Origins of Canadian Raising in voiceless-coda effects:
A case study in phonologization

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Abstract

Canadian Raising is the best-known of a diverse class of English allophonic height alternations in /ai/ conditioned by coda voicing. The alternations have been independently re-innovated and show a systematic typology: The voiceless environment selects the higher allophone. We hypothesize that the phonetic basis of the asymmetry is the tendency for diphthongs to assimilate to their nuclei before voiced codas and to their offglides before voiceless ones.

Predictions are tested in an instrumental study of the development of a Canadian-Raising-like alternation in and around Cleveland, Ohio, in 28 speakers born between 1878 and 1977. Results support the hypothesis and contradict two widespread views about Canadian Raising, (1) that it arises out of the Great Vowel Shift and (2) that diphthongs are less diphthongal in the short pre-voiceless environment.

1. Introduction[1]

When a phonetically systematic class of phonological processes is unattested, there are at least two possible explanations. One is that cognitive or physiological factors make them hard to encode or perform; the other, that they are unlikely to arise via phonetically-driven sound change. How to allocate the responsibility for typology between synchrony and diachrony is a vexed question at present (e.g., Hume & Johnson 2001; Kavitskaya 2001; Barnes 2002; Holt 2003; S. Myers 2003; Blevins 2004).

To get a better idea of this allocation in a particular set of circumstances, we investigated what we call English Diphthong Raising, the class of allophonic processes affecting vocoid height in /ai/, conditioned by coda voicing, which have developed in many English dialects. Canadian Raising has figured prominently in theoretical phonology, but little is known about the synchronic and diachronic bases of the alternations, and existing proposals for Canadian Raising do not fit well with the other members of the class. Our aim in this research was to test a new diachronically-based hypothesis about English Diphthong Raising in general against established diachronic and synchronic hypotheses about Canadian Raising.

The rest of the paper is organized as follows. The typological facts are reviewed in §2, where we argue that they represent independent re-innovations rather than shared inheritance. Contending hypotheses are laid out in §3, and tested in §4. Conclusions and discussion are in §5.

2. English Diphthong Raising

English /ai/ is subject to allophony conditioned by coda voicing in many dialects. The best-known version is Canadian Raising, seen as a paradigmatic case of a rule-governed alternation ever since it was first brought to the attention of the wider linguistic community by Martin Joos (Joos 1942; see also Shewmake 1925; Greet 1931; Lowman 1936).

As usually described, the rule is that /ai/ is realized with a higher nucleus before a voiceless coda consonant than in other environments: approximately *ice* [ʌɪs] on the one hand versus *eyes* [aɪz], *eye* [aɪ], and *isosceles* [ˌaɪ.ˈsɑ.sə.liz] on the other (Chambers 1973; Paradis 1980). Resyllabification of a voiceless coda causes alternation within a morpheme (*psychology* vs. *psych*). The alternation is regular and productive, extending to proper names, loan words, and acronyms, and native speakers have clear intuitions about which alternant is appropriate to a given context (Kilbury 1983; Vance 1987). In many dialects the /ai/ alternation is accompanied by a parallel alternation in /au/; however, this paper focuses only on /ai/.

"Canadian" Raising of /ai/ is by no means limited to Canada. The /ai/ alternation has been reported from Ontario and other parts of Canada (Joos 1942; Bloomfield 1948; Avis 1956; Gregg 1957, 1973; Chambers 1973; Warden 1979; Thomas 1991), Michigan (Eckert 1996; Niedzielski 1999; Dailey-O'Cain 1997), North Dakota, Minnesota, and western New York State (Vance 1987; Allen 1989), northeastern Ohio (this paper), Martha's Vineyard off the coast of Massachusetts (Labov 1963; Blake and Josey, forthcoming), mainland New England (Thomas 1991); Philadelphia (Labov 1980, 2001:172f.), Virginia and adjacent parts of Maryland and North Carolina (Shewmake 1925, 1943, 1945; Greet 1931; Lowman 1936; Tresidder 1941, 1943; Dorrill 1986:86), coastal South Carolina and Georgia (McDavid 1955; Kurath and McDavid 1961), the Bahamas, St. Helena, Tristan da Cunha, the Falkland Islands (Trudgill 1986:160), and the English Fens (Britain 1997).

The wide distribution of the alternation in former British overseas colonies, and its rarity in Britain itself, suggests independent re-innovation (Chambers 1989). It has certainly developed independently at least twice, as the English Fens version is demonstrably unconnected to the Canadian one (Britain 1997). Without a common British source, there seems also to be no connection between the Canadian version, the coastal U.S. version, and the South Atlantic versions. We will argue below as well that the alternation in northeastern Ohio has developed on its own.

In a number of other dialects, /ai/ is reported to undergo Glide Weakening, an alternation in which the offglide is higher before voiceless codas. They have (e.g.) *ice* [aɪs] versus *eyes* [az] or [aɛz], and some are documented to have *eye* [a] or [aɛ]. (This [a] is distinct from the [ɑ] of *hot*.) Among them are many varieties of African American Vernacular English (Thomas and Bailey 1998; Thomas 2001; B. Anderson 2002), as well as the speech of white speakers in many parts of the southern U.S. (Greet 1931; Edgerton 1935; Evans 1935; McDavid 1958; Kurath and McDavid 1961; Sledd 1966; Pederson et al 1986-92; Hazen 2000; Thomas 2001), in the Humberside region of northern England (Trudgill 1999:72), and in Devon and Cornwall in southwestern England (Orton, Sanderson, & Widdowson 1978). Again, the wide geographical distribution of the alternation, coupled with the apparent lack of historical connection, suggest independent re-innovation at least twice.

Finally, there are dialects with no phonological alternation at all, which may have any of [ʌɪ aɪ aɛ a]. The situation is summarized in Table 1. Although the relevant environments are usually described as “voiceless codas” versus “elsewhere”, some sources do not say what happens in, e.g., open syllables, or before nasals; hence, we consider only voiceless and voiced obstruent codas.

TABLE 1

3. The phonetic basis of English Diphthong Raising

3.1. Proposal: Asymmetric assimilation of nucleus and offglide

As Table 1 shows, voiceless codas are associated with allophones that are further to the left on the scale ʌɪ ≻ aɪ ≻ aɛ ≻ a. The allophone which occurs before voiceless codas is never lower, in terms of vowel height, than the one which occurs before voiced codas. In dialects with an alternation, the pre-voiceless allophone is higher in the nucleus, the offglide, or both.

We propose that this is because voiceless codas promote assimilation of the /ai/ nucleus to the offglide, while voiced ones promote assimilation of the offglide to the nucleus. Since the offglide is high and the nucleus low, assimilation creates higher pre-voiceless allophones and lower pre-voiced ones.

The nucleus and offglide of /ai/ place conflicting demands on the tongue body, more so than any other English vocoid. As a result, either or both can suffer undershoot, i.e., phonetic assimilation (Lindblom 1963), especially at faster speaking rates. English diphthongs in general undershoot the offglide more than the nucleus (Gay 1968; Gottfried, Miller, & Meyer 1993). However, voiceless codas protect the offglide against undershoot in two ways.

First, voiceless codas cause peripheralization of offglides in formant space. Low F1s are lower, high F2s are higher, and low F2s are lower, before voiceless than voiced codas. This is true of /ai/ in English dialects with no phonological Canadian Raising, such as Mexican-American English (Thomas 2000), as well as /oi ei au/ in American English (Moreton 2004). The reason for this effect is not known, but it may be related to the well-documented lowering of monophthongs before voiceless codas (reviewed in Moreton 2004; see also de Jong & Zawaydeh 2002; Gussenhoven this volume)—a general exaggeration of articulations before voiceless codas. Diphthong nuclei are not themselves peripheralized. Instead, they change in the same direction as the offglide, though not as much.

Second, vocoids, are shorter before voiceless codas. In diphthongs the duration difference is mostly in the nucleus, which in /ai/ is much abbreviated in the pre-voiceless context (Lehiste & Peterson 1961; Gay 1968). Thomas (2000) has noted that /ai/ in particular tends to have short nuclei and long offglides before voiceless codas, but the reverse before voiced ones (compare the two tokens in Figure 5 below). A short nucleus is more exposed to the coarticulatory influence of the preceding consonant and following offglide, both of which are higher (closer) than it is. Likewise, a short offglide is more exposed to the influence of the preceding nucleus.

The domination of /ai/ by the nucleus before voiced codas and by the offglide before voiceless ones means that the pre-voiceless tokens will be, on the average, slightly higher than the pre-voiced ones. This creates the conditions for phonologization by hypocorrection, in which a learner misinterprets subtle phonetic variation as phonological, and adjusts his or her synchronic grammar accordingly (Hyman 1977; Ohala 1981, 1993).

For example, a speaker for whom *ice* and *eyes* are phonologically [aɪs] and [aɪz] may realize them, on the average, as [a̝ɪs] and [aɪ̞z]. A learner who interprets these as phonological [ʌɪs] and [aɪz] has innovated Canadian Raising; one who interprets them as [aɪs] and [aɛz] has innovated one of the Southern U.S. patterns.

The same assimilatory pressures continue to act on the new allophones and may change them further, e.g., [aɪs aɪz] → [aɪs aɛz] → [aɪs az]. In the absence of other factors, this process would be create /ai/ allophones ranging from /i/ to /a/—roughly speaking, any vocoids from the set [i ʌɪ ʌ aɪ aɛ a], subject to the condition that pre-voiceless /ai/ be at least as high as pre-voiced /ai/. This agrees with Table 1, except that [i ʌ] do not actually occur as allophones of /ai/. These may be avoided in order to prevent the merger of /ai/ with phonemic /i/ or /ʌ/. Aside from that, the attested and unattested /ai/ alternations are as expected if they arise through the asymmetric assimilation effect.

This "Asymmetric-Assimilation" hypothesis accounts retrospectively for the typology of /ai/ rules in Table 1, but it also makes new predictions about how Canadian Raising develops over time. These are schematized in Figure 3

FIGURE 3

If the hypothesis is correct, Canadian Raising must begin as a subtle difference between the pre-voiceless and pre-voiced offglides, of the sort found in the other English diphthongs. In the earliest stages, there may be a parallel difference in the nuclei, or there may be none, but either way voicing will affect the offglide more than it will the nucleus. As the process unfolds over time, the nuclear and offglide effects may grow, and the nuclear effect may or may not overtake the offglide effect. The pre-voiceless allophone in the early stages is predicted to be more diphthongal than the pre-voiced one, despite the greater duration in the pre-voiced context, because it has a higher offglide than the pre-voiced allophone but a similar nucleus. As the next section will show, these predictions are directly opposed to leading historical theories of the origin of Canadian Raising.

3.2. Diachronic alternative: Canadian Raising as a consequence of the Great Vowel Shift.

Most instances of /ai/ in Modern English are descended from Middle English /i:/ via intermediate stages with a mid nucleus (Wolfe 1972); thus, pre-voiceless and pre-voiced /ai/ in Canadian Raising are identical to earlier and later reflexes of Middle Engish /i:/. This observation has been developed in two ways.

One hypothesis is that, within the history of a *single* dialect, successive stages in the Great Vowel Shift systematically reach the voiceless-coda environment late (Ogura, Wang, & Cavalli-Sforza 1991:79–80), perhaps because pre-voiceless vocoids are shortened and hence difficult to diphthongize. In some dialects, the voiceless-coda diphthong has caught up with the elsewhere diphthong; the Canadian Raising dialects are simply those where this has not yet happened (Gregg 1973; Picard 1977; Donegan 1993; Stockwell & Minkova 1997). This has been termed the "Failure-to-Lower" theory by Britain (1997).

Contrasting with that is the "Contact, Focusing, and Reallocation" hypothesis, which derives the alternation from contact between *two* dialects at different stages of the /ai/ shift. Trudgill has proposed (1986:158–161) that language learners in Canada, hearing /ʌɪ/ and /aɪ/ from speakers of less- and more-advanced dialects, “rationalized the situation by redistributing the variants according to ... natural phonetic tendencies” (1986:159), i.e., they reallocated the between-dialect variants to separate within-dialect phonological contexts, with the less-diphthongal raised allophones in the short pre-voiceless environment. The same circumstances obtained in the English Fens, and the same alternation has been established there since the 1860s (Britain 1997).

Neither of these hypotheses accounts for Glide Weakening. Both rely on the incompatibility of the short pre-voiceless environment with the greater diphthongality of /ai/ to get the right assignment of earlier (higher) and later (lower) reflexes to voiceless and voiced contexts. But in such alternations as *ice* [aɪs] ~ *eyes* [az], the more-diphthongal articulation is in the voiceless context. The GVS theories therefore offer no account for the typology of Table 1.

They do, however, make testable predictions about how Canadian Raising progresses over time. Since the main difference between earlier and later reflexes of Middle English /i:/ is in the nucleus, the voiced-voiceless difference should emerge first in the nucleus. As the nuclear difference grows, coarticulation may create a corresponding offglide difference, but the nuclear difference should always be larger. Consequently, the pre-voiceless allophone should be less diphthongal than the pre-voiced one, and the difference in diphthongality should increase over time. These predictions are shown schematically in Figure 4.

FIGURE 4

3.3. Synchronic alternative: Canadian Raising as accommodation to pre-voiceless shortening

Regardless of how Canadian Raising came to be, speakers’ synchronic grammar must have some way to represent it. Since it is impossible to write an Optimality-Theoretic grammar of just one language—constraints used for a single language predict typology via reranking—OT proposals designed for Canadian Raising may also give an entirely synchronic account of English Diphthong Raising typology.

Current OT accounts draw on the suggestion of Chambers (1973) that the environment for Canadian Raising is created by a separate process, pre-voiceless vowel shortening. The difficulty of executing the entire /ai/

articulation in a short time is taken to be the phonetic basis for a synchronic constraint preferring [ʌɪ] to [aɪ] (J. Myers 1997; Bermúdez-Otero 2003).

These proposals were made without reference to Southern Glide Weakening, and clearly do not apply to it, since there the *more*-diphthongal allophone occurs in the short voiceless environment. For Canadian Raising, they predict that the less-diphthongal allophone occurs in the voiceless environment. Surprisingly, this prediction has not yet been tested instrumentally.

4. Case study: Cleveland, Ohio area, 1878–1977.

The main point at issue between the Asymmetric-Assimilation and GVS hypotheses is whether the nuclear or the offglide raising comes first. Testing it would require instrumental data on the diachronic development of Canadian Raising, reaching back to its earliest stages. Archival recordings suggested that the alternation was well established in Ontario speakers born around 1890, which probably puts the origins of Canadian Canadian Raising outside the era of sound recording. However, since the alternation keeps being re-innovated, it is possible to observe the process in other places.

One is Cleveland, Ohio. Cleveland is part of the Western Reserve, a region bordered by Lake Erie and Pennsylvania in northeastern Ohio. The existence in the Western Reserve of an /ai/ alternation similar to that of Canadian Raising was first noted by Thomas (1995, 2001:81–82). It appears to be an independent innovation, rather than an importation from elsewhere. The Western Reserve is relatively insulated from Canadian linguistic influence: U.S. dialects resist a range of Canadian variants (Labov et al. forthcoming Ch. 11; Zeller 1993), documented innovations in the Western Reserve have not come from Canada (Drake 1961, Thomas 2001), and the major sources of migrants to the Cleveland area have not been Canadian Raising areas (Grabowski 1996). Cleveland, unlike Detroit and Buffalo, lacks a direct entry point from Canada by road.

4.1. Speakers

Production data came from recordings of 28 adult white speakers born within 85 km of Cleveland. Three were recorded in Johnstown, Ohio, 170 km from Cleveland; the others were recorded in their place of birth or in Cleveland. The *Dictionary of American Regional English* (Cassidy & Hall 1985–2002) supplied 9 speakers, recorded in 1967 in story-reading and personal-interview situations. Another 8 speakers came from the archives of a local civic organization, the City Club of Cleveland, and consisted of public addresses or debates followed by answers to unscripted audience questions. We chose local political figures whose date of birth, place of birth, and race could be looked up. Finally, 11 speakers were recorded by one of us (ERT) between 1990 and 2004. They participated in reading tasks (one or more passages, and a set of minimal pairs) and a personal interview. Individual speaker information is summarized in Table 2.

TABLE 4

4.2. Measurement procedure.

Recordings were digitized at 20 kHz or more and processed using the Praat software (Boersma & Weenink 2003). Word tokens containing /ai/ were accepted if they met all of the following criteria: The /ai/ had primary or secondary stress. The /ai/ was followed by a labial or coronal obstruent. The obstruent was clearly syllabified with the /ai/, in the sense that it was followed by pause (e.g., *Right!*), or by another consonant with which it could not possibly form a syllable onset (*typed, sidelong*), or by an unstressed vowel (*wiper*). However, if the consonant was /t/ or /d/, and appeared in a flapping context (i.e., followed by an unstressed vowel in the same word, or by any vowel in the next word), the token was excluded regardless of whether the consonant was actually flapped or not. Tokens were also excluded if the formants were too faint to see on a wide-band spectrogram, or if they were obscured by background noise.

Following the procedure used in Moreton (2004), the nucleus of /ai/ was measured at the point of maximum F1, and the offglide was measured at the point of maximum F2. The F1 maximum is the point of greatest vocalic openness, maximally remote from the effects of the initial consonant. This point typically lay at or near the start of the gliding transition from the nucleus to the offglide. The F2 maximum is the point immediately before the downward-sloping labial and coronal formant transitions. Each token thus provided five numbers: nuclear F1, offglide F1, nuclear F2, offglide F2, and glide duration (the interval between the nucleus and the offglide). An example is shown in Figure 5.

FIGURE 5

Measurements were made using a supervised automatic procedure. A wide-band spectrogram of each token was displayed with overlaid LPC formant tracks. The LPC parameters were initially 10 poles, a 50-ms window, and a formant maximum of 5500 Hz (for women) or 5000 Hz (for men). For some speakers these parameters were adjusted to improve the match between LPC and spectrogram formants.

A search interval was defined by placing marks before the apparent F1 maximum and after the apparent F2 maximum. The interval was made as wide as possible subject to the condition that it exclude frication, stop closure (disappearance of F2 on the spectrogram), and peripheral gaps or bobbles in the F1 and F2 tracks. A Perl script then searched in that interval, located the nucleus and offglide, and extracted F1 and F2 at those points. The results were overlaid on the spectrogram and checked by the experimenter. Clearly incorrect values resulting from internal gaps or bobbles in the formant track were corrected by hand (125 of 849 voiceless tokens (15%), 119 of 806 voiced tokens (15%)).

4.3. Speaker and duration normalization

In devising a means to quantify the coda voicing effect on F1 and F2, we sought to minimize interference from three principal sources: the consonant preceding the vocoid, variation in vocoid duration caused by coda voicing itself , by speaking rate, or by task (e.g., spontaneous versus read speech), and inter-speaker differences in vocal-tract size. Normalization is commonly used to counteract inter-speaker differences in vocal tract size. However, several of the most frequently used techniques involve comparison with other vowels (Nearey 1989), which is skewed by diachronic changes, as have occurred in Cleveland (Thomas 2001:82). Intraspeaker analyses proved adequate for our purposes.

We compared the voiced and voiceless /ai/ within each speaker using the procedure shown in Figure 6. The raw formant values were natural-log-transformed and plotted against glide duration. Smooth lines were drawn through the voiced and voiceless point clouds using a moving average weighted with a Gaussian window having a standard deviation of 25 ms. The voicing effect was quantified as the mean difference between the two curves in the region where they overlapped. This provided some degree of duration normalization, since it represents the difference in formant value caused by changing coda voicing when duration is held constant.

FIGURE 6

Since differences in log Hz correspond to ratios in Hz, log-transforming the formant values before computing the difference yields a measurement of the ratio between a given formant before a voiceless coda and the same formant before a voiced one. The difference in log-transformed formant frequencies is invariant under changes in vocal-tract length, and therefore normalizes away much of the inter-speaker variation.

The log-Hz scale has two other advantages as well. It allows us to compare effect sizes between the /ai/ nucleus and offglide, and it corresponds more closely to the ear's own perceptual scale than does untransformed Hz (Traunmüller 1990).

4.4. Results

We asked three questions of the data. First, did the study achieve sufficient time depth, i.e., does the 1878–1977 period encompass the emergence of Canadian Raising in the Cleveland area? Second, does offglide raising predate nuclear raising (as the Asymmetric-Assimilation hypothesis predicts), or is the reverse true (as the Great-Vowel-Shift hypotheses predict)? Third, is /ai/ more diphthongal before voiceless codas (Asymmetric Assimilation) or voiced ones (Great Vowel Shift)?

Figure 7 shows the voicing effect on nuclear F1 as a function of birth year. A positive value means that F1 is higher in the voiceless environment. Thus, negative values indicate pre-voiceless raising of the nucleus. The earliest speakers show a minimal degree of raising. The 7 speakers born before 1910 have an average nuclear F1 effect of –0.019 log-Hz., corresponding to a 2% reduction in F1 before voiceless codas compared to voiced ones. The 6 speakers born after 1965 average –0.154, or 14%. An increase over time is apparent within each of the three speaker groups (DARE, City Club, and Thomas interviews), which gives some reassurance that the trend is not a sampling or task artifact. These results confirm the emergence of a voicing-conditioned nuclear height alternation in the Cleveland area between 1878 and 1977.

FIGURE 7

Was there also pre-voiceless raising in the offglide? Figure 8 shows that there was. Everyone—except, for unknown reasons, the 1878 Madison speaker—had lower offglide F1 before voiceless codas. The size of the effect increases over time.

FIGURE 8

For statistical tests, we assumed a linear relation between raising and birth year. (Other models, such as a sigmoid, may be more plausible *a priori*, but the linear model is simplest and is not contradicted by the data.) A linear mixed-effects model with Individual as a random effect (to absorb within-speaker covariation between nuclear and offglide raising) was fit to the data in Figures 7 and 8 by maximum likelihood, and reduced by backwards elimination. The initial model had separate slope and intercept terms for nucleus and offglide. Terms were deleted if and only if the resulting model did not fit worse than the initial model (using a liberal criterion of $p < 0.2$ by a likelihood-ratio test). Parameters for the final model are shown in Table 9. A rough indicator of goodness-of-fit is R^2, which was 0.863.

TABLE 9

The x-intercepts of the regression lines estimate the years in which each alternation began: 1879 for the nucleus, 1844 for the offglide. A 99% confidence interval for the time by which the offglide leads the nucleus can be derived from the expression for the difference in x-intercepts using the delta method for functions of a random vector (Agresti 1990:418–423). It is 35.2 years ± 22.4 years.

Results for F2 are shown in Figures 10 and 11. The same procedure was followed as for F1, yielding a final model with no effect of birth year (Table 12). Coda voicing had no significant effect on nuclear F2, but offglide F2 was consistently higher by about 7% before voiceless codas.

FIGURE 10

FIGURE 11

TABLE 12

If the F1 diphthongality of a given /ai/ token is defined as (nuclear F1 – offglide F1), then the voicing effect on diphthongality is (voiceless nuclear F1 – voiceless offglide F1) – (voiced nuclear F1 – voiced offglide F1). Rearranging terms yields (voiceless nuclear F1 –voiced nuclear F1) – (voiceless offglide F1–voiced offglide F1); i.e., the effect of voicing on diphthongality is the difference between the nuclear raising effect and the offglide raising effect. Figure 13 is simply the difference between Figure 7 and Figure 8, while Figure 14 is the difference between Figures 11 and 10.

FIGURE 13

FIGURE 14

F1 was more diphthongal in the voiceless environment for 20 of the 26 speakers, while F2 was more diphthongal in the voiceless environment for 25 of the 26 speakers. The diphthongality plots do not constitute an independent result; rather, they restate the nuclear and offglide results so as to illustrate the relative unimportance of the supposed phonetic pressure against diphthongality before voiceless codas. The redundant statistical tests are therefore omitted.

Since speakers differed in both birth year and recording year, the study confounded change in real and apparent time (Bailey, Wikle, Tillery, & Sand 1991). Sound change in real time may be faster (Boberg 2004) or slower (Harrington, Palethorpe, & Watson 2000) than in apparent time. However, is not likely that we were misled by an apparent-time/real-time mismatch. Suppose nuclear raising actually did come first. Then when the earliest speakers were young they had no glide raising, but some nuclear raising. The most recent speakers, recorded young, have sizable nuclear and glide raising. Hence glide raising must have increased from one birth year to the next, while nuclear raising remained constant or increased. By the time of recording, the earliest speakers have glide raising but no nuclear raising; hence, glide raising must increase, and nuclear raising diminish, as a speaker ages. Real time would therefore have to lag apparent time in the nucleus, but lead it in the offglide—an unlikely (though not impossible) scenario.

5. Conclusions

5.1. Canadian Raising is not a side effect of the Great Vowel Shift

These results show that Canadian Raising in the Cleveland area did not arise through the interaction of the Great Vowel Shift with a dispreference for diphthongality in the pre-voiceless environment. Offglide raising came first and was about 35 years ahead of nuclear raising throughout the century, whereas the Shift primarily affected nuclei. The Cleveland alternation seems instead to have developed by progressive magnification of the subtle phonetic voicing effect— strengthened offglides and weakened nuclei before voiceless codas—found in the early Cleveland /ai/, in the /ai/ of non-Canadian-Raising dialects (Thomas 2000), and in /oi/ and /ei/ (Moreton 2004).[2]

5.2. Canadian Raising is not diphthong reduction

Although durational shortening before voiceless codas has long been thought to reduce diphthongality (Chambers 1973; Trudgill 1986; Britain 1997), this expectation was not confirmed. The earliest- and latest-born speakers had allophones of roughly equal F1 diphthongality in both contexts, while the others had more F1 diphthongality in the voiceless context. Speakers throughout the period had more F2 dipthongality in the voiceless context as well. These results match recent findings in other English dialects and with other diphthongs (Thomas 2000; Moreton 2004).

Pre-voiceless shortening being the only phonetic basis that has hitherto been offered for Canadian Raising, these results also challenge current synchronic theories which rely on it (J. Myers 1997; Bermúdez-Otero 2003).

5.3. English Diphthong Raising is a unitary phenomenon

In this paper we have argued, on the basis of cross-dialectal comparisons, that Canadian Raising, Southern Glide Weakening, and similar alternations form a single class (Thomas 1995: Chapter 3, 2000). They are related not by common ancestry but by common phonetic motivation—the tendency of diphthongs to be dominated by the offglide before voiceless codas, and by nuclei elsewhere. The Cleveland results corroborate this in two ways. First, by showing re-innovation, they provide evidence against common ancestry. Second, they show that the alternation develops as predicted by the Asymmetric-Assimilation hypothesis in a case of Canadian Raising, which is precisely where Asymmetric Assimilation makes its most novel predictions (more diphthongality before voiceless codas in the early stages, and no interaction with the Great Vowel Shift).

We have not shown conclusively that every English /ai/ alternation came about through the same mechanism. However, they clearly *could* have, and there is no other theory in sight that derives the typology of Table 1. Asymmetric Assimilation even has the potential to explain why different dialects phonologize nuclear raising, offglide weakening, both, or neither, on the basis of differences in the basic nucleus-offglide balance which the voicing effect modulates. The "drawled" Southern U.S. dialects, for instance, which have extra-long nuclei throughout the vowel system, develop /ai/ alternations in the more vulnerable glide (Sledd 1966).

5.4. The typology of English Diphthong Raising can be explained without reference to phonetic bias in synchronic phonology

We have shown that an improvement over previous accounts of the facts (synchronic and diachronic, phonetic and phonological) can be achieved without having to assume that Universal Grammar favors the attested alternations over the unattested ones. This is consistent with the view that synchronic phonology is neutral as between phonetically “natural” and “unnatural” grammars, and that grammars tend to be phonetically natural only because they are formed by phonetically-driven sound change (e.g., Hale & Reiss 2000; Hyman 2001; Barnes 2002, Chapter 1; Blevins 2004:19ff., 81ff., 250).

However, this is only half of the story; the typology may still have been shaped by a phonetic bias within synchronic phonology. Our data would look no different if the missing alternations were redundantly ruled out by synchronic constraints (S. Myers 2003). The most we can say at this point is that previous proposals are inadequate, and that the solution is not obvious. Space does not permit a full discussion, but we will briefly consider the most straightforward proposal, and point out two objections to it:

Suppose Universal Grammar provides a constraint favoring higher diphthongs in a voiceless environment, but lacks the reverse constraint. (This would immediately generate the typology in Table 1.) One objection has to do with phonetic naturalness. As mentioned in §3.1, voiceless consonants are usually associated with higher F1, in production, perception, and phonology, so Universal Grammar would contain an “unnatural” constraint and lack its “natural” counterpart. The other objection is that the reverse alternation *is* attested, as the result of a different historical process. The Scots dialect of central and south Shetland realizes historical /ɛ/ as [ɛ(ː)] or [æ(ː)] before voiceless sounds and as [ɛ̝ɪ] or [eɪ] before voiced ones, e.g., *bet* [bæt], *bed* [bɛ̞ɪd] (Johnston 1997:471, p.c. to EM 2003). This differs from the unattested *[as ʌɪz] only in the backness of the nuclei.

The synchronic motivation of Canadian Raising (if any) thus turns out to be a more interesting problem than has hitherto been realized, and we leave it to future research.

Notes

1. The authors are indebted for comments and suggestions to Misha Becker, Abigail Cohn, Henrietta Jonas-Cedergren, Randy Hendrick, Craig Melchert, Jennifer Smith, Paul Smolensky, and an anonymous Lab Phon reviewer; also audiences at New York University's "Redefining Elicitation" workshop (2004) and at Lab Phon itself. Chris Wiesen provided statistical advice. Gary Musselman of the City Club of Cleveland and Joanne Cornelius of the Cleveland State University library tracked down and provided archival recordings. We are also obliged to *The Dictionary of American Regional English* project and its chief editor, Joan Hall, for the use of their recordings. Any remaining errors of fact or interpretation are the responsibility of the authors.

2. The Great Vowel Shift theory is unarguably superior in one point: It neatly explains why no Canadian-Raising-like alternation has been reported outside of English. This may be due to the scarcity of languages with the necessary prerequisites: /ai/, a coda voicing contrast, and asymmetric assimilation. Only about 25% of languages have /ai/ (Maddieson & Ladefoged 1996:321); of those, only a fraction will have a voicing contrast in codas. Asymmetric assimilation as a phonetic process has so far been found only in English, though there is some reason to expect it in other languages (Moreton 2004).

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Table 1. Height alternation in /ai/ conditioned by voiceless (–) versus voiced (+) coda obstruents. (Other environments, such as nasal and zero codas, were not reported by all sources.)

/ai/ alternants				
ʌɪ	aɪ	aɛ	aᵊ aː	Dialects
–	+			Canada (Joos 1942, Chambers 1973, Paradis 1980)
				North-central U.S. (Dailey-O'Cain 1997, Thomas 2000)
				East coast of U.S. (Labov 1963, 2001)
				Low Country of South Carolina and Georgia (Kurath & McDavid 1961)
				South Atlantic islands (Trudgill 1986)
				English Fens (Britain 1997)
–		+		Southeastern U.S. (Greet 1931, Kurath & McDavid 1961)
–			+	Eastern Virginia, northeastern North Carolina (Kurath & McDavid 1961)
	–	+		Southeastern U.S. white (Edgerton 1935, Hall 1942, Sledd 1966)
	–		+	Detroit African-American English (B. Anderson 2002)
				Southeastern U.S. white speakers (Evans 1935, Sledd 1966, Bailey et al 1991, Bernstein 1993)
				Devonshire (P.Anderson 1987)
				Humberside (Trudgill 1999:72)
		–	+	Texas African-American English (Bailey & Thomas 1998)
±				Hertfordshire, Worcestershire, Norfolk (Orton et al. 1978)
	±			Texas Mexican-Americans (Thomas 1995, 2000)
		±		Texas Anglos (Bailey et al. 1991)
			±	Western North Carolina white speakers (B. Anderson 1999)
				Texas Anglos (Bernstein 1993)

Table 2. Speakers.

Birth Year	Place of birth	Sex	Source	Valid tokens	
				Voice-less	Voiced
1878	Madison	f	DARE OH015	7	17
1880	Hudson	m	DARE OH011	5	8
1884	Norwalk	f	DARE OH028	23	14
1887	Westfield Center	f	DARE OH017	23	14
1892	Burton	m	DARE OH006	14	12
1898	Chagrin Falls	f	DARE OH001	11	16
1905	Lakewood	m	CCC 1966/10/21	17	20
1910	Hudson	m	DARE OH010	7	14
1911	East Cleveland	m	CCC 1970/9/18	11	17
1913	Cleveland	m	CCC 1967/1/20	28	51
1914	Cleveland	m	CCC 1971/12/17	24	48
1915	Cleveland	m	CCC 1966/10/7	13	27
1918	Akron	f	ERT 1991	22	18
1920	Wellington	m	DARE OH020	52	56
1924	Chagrin Falls	f	DARE OH002	27	15
1927	Cleveland	m	CCC 1966/10/7	7	39
1934	Cleveland	m	CCC 1970/9/18	25	28
1946	Mentor	m	ERT 1994	20	21
1946	Cleveland	m	CCC 1977/1/7	145	67
1948	Bainbridge*	m	ERT 1994	18	16
1952	Solon*	f	ERT 1994	18	15
1960	Cleveland*	f	ERT 1994	24	21
1967	Cleveland	m	ERT 2004	56	44
1967	Cleveland	f	ERT 2004	60	43
1969	Euclid	f	ERT 1996	56	54
1969	Lakewood	f	ERT 2004	45	40
1970	Lakewood	m	ERT 2004	53	44
1977	Brunswick	m	ERT 1991	38	27
			TOTAL	849	806

Note: DARE = Dictionary of American Regional English (Cassidy & Hall 1985–2002). CCC = City Club of Cleveland archives. ERT = interviews by Erik R. Thomas. * = recorded in Johnstown, Ohio.

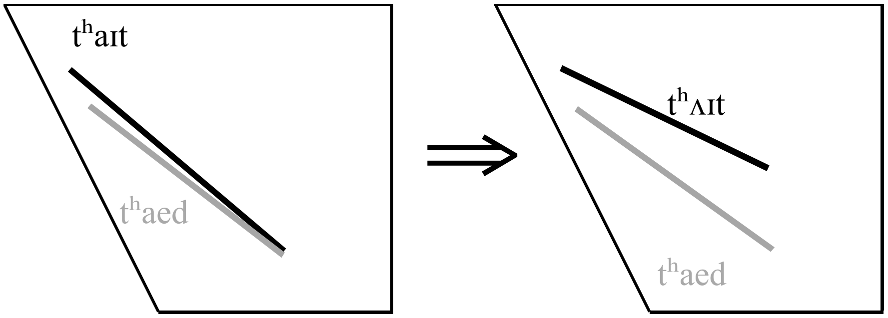

Figure 3. Development of Canadian Raising by asymmetric assimilation (in this case, nucleus to offglide before voiceless coda).

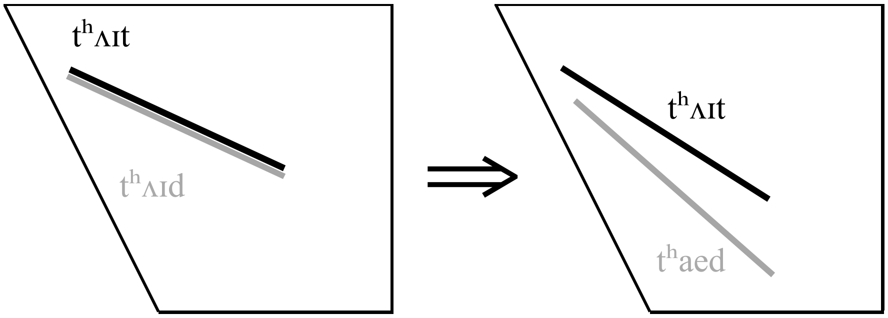

Figure 4. Development of Canadian Raising by inhibition of the Great Vowel Shift before voiceless codas

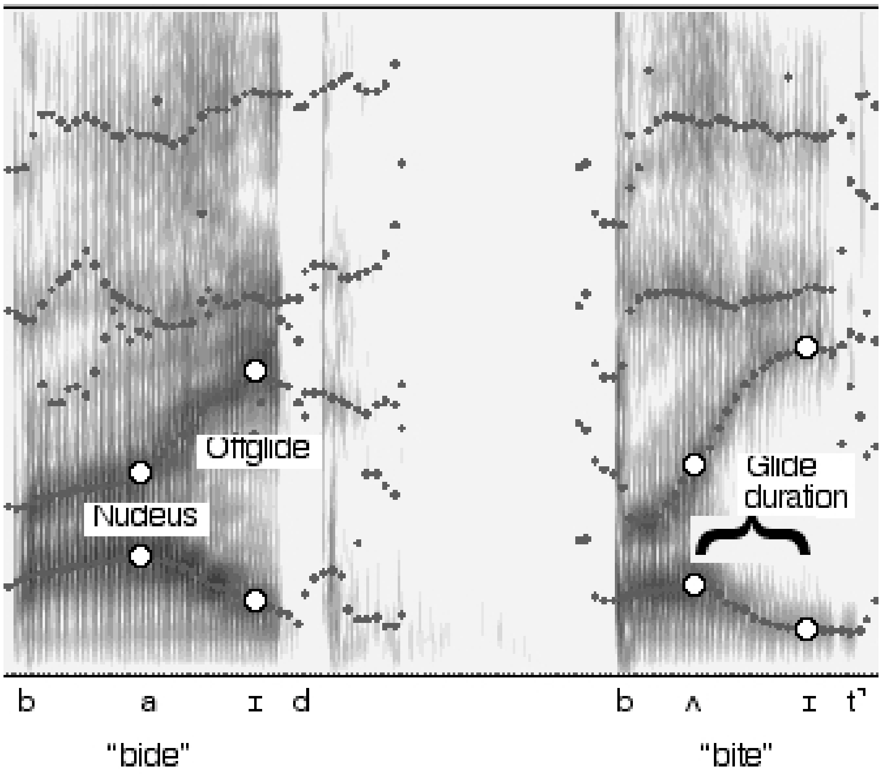

Figure 5. Measurement points (nuclear F1 and F2, offglide F1 and F2, and glide duration) for examples of *bide* and *bite*. Frequency range shown is 0 to 5000 Hz. The window is 1.00 s wide.

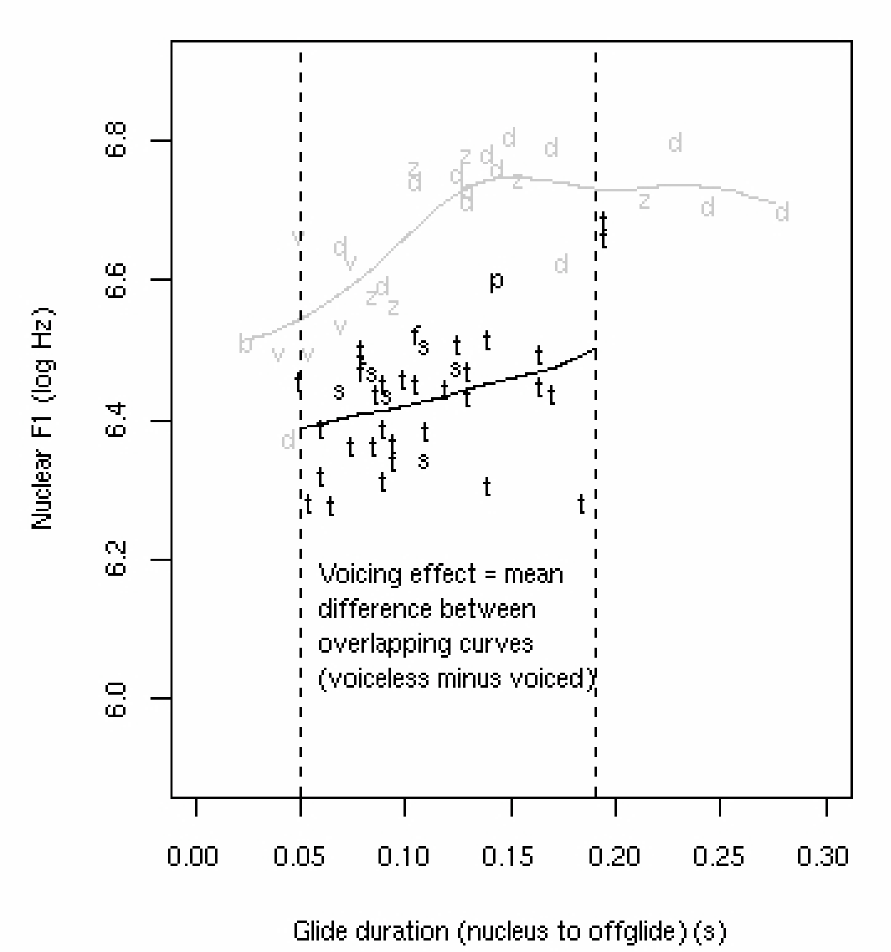

Figure 6. Computing the effect of voicing. Example: nuclear F1 of the speaker born in 1977, from Brunswick.

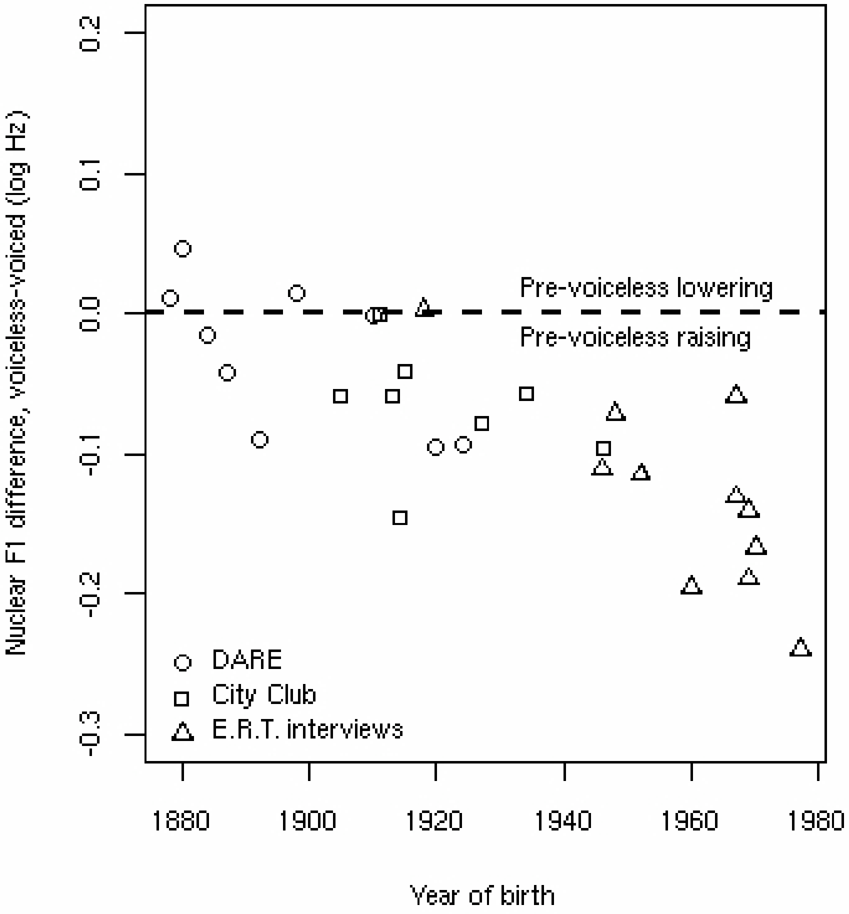

Figure 7. Effect of voicing on nuclear F1 as a function of speaker birth year.

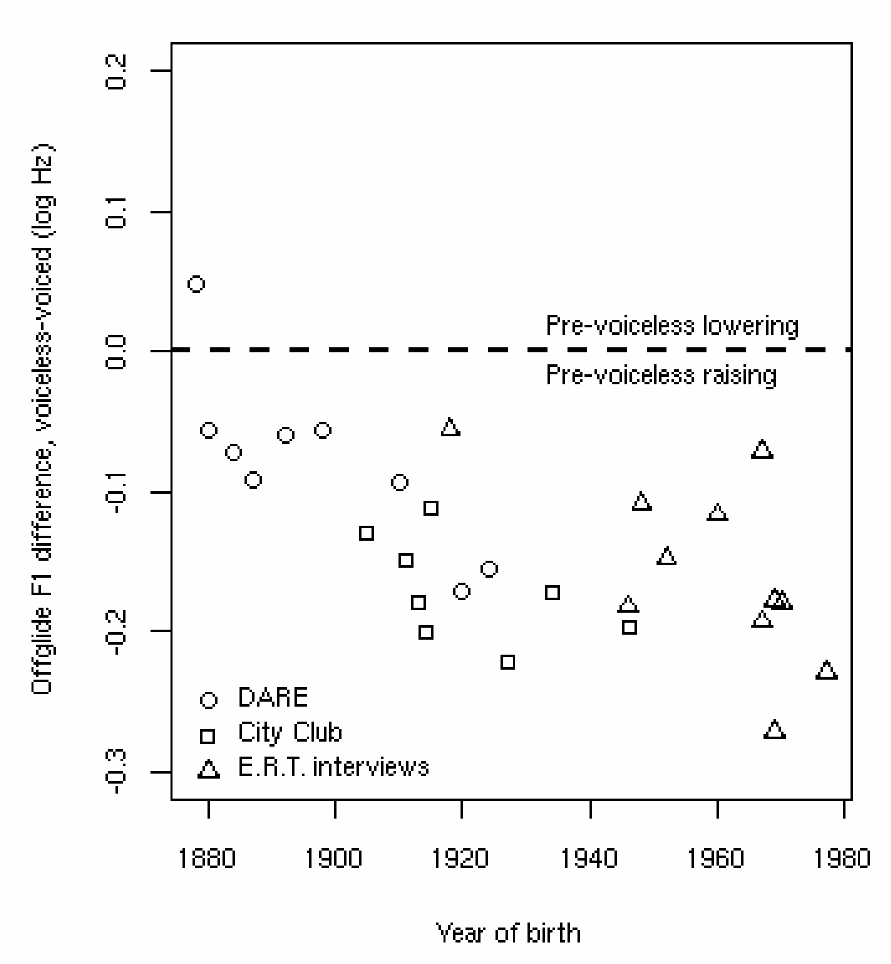

Figure 8. Effect of voicing on offglide F1 as a function of speaker birth year.

Table 9. Fixed-effect parameters for nuclear and offglide voicing effect on F1 as a function of speaker's year of birth.

Parameter	Value	Units	s.e.	df	*t*	*p*
Nucleus	3.033	log-Hz	0.460	27	6.597	<0.0001
Offglide	2.976	log-Hz	0.460	27	6.473	<0.0001
Birth year	–0.161	log-Hz/ century	0.024	27	–6.770	<0.0001

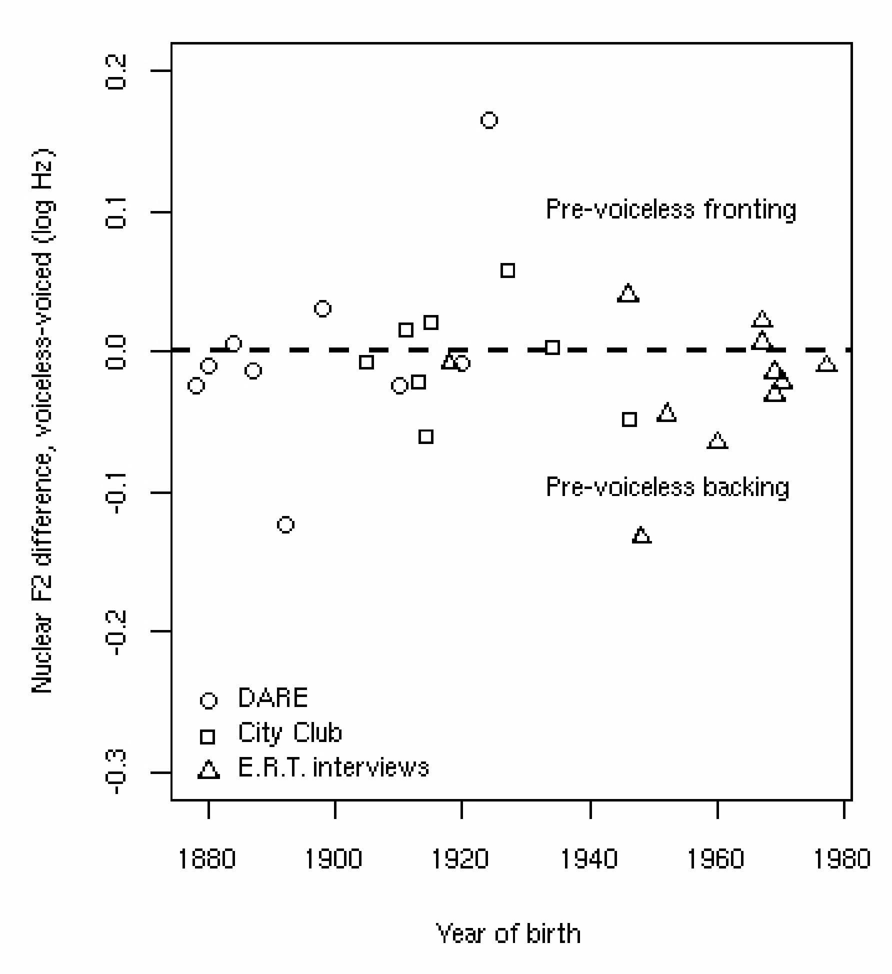

Figure 10. Effect of voicing on nuclear F2 as a function of speaker birth year.

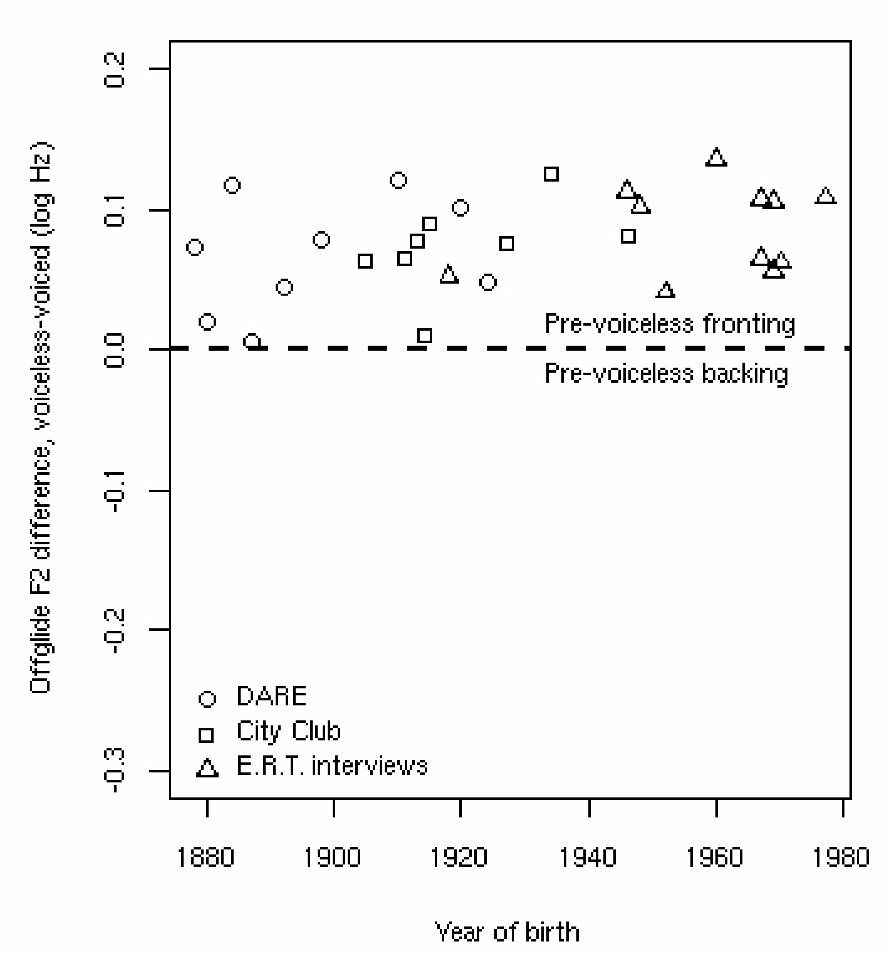

Figure 11. Effect of voicing on offglide F2 as a function of speaker birth year.

Table 12. Fixed-effect parameters for nuclear and offglide voicing effect on F2 as a function of speaker's year of birth.

Parameter	Value	Units	s.e.	df	*t*	*p*
Nucleus	–0.011	log-Hz	0.864	27	–1.254	0.221
Offglide	0.077	log-Hz	0.864	27	8.886	<0.0001

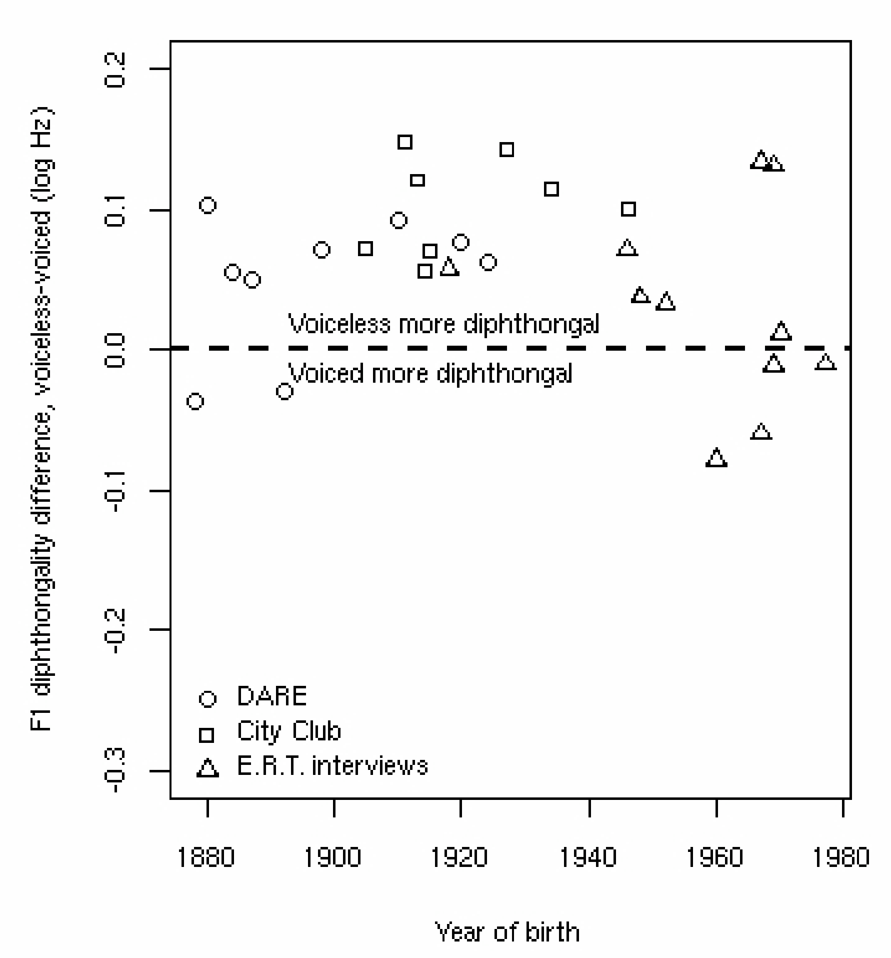

Figure 11. Effect of voicing on F1 diphthongality (nucleus-offglide difference) as a function of speaker birth year.

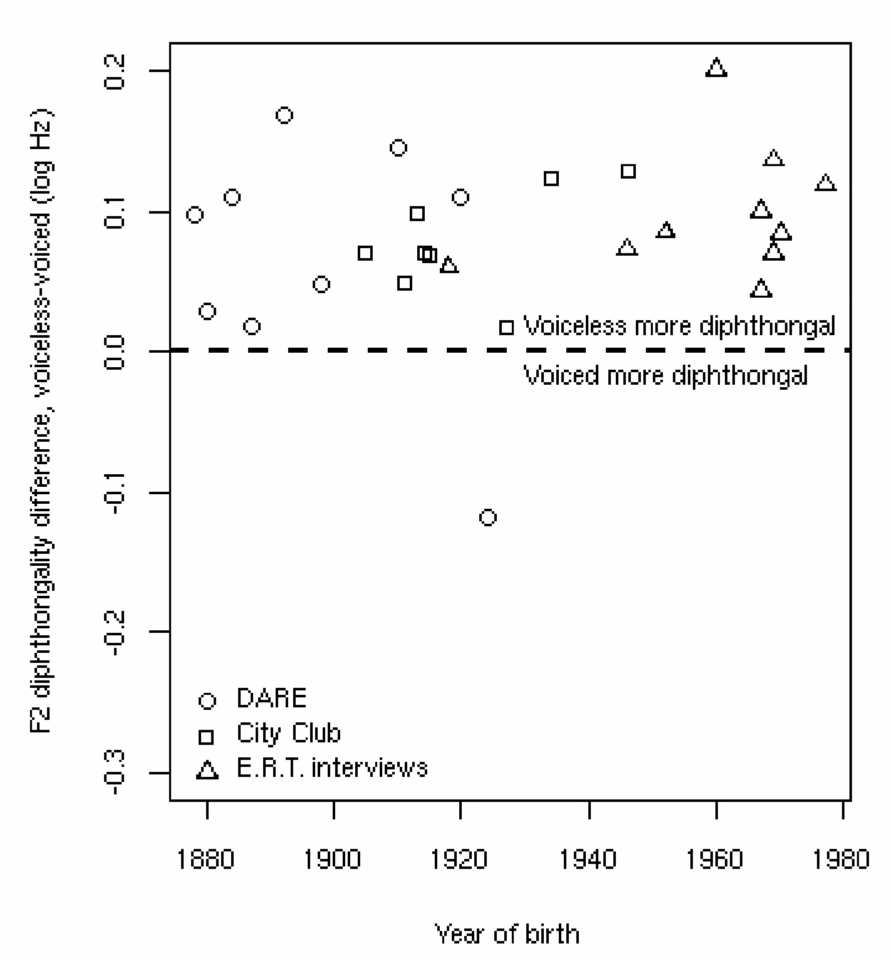

Figure 12. Effect of voicing on F2 diphthongality (nucleus-offglide difference) as a function of speaker birth year.