MORPHEMES, PHONETICS AND LEXICAL ITEMS: THE CASE OF THE SCOTTISH VOWEL LENGTH RULE

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ABSTRACT

We show that, in the Scottish Vowel Length Rule, the high vowels in the sequences /i#d/ and /ʉ#d/ are 68% longer than in the tautomorphemic /id/ and /ud/ sequences, while /ai#d/ is only 28% longer than /aid/. There is no quality difference associated with /i/ and /ʉ/, but long and short /ai/ *do* differ in quality. Spectral analysis of F1 and F2 trajectories indicates that the prime difference in the vowels due to the SVLR appears to be the *timing* of formant movements, not the *location* of the targets in formant space. In the longer vowel of *sighed*, the rise towards a high front position starts at about 75ms-100ms into the vowel, and in the shorter vowel of *side* it is aligned nearer the start of the vowel. There are, moreover, genuine target differences which function as a marker of social class.

1. THE SCOTTISH VOWEL LENGTH RULE

1.2 Introduction

Certain secondary phonetic characteristics of Scottish English and Scots vowels are conditioned by (1) the post-vocalic consonant, and (2) the presence of a post-vocalic morpheme boundary. Factor (1) has highly marked typological characteristics. Factor (2) leads to "quasi-phonemic" (or "marginal") contrasts in the vowel system. Together, these morphological, phonological and phonetic aspects of the vowel system comprise what Aitken [1] called the Scottish Vowel Length Rule ("SVLR").

Scottish Standard English ("SSE") as spoken in Glasgow has 12 vowels: six bimoraic monophthongs /i e a ɔ o ʉ/; three monomoraic monophthongs /ɪ ɛ ʌ/; three (bimoraic) diphthongs /ai aʉ ɔi/. This inventory can be seen as the "basic Scottish vowel system" [2]. Scobbie, Hewlett and Turk [3] argue that all three previous instrumental studies of SVLR demonstrate that the specifically Scottish aspects of patterning described below only apply to three vowels: the high bimoraic vowels /i/ and /ʉ/ and the diphthong /ai/. Of these previous studies, McKenna's [4] is the most reliable, but is limited to the monophthongs of four middle class ("MC") SSE subjects from the east of Scotland.

1.2 Consonantal conditioning of vowel duration

First, let us consider vowel duration as it is influenced by a post-vocalic obstruent. Voiced fricatives condition markedly greater vowel duration than voiceless ones, e.g. *seize* > *cease*, *lose* > *loose*, *rise* > *rice*. Voiced stops only condition a very small increase, which is quite different from General American English, Standard Anglo English (i.e. RP) and many other varieties of English [5]. In the case of /ai/ the increase in vowel duration in accompanied by a change of quality (see §1.4). The vowels in the following pairs therefore are practically identical: *need*/*neat*, *brood*/*brute*, *tide*/*tight*. McKenna's durational study of vowels preceding /t d s z/ (and /#z #d/, see §1.3) confirms previous impressionistic accounts for the high vowels /i/ and /ʉ/ [4]. These vowels hardly lengthen at all in a voiced stop context (+11%, from 92ms to 102ms), but lengthen a great deal in a voiced fricative context (+82%, from 93ms to 168ms). McKenna's study examined all nine monophthongs of SSE, so he was able to show convincingly that, contrary to expectations, the SVLR affected only /i/ and /ʉ/. The other vowels patterned in a relatively manner-independent way, more like other varieties of English.

1.3 Morphological conditioning of vowel duration

The morphological conditioning of vowel duration is especially evident before the suffix /d/. Despite preceding a shortening consonant, vowels /i ʉ ai/ are *long* in duration. This gives rise to quasi-phonemic contrasts between words with different morphological structures: *kneed* > *need*, *brewed* > *brood*, *sighed* > *side*. Although other suffixes can give rise to similar contrasts, the suffixation of /d/ does not change the syllable structure of the stem, so is an especially clear case — in fact it is the only case to have been studied instrumentally.

1.4 Vowel quality variation

Vowel quality aspects of the SVLR have been addressed impressionistically, and the important point to note is that /ai/ has two clear qualitative variants the distribution of which conforms to the SVLR long/short environment as described above. Other vowels are relatively invariant in quality. The long variant of /ai/ has a back-central open or mid-open target, which is typically held stable and followed by an off-glide in the direction of [i]. It is transcribed [aɐ] or [aːɐ]. The short variant [ʌi] has a more transitory low target, which can even be viewed as an onglide coming from the direction of [ɑ], and the diphthong then approaches [i] and may be held stable there.

1.5 The goals of the present study

First, we seek confirmation from a large group of speakers that the SVLR affects only /i ʉ ai/ by probing potential cases of marginal contrast for /ai i ʉ o ɔ/.

Second, we undertake the first spectral study of /ai/, paying special attention to variation in formant targets and their timing.

Third, we make a small impressionistic study of the distribution of /ai/ variants in the first syllable of disyllabic words, a context which has been said to foster a phonemic split in /ai/ [1].

Fourth, we seek a more sociolinguistically balanced group

of subjects. Previous studies have only looked at, in total, nine middle class (MC) speakers, mostly university students [3]. Such speakers' phonological and phonetic systems are closer to standard Anglo English than working class (WC) speakers are. Our subjects are more representative: they are from Glasgow, the centre of a populous conurbation, and half are WC.

Note also a companion paper on acquisition [6].

2. METHODOLOGY

Our data was collected as part of the Glasgow Speech Project [7, 8]. A wordlist was prepared including (near-)minimal pairs (Table 1). Since no reliable instrumental investigation has been made of /ai/ we included further instances of it in a wider range of contexts: _t, _d, _#d, _s, _#z. Results are presented here from the /s/ initial set (including *side*, *sighed*), but equivalent results were obtained from a /t/ set (including *tide*, *tied*). A phonotactically varied range of 15 polysyllabic words containing /ai/ were also included in the wordlist, e.g. *hydro*, *pylon*, *libel*, *crisis*...

	/i/	/ʉ/	/ai/	/ai/	/o/	/ɔ/
_d	greed	brood	side	tide	road	odd
_#d	agreed	brewed	sighed	tied	rowed	awed

Table 1. Materials probing quasi-phonemic contrast.

Half of the 32 subjects were approximately 14 years old, half over 40. Half were male, and half female. Half were WC, and half MC. Each group (e.g. young male MC) therefore consists of 4 speakers. Each speaker took part in a naturalistic dialogue and then read the list of materials at a self-selected rate. Each item in the wordlist was spoken once. Where speakers made a mistake, the word was omitted from the analysis (though its minimal pair *was* included). The word *agreed* unfortunately provided only 25 useable tokens for durational analysis. Even more problematic was the word *awed*, with only 21 analysable results, mainly due to reading errors, although we excluded the tokens of *awed* and *odd* from one older female MC speaker who, atypically, had a *cot*/*caught* contrast. The number of useable tokens otherwise ranged from 30 to 32.

The words were digitised at 11,025Hz and analysed using KAY Multispeech. We measured vowel duration and F1 and F2 formant frequencies. Segmentation was performed using standard criteria. VOT was not included in the vowel duration.

Formant measurements of the monophthongs were made 75ms into the vowel using LPC and visual spectrographic analysis, unless, as happened occasionally, there was a clear F1 or F2 target at some other point in the vowel. In the case of /ai/, measurements were made at the start of the /ai/ diphthong and at up to ten subsequent points at 25 ms intervals, which, at 250ms, was in most cases sufficient for the entire vowel. Spectrographic analysis required resetting of LPC analysis parameters to suit the differing fundamental and formant frequencies of the speakers.

3. VOWEL DURATION

The high vowels /i/ and /ʉ/ have greater duration before /#d/ than before tautomorphemic /d/, $F(1,31)=186.93$, $p<.0001$.[1] The additional 68% duration induced by the stem boundary (Figure 1) is the source of the quasi-phonemic contrast in the SVLR. The diphthong /ai/ exhibits only a 28% increase, $F(1,15)=26.62$, $p<.0001$. /o/ and /ɔ/ show no significant differences. The results for the monophthongs confirm previous findings [3,4]. There are also a number of sociolinguistically relevant differences in the wordlist data (not reported here due to space limitations).

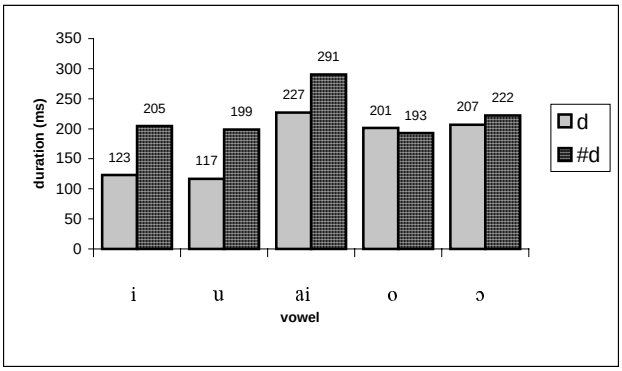

Figure 1. Mean duration of each vowel.

4. VOWEL QUALITY

4.1 Monophthongs

Formant measures show no SVLR-based variation in the monophthongs.[2] Given the physiological variation of our subjects and the concomitant effects on formant frequencies, we present spectral means for each subgroup in Table 2. We do not have space in this paper, however, to discuss the variation in these results and their physiological and sociolinguistic causes.

The general situation is that each of the four groups' four vowels are found in the same relative positions in formant space.[3] All groups have a central target for /ʉ/ which is phonetically generally slightly lower than /i/ and /o/ on the basis of F1.[4]

	F1 /i/	**F2 /i/**	**F1 /ʉ/**	**F2 /ʉ/**
Younger F	412	2749	445	1977
Younger M	328	2521	412	1787
Older F	296	2707	370	1764
Older M	296	2231	345	1567
	F1 /o/	**F2 /o/**	**F1 /ɔ/**	**F2 /ɔ/**
Younger F	419	1034	570	1070
Younger M	415	957	533	978
Older F	354	818	504	907
Older M	375	868	478	851

Table 2. Mean formant values (Hz) for the monophthongs.

4.2 Formant targets and timing in the diphthong /ai/

Impressionistically, the /ai/ variants appear to differ in their targets and in duration. Spectral analysis of the variants of /ai/ in *side* and *sighed* reveals a complex basis for this (Figure 2). (*Tide* and *tied*, not shown, are very similar.) The quality difference is not, however, in terms of the *targets* of the diphthongs; rather the formant differences are *dynamic* ones (see below). The combination of dynamic quality differences and durational differences are the source of quasi-phonemic contrast.

There are non-dynamic differences too. The exponent of the first mora of s*ighed* is lower and backer than that of *side*. We hypothesise that this is because in *sighed* there is at least 75ms of stable vowel quality produced before the rapid diphthongal

movement upwards and forwards begins. On the other hand, the beginning of the vowel in s*ide* is barely stable at all, and is indicated more by the change in formant direction than any slowing down. We therefore consider that the first mora's low target in *side* is undershot rather than being different from that of *sighed* in phonetic interpretation. The second morae of each diphthong appear to have the same target,[5] although individual productions of *sighed* may be undershot. In *side*, the target is achieved after about 125-150ms of the vowel, followed by stable articulation at the target. In other words, the long and short variants of /ai/ differ in their relative timing, and the targets differ only as a *secondary* effect. Consequently, /ai/ need not have two phonological representations which differ solely in featural content. [8]

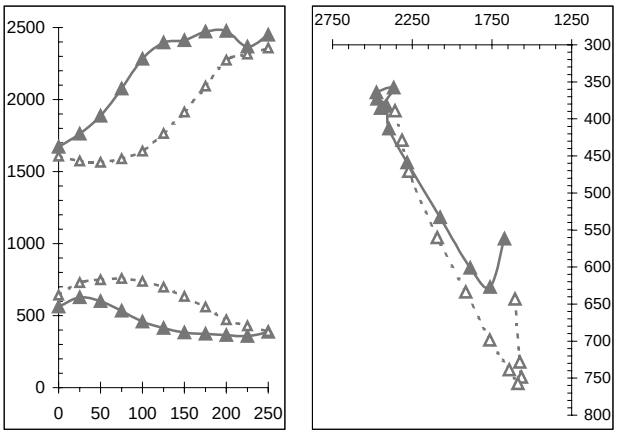

Figure 2. Dynamic quality differences for all speakers (*n*=32) between the shorter, higher /ai/ in *side* (solid) and the longer, lower /ai/ in *sighed* (dashed). Left panel shows frequency (Hz) vs. time (ms). Right panel shows the same data represented in formant space (negative F2 on the x-axis and negative F1 on the y-axis). Time is indicated indirectly: 25ms separate each point.

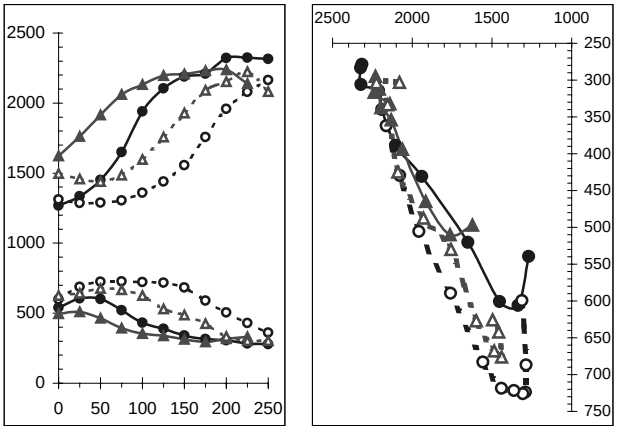

Figure 3. Formant movements in /ai/ variants in *side* (solids) and *sighed* (dashed) for older male subjects. Left panel shows frequency (Hz) against time (ms). Right panel shows the same data represented in formant space (negative F2 on the x-axis and negative F1 on the y-axis). Time is indicated indirectly: 25ms separate each point. Each panel shows both the lower, backer MC SVLR pair (circles) and the WC pair (triangles).

The dynamic hypothesis receives support from phonetic social class differences in /ai/. Since the socially relevant difference is based on *non-dynamic* vowel targets, it is possible to illustrate both types of quality difference simultaneously. We will present here just the results for the older male speakers, though similar patterns hold for the other three groups. Older MC males have first mora targets which are backer and lower than WC speakers for *both* /ai/ variants (Table 3, Figure 3). The sociolinguistic target difference therefore cross-cuts the morphologically conditioned dynamic difference. This can be clearly seen in Figure 3. In the left panel, at 0ms, F2 in both WC /ai/ variants cuts the axis at a higher frequency than either MC F2 trajectory.

	F1		F2	
	MC	WC	MC	WC
side	600	500	1325	1750
sighed	725	675	1300	1450

Table 3. Older males' low target in /ai/ to nearest 25Hz.

5. /ai/ IN NON-FINAL SYLLABLES

We undertook an impressionistic analysis of the distribution of long and short variants of /ai/ in the non-final syllables of 15 polysyllabic words.[9] For space reasons we can report only two (related) findings. The first is that the young female group exhibits a great deal of speaker-to-speaker variability in the assignment of /ai/ variants to morphemes and lexical items such as *nitro*, *bible*, *sidle* and *micro*. Similar unpredictability has been used in the past as an argument for an incipient phonemic split [1] in /ai/, a position that we tentatively support (for this environment).

Secondly, this group shows no consistent durational difference between "long" and "short" /ai/. Taking *nitro* as an example, "short" /ai/ was 163ms (n=3), "long" /ai/ was 142ms (*n*=4). Spectrally, however, the variants are similar to those in Figure 2.

6. CONCUSIONS

6.1 Phonetic cues to the stem/suffix boundary in /#d/

Our sociolinguistically balanced sample of 32 Glaswegians confirms McKenna's results [4] that a postvocalic morpheme boundary followed by a tautosyllabic /d/ conditions 68% longer duration in the phonologically high vowels /i/ and /ʉ/, compared to their duration before a tautomorphemic /d/ (120ms). (McKenna found a 65% increase from 102ms.) We sampled two further bimoraic monophthongs, /o/ and /ɔ/, and they show no statistically significant differences. McKenna's findings were insignificant for /o/ and /ɔ/, and for all the other monophthongs. (For comparison, note that in his study /o#d/ and /od/ were 202ms and 193ms respectively; /ɔ#d/ and /ɔd/ were 197ms and 185ms.) We also measured /ai/, which McKenna did not. /ai/ shows a smaller relative increase (28%) than /i/ or /ʉ/.

We undertook the first spectral study of vowel quality in SVLR environments. There are no quality differences conditioned by the morpheme boundary for any of the 4 monophthongs, although a potential difference between /i#d/ and /id/ in the young WC female group should be investigated further.

The well-known quality difference between the long and short variants of /ai/ (often notated [ae] and [ʌi] respectively) was revealed to be *dynamic*. Although there is a small F1 difference

in the realisations of the first mora, the major difference conditioned in /ai/ by the SVLR is the clear difference in the timing of F1 and F2 trajectories. The longer [ae] variant aligns its rise to a high front position *later* than the shorter [ʌi] does. We have argued that the first morae differ neither in phonological feature content nor target assignment but due to an undershoot in [ʌi] induced by temporal pressure. The second morae reach the same target on average, but in individual cases, [ae] can be seen to undershoot the second target.

Although we have not presented data here, the duration of the long SVLR variants before /#d/ is similar to, although slightly shorter than, the duration of the vowels in open syllables. The quality of /ai/ in open syllables and in syllables closed by /#d/ are very similar also. Two models therefore suggest themselves to account for the SVLR. In a derivational model the phonetic interpretation of the vowel in the morphologically complex cases could be said to *precede* suffixation. In a nonderivational model, the phonetic interpretation of the vowel must be *sensitive* to the presence of the morpheme boundary, i.e. to give a phonetic interpretation to the morphological unit *stem*. A further alternative would be to analyse words like *sighed*, *brewed* and *agreed* as a clitic group comprising a prosodic word and the clitic /d/. To enable the vowel to be prosodic-word-final, and hence lengthened, the hypothetical /d/ clitic would have to be unattached to any mora, syllable, foot or prosodic word. It is not clear that attaching lone segments so high into the prosodic hierarchy is anything other than a notational variant of the clearly morphological nonderivational model mentioned above.

6.2 Lexical specification of /ai/ variants

From the point of view of the phonological vowel inventory, we see no formal phonological necessity to increase the size of the inventory by splitting each high vowel into two categories, despite the quasi-phonemic contrast exhibited by these vowels in Scottish English in monosyllabic words. Long and short variants appear to be in contrast when the segmental string alone is considered, but are predictable when the morphological structure is consulted. This situation is, however, presumably more likely to induce phonological contrast diachronically than allophony is.

The situation with /ai/ is more complex. In the Scots language there are a few minimal pairs such as *gey* /gʌi/ "very", vs. *guy* /gae/, and consequently /ae/ and /ʌi/ are usually regarded as phonemically distinct [1]. Scottish Standard English speakers will usually produce short [ʌi] in open syllables to realise such lexemes, if they use them, favouring an analysis incorporating a split in /ai/.

Furthermore, we do not be appear to be able to predict young female speakers' choice of "long" or "short" variant of /ai/ in polysyllabic words with any great certainty. Nor does there appear to be a durational difference between the variants, only a dynamic spectral difference. We conclude that in such words there may well be a contrast between two diphthongs (/ae/ and /ʌi/) expressed phonetically with the *same* timing differences that function allophonically elsewhere. We propose to interpret both contrastive and allophonic pairs as equivalent phonetic scores.

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NOTES

1. We performed separate ANOVAs on /ai/, /o/ and /ɔ/ with duration as the dependent variable and presence of a postvocalic morpheme boundary, age group, sex and class as factors. We analysed /i/ and /u/, the "high vowels", in a single ANOVA, using an additional vowel factor.
2. Note however that a ANOVA with F2 of /i/ as the dependent value reveals a significant three-way interaction between sex, class and the presence of the morphological boundary $F(1,15)=4.75$, $p<.05$. This is due to the WC young females, who have 390Hz, 2616Hz for *greed* and 466Hz, 2991Hz for *agreed*. This requires further investigation.
3. Again the young females are possibly different. Their /i/ has a higher F1 and lower F2 than might have been expected.
4. These results replicate the findings of McClure (19 xx) [x]. We concur that *phonetically*, either /i/ alone is high, or that /i/, /ʉ/ and /o/ all are, but maintain that only /i/ and /ʉ/ are phonologically high.
5. The offglide target is just posterior to and below the target for /i/ as measured in *greed* and *agreed* (F1= 334Hz, F2=2558Hz).
6. Dynamic differences are reported in /ai/ and /au/ in Canadian English's SVLR-like "raising" [10] and in Swabian German [11, 12].
7. The fricatives /#z/ and /s/ have comparable dynamic differences conditioned by the segmental context and sociolinguistic target differences.
8. Note, however, that not all geographically defined dialects of SSE will have this timing difference: SVLR long /ai/ is said to be [E:] in Dundee.
9. The first author, a native speaker, categorised the data impressionistically from the DAT tape recordings.

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