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Vowel Retraction Before Dark /l/

1. State of research
1.1 Introduction

The present paper is an attempt at describing the coarticulatory influence that [h] exerts on preceding monophthongs in near RP English. Most descriptions confine the effect only to front vowels and schwa. The main objective of this work is to scrutinize the assumptions that these vowels retract when followed by [h]. Another goal is to describe the strength of this retraction, if its existence is confirmed.

1.2 Hypotheses concerning the retraction of vowels followed by dark /l/

It transpires that phoneticians share the view that vowels which precede dark /l/ retract. According to Ladefoged (1975:81), all front vowels become considerably retracted when they occur in syllables closed by [h]. The scope of retraction causes diphthongisation of the vowel with [u] as the last element. Transcribed in the narrow transcription, this element would be [pʰiːut, pʰeʊt, pʰeʊt] in words “peel, pail, pal”. Ladefoged argues further that back vowels as in “hail, pull, pool,” are usually less affected by the final [h] because they already have tongue positions similar to that of [h]. He postulates that the rule for specifying vowel allophones before [h] will vary from speaker to speaker. Yet, to summarize some of the main allophones in
English, he formulates the following rule which implies that front vowels become retracted when followed by [h]:

\[
\begin{array}{ccc}
+ \text{front} & \rightarrow & [ \text{+ retracted}] \backslash \text{syllable final} /l/ \\
+ \text{vowel}
\end{array}
\]

Gimson (1994:204) has also observed the regularity presented by the rule specified above. Additionally, he claims that [h] often has the effect of lowering slightly the articulation of a preceding front vowel as in feel, fill, fell, and canal. Moreover, Gimson states that in the case of /i:/ + [h], a central glide between the vowel and [h] is noticeable.

Jassem (1993:210-226) still extends the scope of the application of the rule of retraction. In his opinion, it applies not only to front vowels but also to /o, u, /, and /a/. He postulates the following characteristics of the allophones of vowels which are followed by [h]:

- /i:/ and /i/\(^2\) have, in these circumstances, half-close, front, and strongly retracted articulation. They are near the border of central vowels.
- /e/ becomes slightly retracted and lowered. The height of this allophone is insignificantly higher compared to the height of cardinal /e/.
- /ae/ is retracted and lies in the region near the border between half-open and open vowels.
- /a/ is precisely midway between front and back vowels and is slightly more close than cardinal /a/ and /a/.
- /u/ has the same degree of backness as cardinal /o/, but is slightly higher from it.

1 Ladefoged (1975:81)
2 Jassem regards these two sounds as allophones of one phoneme, /i:/ being the glide /i/.

Figure 1. Jassem's view concerning coartulatory effect of [h] on vowels.
As shown above, different authors allow for various views concerning vowel retraction before [H]. They do not agree, either, as to the scope of the application, or as to the strength and nature of this process.

2 Experiment

2.1.1 Preparation of material

The data used in the experiment consisted of two groups of words: one with and the other, without the vowel+[H] sequence. The reason for creating the second group of words was to distract the speakers from noticing the regular occurrence of [H], and thus to prevent hypercorrect pronunciation. Secondly, the data in the latter group were used to establish average qualities of particular vowels of each speaker.

Because vowel production by an individual is not a random process and values of the acoustic measurements are context-dependent (Peterson and Barney, 1952:184), in order to obtain samples of speech which would contain vowel+[H] sequence in the least affected form, the environment in which these items occurred was also specifically chosen. The objective of the selection of the environment was to evade any coarticulatory effects which neighbouring sounds could exert upon the series in question; in particular, avoided were sounds which could influence the degree of backness of a vowel. With targets and conjoining rules in mind (Ladefoged, 1975:52), the main objective was to single out words in which the targets of the adjacent sounds were as close as possible to the targets of either the vowel or [H], depending which one was neighbouring, so that the targets of vowel or [H] would not be affected. The sounds flanking the vowel+[H] sequence were chosen so that they would not affect the articulation of this sequence. As the result, a favoured string of phonemes was:

\[
\begin{align*}
&\text{labial} \\
&\text{(silence)} \\
&\left\{\begin{array}{l}
\text{coronal} \\
\text{glottal}
\end{array}\right. \\
&\text{vowel} + [H] \\
&\left\{\begin{array}{l}
\text{coronal} \\
\text{glottal}
\end{array}\right. \\
&\text{(silence)}
\end{align*}
\]

Labial and glottal sounds were chosen on the basis that they do not involve tongue movement. Coronal sounds were selected due to the fact that during their articulation the body of the tongue is neither retracted nor advanced and, thus, the presence of coronal sounds does not influence the degree of backness of sounds adjacent to them.

The inventory of the English language does not contain a sufficient number of words which display the above formation with all vowel+[H] sequences, hence some words with structure other than the favoured one were placed in the wordlist. In these instances, the adjacent phonemes were chosen on the basis that they did not display the tendency to change the degree of backness of the vowel.

Apart from the above, the choice of words in the first group was determined by two factors:

- number of syllables in a word
- position of the sequence vowel+[H] within a word

The criteria employed in choosing the words for analysis give rise to four subgroups, namely:

- monosyllabic words with vowel+[H] positioned finally (where [H] is the last phoneme)
- monosyllabic words with vowel+[H] sequence placed in the middle
- polysyllabic words with vowel+[H] positioned finally
- polysyllabic words with vowel+[H] placed medially
The above division was taken into consideration in order to avoid structures of similar rhythmic configuration which would not be representative of the behaviour of all near R.P. monophthongs.

2.1.2 The recording procedure

The material was recorded by three speakers of near RP English recorded: RP (male, early sixties), PM (male, early fifties), and AT (male, early fifties). None of the speakers was aware of the nature of the experiment, nor had they had any phonetic training. All speakers were informally assessed as having normal speaking and hearing and were asked to produce all utterances at a conversational pace.

The recording was performed on a PC computer equipped with a Sound Blaster 128 PCI OEM music card working in the Windows environment. The recordings were made with use of Cool Edit 96\(^9\), a sound editing programme made by Syntrillium Software Corporation. The parameters of the recordings were as follows:

- mono channel
- 16-bit storage format/quantization size
- sampling rate – 16,000

All the data were saved in Windows PCM wave file format (*.wav).

2.1.3 The analysis of the material

In order to obtain formant values for vowels, the data were subjected to spectrographic analysis. The goal of the analysis was to verify the values of \(F_1\) and \(F_2\) in vowels occurring in the recorded words. The measurements taken were at a later stage used to establish the quality of each investigated sound. To complete this task, criteria for segmentation of the vowel-\(+[H]\) sequence were established in order to distinguish points at which formant values were to be measured.

2.1.3.1 Segmentation of the material

In a spectrographic image of an utterance, the characteristics change in time. In many cases, there are relatively unambiguous indications of the beginning and end of a segment, but there is a number of instances where it is very difficult to carry out segmentation. The vowel-\(+[H]\) sequence presents particularly complicated problems because the formant movements are smooth and the identification of the segment boundaries on the basis of a broad-band spectrogram is questionable (Peterson and Lehiste, 1960:698). Following Holbrook and Fairbanks (1962:41), the introductory segmentation involved marking the beginning and end of the studied sequence. The segments delimited in this way were further decomposed into three segments on the basis of formant movements: steady state of the vowel, transition, and steady state of \([H]\). The main difficulty lies in the fact that it is not always clear where to place the boundaries between these segments. Therefore, criteria for segmentation had to be developed.

The criteria of distinguishing the first segment, i.e. the vowel, were adapted from Gonet (1989). He argued that to regard a waveform as a vowel, two conditions must be fulfilled: presence of at least two formants and absence of any superimposed noise. For the purpose of this work, it was decided that the boundaries of this segment were defined by steady states of formants. The rationale behind the latter postulate is that the point of measurement should be placed in an area where a sound is in its least affected and fully developed form. Changes in formant frequency indicate movements of the speech organs and this fact, in turn, implies that corresponding position of a vowel is in a transient state and has not reached, or has
passed, its target. Measurements taken in such circumstances would be questionable.

The boundary between the first and the second segment was placed at the point where steady formants changed their frequencies. This change was not always abrupt and clear-cut and there were cases when it was difficult to place a borderline between a steady and a transient segment. In such circumstances, changes in the shape of the waveform were helpful in determining the onset of transition. The placement of the boundaries was also assessed perceptually.

Apart from the vowel+[H] sequence, formants of vowels in other contexts needed to be measured. In these instances, the same criteria as for the first segment applied.

2.1.4 Analysis of formant values

When all the spectrograms of the recorded words were analysed and vowel formant values read out, the measurements were transferred to a spreadsheet and grouped into two parts: the measured values of vowel formants in vowel+[H] sequence and the read-outs for vowels in the words constituting the control group. Subsequently, the figures in both groups were sorted with regards to the vowel they refer to.

In the next step of the experiment, mean values of each formant for each vowel of every speaker in every group were calculated. The results are presented in Table 1.

<table>
<thead>
<tr>
<th>SPEAKER 1</th>
<th>SPEAKER 2</th>
<th>SPEAKER 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>vowel</td>
<td>vowel+[H]</td>
<td>vowel</td>
</tr>
<tr>
<td>F₁</td>
<td>F₂</td>
<td>F₁</td>
</tr>
<tr>
<td>/ɔː/</td>
<td>337</td>
<td>2406</td>
</tr>
<tr>
<td>/ɑː/</td>
<td>411</td>
<td>1976</td>
</tr>
<tr>
<td>/æ/</td>
<td>567</td>
<td>1834</td>
</tr>
<tr>
<td>/æ/</td>
<td>645</td>
<td>1779</td>
</tr>
<tr>
<td>/uː/</td>
<td>696</td>
<td>1283</td>
</tr>
<tr>
<td>/uː/</td>
<td>541</td>
<td>1548</td>
</tr>
<tr>
<td>/uː/</td>
<td>608</td>
<td>1157</td>
</tr>
<tr>
<td>/ɔː/</td>
<td>565</td>
<td>1020</td>
</tr>
<tr>
<td>/ɑː/</td>
<td>578</td>
<td>867</td>
</tr>
<tr>
<td>/uː/</td>
<td>405</td>
<td>1131</td>
</tr>
<tr>
<td>/uː/</td>
<td>361</td>
<td>1384</td>
</tr>
<tr>
<td>/aː/</td>
<td>553</td>
<td>1518</td>
</tr>
</tbody>
</table>

Table 1. Mean formant values.

On the basis of the means, formant charts were drawn for every speaker in order to obtain graphic representations of the quality of particular vowels as well as to compare the positions of vowels in the control group and those followed by [H]. Bearing in mind Ladefoged’s (1975:174) claim concerning the relation between different types of formant charts and appropriate reflection of the place of articulation,
formant charts and appropriate reflection of the place of articulation, the formant charts used plotted $F_1$ on the ordinate and the difference between $F_2$ and $F_1$ on the abscissa. The scale used was logarithmic Hertz scale. Formant values of the three speakers were plotted on the above described charts (figures 2, 3, and 4). White circles indicate mean quality of vowels in the control group, whereas black circles present quality of vowels followed by [h]. All phonemes of the same vowel phonemes are joined by arrows unless they are in contact.

![Figure 2. Formant chart for Speaker 1.](image)

Points in Fig. 2 show the placement of vowels as pronounced by Speaker 1. Vowels /i/, /e/, /æ/, and /a/ become centralised when followed by [h]. Moreover, strong retraction can be noticed in the instances of /u/, /u/, and /a/; also /i:/ undergoes retraction, but to a lesser extent.

![Figure 3. Formant chart for Speaker 2.](image)

In Speaker 2 tendencies similar to those in Speaker 1 can be observed. In this chart, moreover, the notion of centralisation extends also to /i:/, /b/, and /s/.
Figure 4. Formant chart for Speaker 3.

The chart drawn according to the data obtained from Speaker 3 displays characteristics similar to those above. Front vowels and /ʊ/ become centralised in pre-[t] position and retraction occurs with /u:/ and /ɒ/.

2.1.4.1 Final calculations

At a later stage mean values of $F_2$ for each vowel in the two groups were calculated and on the basis of the obtained estimates yet another formant chart was created which presented average vowel qualities of the three speakers.

Figure 5. Formant chart based on mean formant values for the three speakers.

The above chart presents mean values for the three speakers of every monophthong both followed and not by [t]. The chart shows the general influence that [t] has on the sounds. On the basis of this chart it can be stated that all front vowels as well as /uː/, /ʊː/, and /ɒ/ become retracted when preceding [t]. Moreover, /ʊː/, /ɒː/, /ɑː/ and /ɒ/ display the tendency to become centred when followed by [t].
III - Results

On the basis of Figure 5 it can be stated that [h] exerts coarticulatory influence upon preceding vowels which is of twofold nature:
- vowel retraction
- vowel centring

3.1 Vowel retraction

Firstly, the experiment proved that the notion of retraction applies to all the front vowels (/i:/, /u/, /e/, and /æ/), close back vowels (/u:/, /u/), and /a/.

Consider the following table:

<table>
<thead>
<tr>
<th></th>
<th>(A) Vowel</th>
<th>(B)Vowel+[h]</th>
<th>A-B</th>
</tr>
</thead>
<tbody>
<tr>
<td>/a/</td>
<td>1418</td>
<td>967</td>
<td>451</td>
</tr>
<tr>
<td>/u:/</td>
<td>1341</td>
<td>903</td>
<td>438</td>
</tr>
<tr>
<td>/u/</td>
<td>1044</td>
<td>832</td>
<td>212</td>
</tr>
<tr>
<td>/i/</td>
<td>1947</td>
<td>1739</td>
<td>208</td>
</tr>
<tr>
<td>/e/</td>
<td>1802</td>
<td>1613</td>
<td>189</td>
</tr>
<tr>
<td>/æ/</td>
<td>1689</td>
<td>1544</td>
<td>145</td>
</tr>
<tr>
<td>/i:</td>
<td>2403</td>
<td>2310</td>
<td>92</td>
</tr>
<tr>
<td>/a:</td>
<td>1475</td>
<td>1420</td>
<td>55</td>
</tr>
<tr>
<td>/ɑ:/</td>
<td>1140</td>
<td>1127</td>
<td>13</td>
</tr>
<tr>
<td>/ɔ:/</td>
<td>834</td>
<td>842</td>
<td>-8</td>
</tr>
<tr>
<td>/ʌ/</td>
<td>1247</td>
<td>1265</td>
<td>-18</td>
</tr>
<tr>
<td>/o:/</td>
<td>974</td>
<td>1048</td>
<td>-73</td>
</tr>
</tbody>
</table>

In the table above, mean F2 values of vowels followed by [h] were subtracted from F2 values of vowels not followed by [h] and sorted in the descending order. The values in the last column present the intensity of retraction in particular cases. It can be noticed that /a/ is most retracted of all, and /u:/ is only 13Hz behind, while /o/, /æ/, and /i:/ become advanced. Moreover, the figures in the table discussed widen the scope of the application of the process of retraction. To the group of vowels that become retracted one should also add /ɔ:/ and /a:/ . The levels of strength of this process are more clearly presented in the following graph (Figure 6).

Figure 6. The strength of retraction.

As seen in Fig. 6, the process discussed can operate with varying force. /u:/ and /æ/ have the most extensive degree of retraction. In the case of these two phonemes the discussed process can lower F2 by over 400Hz, which is over 50% more than with /u/, /i/, /æ/. The three phonemes enumerated latter seem to constitute a group upon which [h] exerts moderate effect and lowers their F2 by approximately 200Hz.
Whereas with /æ/, /i:/, and /u:/ one can notice gradual decrease in the strength of retraction. Hence, one can postulate that [r] exerts a weak coarticulatory effect on these vowels. As far as /a:/ is concerned, the data show F₂ lowering of only 13Hz, which, when compared to 400Hz in the case of /u:/ and /æ/, can be interpreted as very weak retraction or no retraction at all. The remaining monophthongs (/o/, /ɔ/, and /ɔ:/) display no tendency to become retracted, but, to the contrary, become advanced.

On the basis of the experiment (the retraction of /a:/ being relatively imperceptible) one can postulate a rule that all the English vowels except open and mid back vowels become retracted when followed by [r].

3.2 Vowel centring

The configuration of vowels followed by [r] can also be looked at from the perspective of vowel centring. The data in Figure 27 show that back vowels pronounced within the half-close to open region become centred when preceding [r]. This phenomenon calls for revision of our previously established rule concerning retraction and formulating it in the following way:

**Open and mid back vowels become centred and the remaining vowels, retracted, when followed by [r].**

3.3 Statistical analysis

The data discussed above constitute only a sample of the population of near R.P. speakers of English. Statistical analysis helped to describe what the chances are that the results of the experiment can also be applied to the whole population. The predicted range for the variability from the population mean (confidence interval), as a desired in this case analysis (Andrews, et al., 1980:196), was calculated for each pair of vowel formants and

consequently these values were checked if there were instances of overlap between them. The lack of overlap proves that there are considerable differences between the two groups compared and thus confirms the statement about the existence of retraction. The results of this analysis are shown in Table 3.

<table>
<thead>
<tr>
<th>Vowel</th>
<th>/i:/</th>
<th>/ɪ/</th>
<th>/æ/</th>
<th>/æ/</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pure</td>
<td>before /ι/</td>
<td>Pure</td>
<td>before /i/</td>
<td>Pure</td>
</tr>
<tr>
<td>Mean</td>
<td>129,07</td>
<td>207,84</td>
<td>153,26</td>
<td>176,35</td>
</tr>
<tr>
<td>CI</td>
<td>210,05</td>
<td>165,35</td>
<td>58,222</td>
<td>72,467</td>
</tr>
</tbody>
</table>

Table 3. The predicted range for the variability from the population mean overlap.
In Table 3, ‘pure’ columns contain \( F_2 \) values of vowels not followed by [t], whereas adjacent columns hold \( F_2 \) values of vowels followed by [t]. This statistical test calculated confidence interval value for every sample.

Consequently, the results were checked for overlap. With reference to the subject discussed in this work, it can be stated that if there is no overlap, then the difference between the predicted ranges for population means of \( F_2 \) of vowels followed by [t] and of vowels not followed by [t] is significant with regards to the population of near R.P. speakers and, in this work, provides evidence for the existence of retraction. The overlap is shown in Figures 7, 8, and 9. White points represent mean values of \( F_2 \) of vowels in the control group and black ones \( F_2 \) of vowels followed by [t].

**Figure 7.** Confidence interval plot for front vowels.

**Figure 8.** Confidence interval plot for mid vowels.

**Figure 9.** Confidence interval plot for back vowels.
It can be seen that there are significant differences between the pairs of samples of all the speakers in the case of /i:/, /u/, /æ/, /æ/, /a/, /a:/. Thus, it can be stated that there is high probability that the population of near R.P. speakers displays the feature of retracting the above mentioned vowels when they are followed by [H]. The predicted ranges for the population means of /a/, /a:/, /o/, /o:/, and /æ:/ on the other hand, seem to overlap. Thus, the discussed differences concerning these sounds are not significant.

3.4 Conclusion

The experiment has proved that the scope of coarticulatory influence of [H] upon preceding vowels is greater than it was postulated by Ladefoged, Gimson, or Jassem. It was revealed that [H] affects not some, but all R.P. monophthongs. The result of this coarticulatory process exerts not only retracting, but also a centring effect on the preceding vowel. On the basis of regularities observed in the experimental data it was possible to formulate a general rule which codifies this influence.

In addition, it was brought to light that retraction operates with different intensity on particular vowels, and this intensity was classified as strong for /a:/ and /o/, moderate in the case of /a/, /u/, and /æ/, and weak for /æ/, /i:/, /æ:/, and /æ:/.

References