates for sets SD or D. Words with [Er] also proved to be anomalous when compared to /ɛ/. The *Yes* rate was 23%, higher than that for set D, but much lower than that for set SD. The percentage of *Delayed* responses for this group was 22%, much higher than any group mentioned above.

The pairs comparing [Or] to /ow/ (*bore/load* and *boar/boat*) showed a 28% *Total Yes* rate, and 22% *Total Delayed* responses, thus patterning neither with group SD nor group D. The pairs comparing [Ar] and /ɑ/ (*car/dock, car/pod*) showed a 17% *Yes* response rate, with 6% *Total Delayed* responses. This result is much closer to group D than group SD, but still does show a somewhat higher *Total Yes* rate, and a significantly higher percentage of *Delayed* responses.

As a whole, the pairs involving /r/ had a higher rate of *Delayed* responses than any pairs not involving /r/. Some of the groups ({Ir-ɪ}, {Er-ej}, all those involving [ɚ]) pattern just like the pairs containing distinct vowel phonemes. None of the pairs in set R patterned like the same-vowel-phoneme pairs in sets SS and SD. Only the /Ir-i/ pairs had a greater than 50% *Total Yes* rate.

### 3.2. Vowels before /l/

Pairs of words with the coda consonant /l/ were also tested, because /l/ has also been known to strongly affect preceding vowels [1]. However, all the monophthongal vowel phonemes (/i ɪ ej ɛ æ u ʊ ow ɑ ʌ/) of California English contrast before /l/, as in the words *eel, ill, ale, L, Al, pool, pull, pole, all,* and *hull*. Since there is no neutralization of contrasts before /l/ in the dialect in question, it is not

difficult to determine phoneme assignment. Thus, groups only contained pairs of words with the expected same vowel phoneme.

The results all showed anomalous patterning. None of the groups patterned with either group SD or D. The highest percentage of *Yes* responses was for the {il-i}, {ejl-ej}, and {owl-ow} groups (*peel/beet, peel/bead, pail/gate, pail/spade*, and *bowl/boat*). The {ɪl-ɪ} group (*will/bit* and *will/bid*) also had a majority of *Yes* responses. The {ɑ-ɑl} and {ʌl-ʌ} groups (*hall/dock* and *dull/luck, dull/bud*) showed a percentage of *Yes* responses near chance. The {ɛl-ɛ} and {ʊl-ʊ} groups (*well/bet, well/bed*, and *pull/look, pull/hood*) show lower percentages of *Yes* responses (30% and 20% respectively). As a whole, the pairs in set L have a very high (10%) rate of *Delayed* responses. Two of the groups in set L ({il-i} and {owl-ow}) show particularly high percentages of *Delayed* responses (17% and 22%, respectively).

### 3.3. Vowels before /ŋ/

Pairs of words in which one word had the coda consonant /ŋ/ (set NG) were also tested in the experiment. This was done because /ŋ/ is the only other consonant of California English before which vowels contrast incompletely. Only five vowels contrast before /ŋ/ in California English, as in the words *sing, sang, length, song*, and *sung*, which we will refer to by their standard orthography <ing>, <ang>, <eng>, <ong>, and <ung>. Categorization of these vowels found before /ŋ/ with vowels found in other environments is difficult for the front vowels found in *sing, sang*, and *length*, but easier for those found in *song* and *sung*, which belong to /ɑ/ and /ʌ/ respectively. The vowel <ing> was compared to both /i/ and /ɪ/ in *sing/bead* and *sing/bid*. The vowel <eng> was compared to /ej/ and /ɛ/ in *length/gate, length/spade*, and *length/bet, length/bed*. The vowel <ang> was compared to /ej/, /ɛ/, and /æ/ in *hang/spade, hang/bed*, and *hang/sad*. The vowels <ong> and <ung> were compared to /ɑ/ and /ʌ/ respectively in *song/pod* and *lung/bud*.

None of the front-vowel pairs patterns strongly with the same-phoneme pairs in set SD. One group ({ang-ɛ}) patterned with the different-phoneme pairs in group D, having a 94% *No* response rate (0% *Delayed* responses). Other groups ({ing-i, ang-æ}) had only a 17% *Yes* response rate. None of the front-vowel groups in set NG had higher than a 39% rate of *Total Yes* responses. The back-vowel groups ({ong-ɑ} and {ung-ʌ}) patterned closer to group SD, with 72% and 56% *Yes* responses respectively. As a group, the pairs in group NG had a 5% *Delayed* response rate, higher than the rates for groups SD and D.

## 4. DISCUSSION

It would appear that speakers do not consider the vowel in [Ir] to be /ɪ/. Most speakers do identify [Ir] with /i/, but the percentage is not as high as that for clearly identical phonemes in pairs like *grieve/bead*, for example. The high percentage of *Delayed* responses may mean that many speakers are unsure as to how to categorize this vowel.

Speakers do not consider the vowel in [Er] to belong to any other vowel phoneme. It is clearly not considered to be /ej/. Some speakers identify it with /ɛ/, but the majority do not. The very high (22%) *Delayed* response rate for the /Er-ɛ/ pairs indicates that this is a vowel which speakers find very difficult to categorize.

Speakers do not consider the vowel in [Or] to be /ɑ/. Some consider it to be /ow/, but the majority do not. The high percentage of *Delayed* responses for the pairs including this vowel indicate that speakers have difficulty categorizing it.

Most speakers do not consider the vowel [Ar] to be /ɑ/, despite the phonetic similarity. The percentage of speakers that clearly identify [Ar] with /ɑ/ (17% *Yes*) is very low. The 6% *Delayed* response rate for this group shows that speakers are somewhat unsure as to how to categorize this vowel.

Speakers definitely do not consider [ɚ] to be either /ʌ/, /ɛ/, or /ʊ/. The low percentage of *Yes* responses and low *Delayed* response rate show that speakers do not identify the vowel in words such as *lurk* or *bird* with another vowel phoneme, but put it in a category by itself. Speakers do not identify [ɚ] with /ɛ ʌ ʊ/ any more than they categorize /æ/ with /ɪ/ in pairs such as *bath/bit*.

In general, speakers show a high degree of uncertainty as to how to categorize the /Vr/ sequences.

Sequences of vowel plus /l/ are generally considered by speakers to be identifiable with other vowels more often than sequences of vowel plus /r/. Many /Vl/ sequences are regularly identified with their expected phonemes. Some, however, are not. As a group, the pairs with /Vl/ sequences showed a very high percentage of *Delayed* responses, indicating that speakers are unsure as to how to categorize these vowels.

Generally speaking, speakers do not consider vowels in /Vŋ/ sequences to belong to other vowel phonemes, at least for the front vowels. Some of the front-vowel sequences show near equal (though low) categorization rates with more than one vowel phoneme, a situation that does not occur with the /Vr/ sequences.

It was also decided to test a control set (set M) containing words with vowels before /m/. Though there has never been any controversy concerning how to categorize vowels found before /m/ in English, /m/ does have specific acoustic effects on preceding vowels, nasalizing the vowel and lowering both the second and third formant. because of its bilabial character [6], [7]. The results of these pairs should show us whether differences in categorization could be merely a matter of phonetic differences caused by different coda consonants. Since there is no controversy as to how to categorize the vowels found before /m/, groups only consisted of pairs of words with expected equivalent phonemes: *beam/beet, beam/bead, dim/bit, dim/bid, game/gate, game/spade, stem/bet, stem/bed, comb/boat, comb/load, mom/dock, some/luck*, and *some/bud*.

The results show that speakers readily identified vowels found before /m/ with other vowel phonemes, with 5% *Delayed* responses. The only exceptions to this were the pairs involving /ʌ/. This is difficult to explain. It could be a matter of orthographic interference, since the /ʌ/ is spelled with an <o> in *some*, but a <u> in *luck* and *bud*.

## 5. PHONOLOGICAL ANALYSIS

The results suggest possibilities for the phonological analysis of vowels before /r/. Analyses which require the R-colored vowels to belong to a natural class, either tense vowels (Kreidler) or lax vowels (Lehiste, Akmajian *et al.*) would appear not to work. The vowel [Ir] does categorize with the tense vowel /i/ somewhat, but the vowel [Er] does not categorize at all with /e/. Likewise, [Er] categorizes somewhat with the lax vowel /ɛ/, but [Ir] does not categorize at all with the lax vowel /ɪ/.

Another possibility is that the R-colored vowels are a product of archiphonemic neutralization of features which contrast before other consonants. This appears to be the categorization advocated by Harris, in which it is claimed that since American English /r/ is not a consonant (but rather the semi-vowel [ɹ]), vowels found before /r/ are in open syllables, and cannot contrast tenseness [4]. This is, however, actually a categorization of the R-colored vowels

as tense vowels, not an archiphonemic approach, since Harris goes on to say that only tense vowels are found in open syllables. The archiphonemic approach, however, is not supported by the data either. Were it true, we would expect [Ir] to categorize equally well (or poorly) with both /i/ and /ɪ/, and [Er] to categorize equally with both /e/ and /ɛ/, but this is not true. It is also not clear as to how the vowels [Ar] and [Or] would fit into such an analysis.

Also, if Harris's analysis is correct, we would expect the pair *bee/bead* to pattern the same way as *beer/bead*, since the vowel in *beer* would show the same sort of open-syllable neutralization as that in *bee*. This is not the case. The pair *bee/bead* categorizes with the same-vowel-phoneme pairs in sets SS and SD, while the pair *beer/bead* shows more anomalous categorization.

The approach suggested by De Camp in which the sequences [Ir Er Ar Or] are considered monophonemic diphthongs akin to /aj aw/ in *buy* and *cow* is the analysis which the data fits best [5]. This analysis would predict that sequences like [Ar] would pattern with /ɑ/ the same way [aj] and [aw] do. This appears to be the case, if we compare the pairs *buy/pod* and *cow/pod* with *car/dock* and *car/pod*. The results are very similar.

There has never been any problem categorizing the vowels found before /l/ phonologically, because a complete range of vowels contrasts before /l/ (see above). However, the lower rate of *Yes* responses and high rate of *Delayed* responses in set L indicate that there may be some phonological changes involving re-analysis of /Vl/ sequences. One such change noted has been the merger of /i-ɪ/ and /u-ʊ/ before /l/ in some Southwestern U. S. speakers [8]. Another such change is the frequent realization of /ʊl/ sequences as a syllabic velarized /l/ ([ɫ̩]) [9], [10]. The existence of such changes supports De Camp's claim that the /Vl/ sequences in English are not yet monophonemic diphthongs, but may be in the process of becoming such in the future [5]. The creation of a stressed syllabic [ɫ̩] out of /ʊl/ is particularly interesting because it could account for the especially low rate of *Yes* responses in the /ʊl-ʊ/ pairs *pull/look* and *pull/hood*.

Sequences of /Vŋ/ are not phonologically analyzable as monophonemic diphthongs because [ŋ] is not a glide like [j], [w], or [ɹ]. Nevertheless, the non-categorization of the /Vŋ/ sequences in *sing, hang,* and *length* with other phonemes requires a careful phonological analysis. Perhaps here an archiphonemic approach would be the best analysis, since <ing> patterns similarly with both /i/ and /ɪ/, and <eng> patterns almost identically with /e/ and /ɛ/. It is unclear, though, how this approach would would work for <ang>. The back vowels found before /ŋ/, as stated above, do not present as great a problem.

It could be argued that the results of the study show a continuum of categorization depending merely on phonetic similarity. The most phonetically similar pairs, those involving the same vowel and coda consonant (set SS), show a 97% rate of *Total Yes* responses. Changing the coda consonant, but keeping the same vowel (set SD), lowers the *Total Yes* rate to 91%. Pairs with vowels before /m/ (set M) show a slightly lower rate of *Total Yes* responses (79%). The next category is vowels before /l/ (50% *Total Yes*), then /Vŋ/ sequences (32% *Total Yes*), then /Vr/ sequences (18% *Total Yes*). The lowest rate was in the pairs in set D with different vowels (3% *Total Yes*). We believe this is not an adequate explanation, though, for the following reasons:

1) If we create a set which eliminates the anomalous /ʌm-ʌ/ pairs from set M (set M'), its percentage of *Total Yes* responses goes up to 85%, not significantly different from that of group SD, which contains pairs with the same vowel phoneme, but different coda consonants. Thus, we have a case in which vowels (those before /m/) are significantly phonetically different, but not identified as phonologically different by the subjects.

2) The pairs of words with different vowel phonemes in set D did not show any continuum based on phonetic similarity. For example, pairs with the similar vowels /i ɪ/ (*beet/bit, bid/bead*) showed 100% *No* responses, akin to pairs with very different vowel phonemes (*bed/load, food/spade*).

3) If we do recognize a continuum based on phonetic similarity, at one end of the continuum are those pairs (set SS) containing the same vowel and coda consonant (97% *Total Yes*), and at the other end are those pairs (set D) with different vowels (3% *Total Yes*). The percentage of *Total Yes* responses in set R is much closer to the latter group, and should hence be grouped as separate phonemes.

Thus, we feel that the analysis which the data fits best is one in which [Vr] sequences of English are categorized as monophonemic diphthongs akin to /aj/ and /aw/. The data shows that the R-colored vowels are not categorized phonologically with vowel phonemes found before sounds other than /r/. Furthermore, the situation may actually be that these [Vr] sequences are in a state of phonological flux, and speakers are unsure how to categorize them, as the high rate of *Delayed* responses suggests.

**ACKNOWLEDGMENTS**

Thanks to Aimée Bartosik, Steve Chang, Gunnar Hanson, Ben James, Lily Liaw, James Ritchie, Kenneth Van Bik, and Sean Ying for their help in the preparation of this experiment.

**REFERENCES**

[1] Lehiste, I. 1964. *Acoustical Characteristics of Selected English Consonants*. Bloomington, Indiana University Press.

[2] Akmajian, A., Demers, R. A., Farmer, A. K., and Harnish, R. M. 1995. *Linguistics*. Fourth Edition. Cambridge, MIT Press.

[3] Kreidler, C. W. 1989. *The Pronunciation of English*. Oxford, Blackwell Publishers.

[4] Harris, J. 1994. *English Sound Structure*. Oxford, Blackwell Publishers.

[5] DeCamp, L. S. 1945. hwɛn ɪz ə dɪfθɔŋ? Le Maître Phonétique, 83, 2-5.

[6] Ladefoged, P. 1993. *A Course in Phonetics*. Third edition. Fort Worth, TX, Harcourt Brace Jovanovich.

[7] Lehiste, I., and G. E. Peterson. 1961. Transitions, Glides, and Diphthongs. JASA, 33, 368-377.

[8] Labov, W., Yaeger, M., and Steiner, R. 1972. *A Quantitative Study of Sound Change in Progress*. Philadelphia, U. S. Regional Survey.

[9] Wells, J. C. 1982. *Accents of English 3*. Cambridge, Cambridge University Press.

[10] Bailey, C.-J. N. 1985. *English Phonetic Transcription*. Dallas, Summer Insitute of Linguistics.