Phonology **21** (2004) 359–407.
doi:10.1017/S0952675704000314 Printed in the United Kingdom

*Vowel height harmony and blocking in Buchan Scots**

Mary Paster
University of California, Berkeley

The Buchan Scots dialect of north-east Scotland exhibits a unique phonological phenomenon: vowel harmony is blocked by intervening consonants that have no secondary articulation or other obvious characteristic that should make them opaque to harmony. In this paper, I describe the harmony and blocking pattern based on new data from speakers of the modern dialect. After establishing this as a phonological rather than phonetic effect, I propose a synchronic analysis of the pattern and a phonetic explanation for the origin of this unusual sound pattern.

1 Introduction and overview

The Buchan dialect of north-east Scotland exhibits a unique phonological phenomenon: vowel height harmony is blocked by intervening consonants that have no secondary articulation or other obvious characteristic that should make them opaque to harmony. The goals of this paper are to describe the harmony and blocking pattern, to establish that it is a phonological rather than a phonetic effect, to propose a synchronic account of the phenomenon and to propose a phonetic explanation for this unusual sound pattern.

The pattern of harmony and blocking was first documented in Buchan Scots by Dieth (1932), though a similar pattern was noted by Wilson (1915) in a Scots dialect spoken in Perthshire. Harmony and blocking applied in Buchan as follows (based on Dieth 1932: 72): any unaccented front vowel in a suffix surfaced as high when following (a) a high vowel and any consonant or (b) a non-high vowel and any of the following

* The data in this paper are from fieldwork conducted by the author in Scotland in June 2002. This research was funded by a UC Berkeley Humanities Research Grant and a National Science Foundation Graduate Research Fellowship. Many thanks to the three linguistic consultants for sharing their language, and to Juliette Blevins, Peter Cowe, Colleen Fitzgerald, Andrew Garrett, Richard Hogg, Sharon Inkelas, Charles Jones, Mark Jones, Julie Larson, Derrick McClure, Ian Maddieson, Jonathan Marshall, Lynn Nichols, John Ohala, Stanley Robertson, Christine Robinson, James Scobbie, Jennifer Smith, Norval Smith, Alice Turk, Bert Vaux and Alan Yu for their contributions to my research and writing. Thanks also to an anonymous associate editor and three anonymous reviewers for their detailed comments and contributions, which greatly improved the paper.

sounds (including combinations of these sounds with each other or any other consonants): [b d g v ð z ʒ] or [l m n ŋ] if followed by [p t k f θ s ʃ]; otherwise, a front vowel in an unaccented second syllable surfaced as non-high. This is schematised in (1).

(1) *Root vowel*	*Medial consonant*	*Suffix vowel*
high	any consonant	high
non-high	voiced obstruent or [l m n ŋ] followed by voiceless obstruent	high
non-high	any other consonant or sequence	non-high

Dieth goes on to say (1932: 73) that this pattern was exhibited 'more or less' in all unaccented second syllables, meaning that it applied to suffixes and clitics as well as within words.

This pattern is noteworthy for several reasons to be discussed: first, this is an example of partial lowering height harmony, which is predicted not to exist by Parkinson's (1996) Incremental Constriction Model of vowel height. Second, the blocking pattern is an example of a rare type of effect (van der Hulst & van de Weijer 1995), where a consonant not directly related to the harmonising feature acts as a barrier to vowel harmony. Third, as mentioned above, harmony applied from roots into clitics, which is usually not the case in other languages with vowel harmony (though, as will be discussed, harmony does not apply to clitics in the modern dialect). Finally, the class of blockers does not appear on its surface to be a natural class, though I will argue that the blocking class can, in fact, be unified.

Because of these unusual aspects of harmony and blocking in Buchan Scots, a field study was undertaken to investigate and confirm the existence of the pattern via auditory transcription and acoustic measurement. Three speakers participated in this study, which was conducted in June 2002. Two speakers were recorded reading poems and a list of 477 suffixed words/clitic groups in carrier sentences: CE, a 44-year old female from Fyvie, and JG, a 71-year old male from Inverurie (note that Inverurie is not in Buchan proper, but JG nonetheless exhibits the pattern of interest in this study).[1] The third speaker, ML, an 82-year old female from Turriff, was recorded reciting a poem; some of ML's words are included as examples in this paper, but are not included in the acoustic data to be presented, since they were not elicited in a controlled carrier phrase. A description of the phonological pattern based on auditory impression is presented in §2. As will be discussed in §3, the phonetic study corroborates the phonological description of this unusual pattern.

[1] Speakers were recorded with an omnidirectional microphone on an analogue tape recorder. Tokens were digitised in Praat for PC, and formant measurements were taken using the Query function in Praat 4.0 for Macintosh. Except where indicated, formants were measured at the steady-state portion near the midpoint of the vowel based on visual judgment. Stimuli and data are available (October 2004) at http://socrates.berkeley.edu/~paster.

An analysis of harmony and blocking is complex, and raises several issues relating to constraints on possible harmony rules, the nature of voicing in obstruents *vs.* sonorants and the relationship between voicing and vowel height. These issues are discussed in the context of a synchronic analysis proposed in §4.

In §5, I present a possible a historical phonetic explanation of the pattern involving laryngeal lowering in voiced obstruents. As will be discussed, there is some evidence that the initial phonetic motivation for the development of blocking by voiced obstruents is no longer present in the modern Buchan dialect. If true, this constitutes an example of a phonetically unnatural phonological rule predicted to exist by Evolutionary Phonology (Blevins 2004) and other approaches where phonetic motivation is relevant in the diachronic rather than the synchronic domain. As will be discussed in §5, phenomena of this type are of critical importance in testing the predictions of Evolutionary Phonology as contrasted with models that incorporate phonetic naturalness into synchronic phonology; other typological and theoretical implications of Buchan harmony and blocking are also discussed in this section.

2 Description

In this section, I lay out a description of the pattern of harmony and blocking as it exists in the modern Buchan dialect.

2.1 The vowel inventory

The monophthongal phonemic vowel inventory of the modern Buchan dialect is given in (2).

(2)	i					u	high
	e					o	non-high
		ɛ	ɜ	ʌ	ɔ		
			a				

This is modified slightly from the phonemic inventory assumed by McClure (2002), in that I have replaced his /ɪ/ with /ɜ/. I have done this because this vowel patterns with non-high vowels for the purposes of harmony, and as shown below, its F1 value places it within the range of F1 values exhibited by other non-high vowels.

A plot of F1 and F2 of speaker CE's stressed vowels is shown in Fig. 1.[2] Most high vowels have F1 less than 400 Hz, while non-high vowels have F1 greater than 400 Hz. As can be seen in Fig. 1, the [ɜ] vowels all have F1 greater than 400 Hz, corroborating the claim that they are non-high. Also

[2] A second, male speaker (JG) shows similar results. The female speaker CE's scatterplot is shown because it more neatly illustrates the quality of each vowel. Note that the /e/ and /o/ vowels are not diphthongs; for this reason, I transcribe them as [e] and [o] rather than [eɪ] and [oʊ].

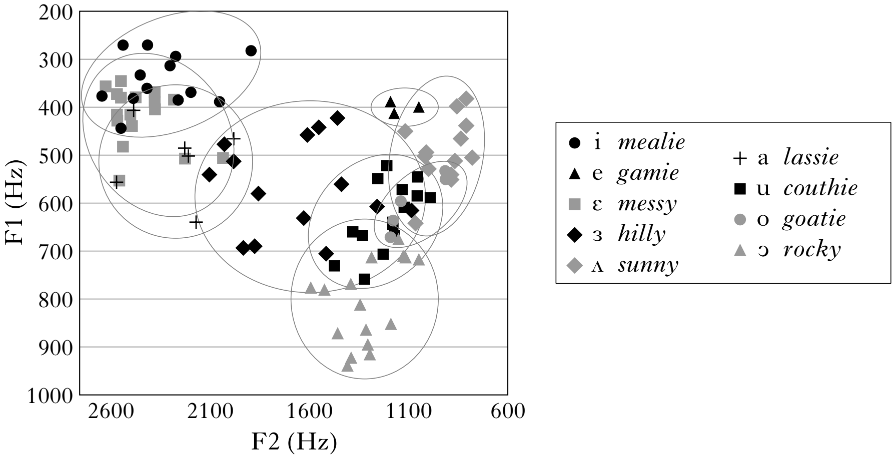


Figure 1
Stressed vowels (speaker CE).

relevant to this study is the fact that, as shown, [i] and [e] are differentiated by F1 but not by F2. Therefore, in the discussion to follow, I use F1 measurements to discuss the [i] *vs*. [e] distinction. (The number of tokens for each vowel is as follows: 13 for [i], 3 for [u], 17 for [e], 13 for [o], 6 for [ɛ], 13 for [ʌ], 14 for [ɜ], 5 for [ɔ] and 16 for [a].) Note that the surrounding consonants have not been controlled for in this data set. While this lack of control may introduce unwanted variation into the formant ranges for each vowel, this effect is minimised by the fact that these tokens were read slowly from a list, making it more likely that each root vowel is long enough to achieve a 'pure' quality after the effects of the preceding consonant have diminished, and prior to the introduction of effects from the following consonant.

2.2 Background

Before looking at the phonological and phonetic pattern of interest, it will be useful to consider the different domains in which we expect to find the pattern. There are six suffixes and clitics listed by Dieth that might be expected to participate in the harmony, since they contain apparent unstressed high vowels. These are listed in (3).

(3) *Buchan suffixes and clitics with unstressed high vowels*

a.	-*ie*, -*y*	diminutive suffix	/i/
	-*y*	adjectival suffix	/i/
	-*ly*	adverbial suffix	/li/
b.	-*ing*	nominalising suffix	/ɜŋ/
	him	object clitic	/hɜm/
	it	object clitic	/ɜt/

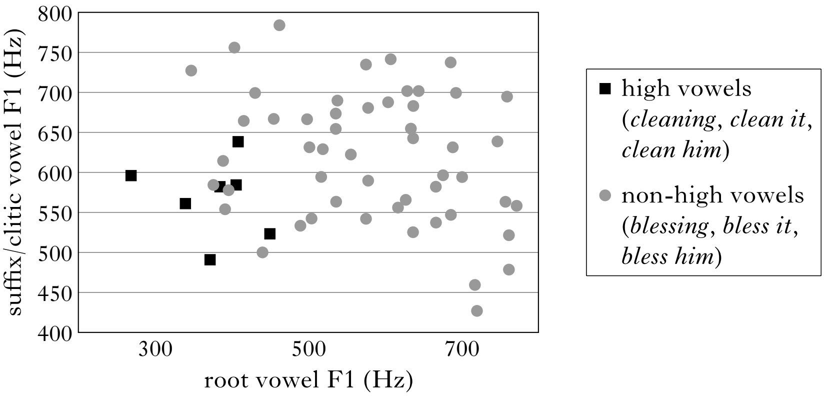


Figure 2
/ɜ/ vowel height in *-ing* suffix and clitics *=it* and *=him* as a function of root vowel height (speaker CE). These data include only forms with a non-blocking medial consonant.

The object clitic *me* /mi/ might also have been expected to participate, but Dieth does not discuss it. *Me* was not observed to undergo harmony in the modern dialect.

As will be demonstrated, the suffixes in (3a), which have /i/, do undergo harmony (note that *-ie* and *-y* are simply different spellings corresponding to the /-i/ diminutive suffix). However, the suffix and clitics in (3b), which have /ɜ/, no longer undergo harmony. The /ɜ/ vowel corresponds to /ɪ/ in many varieties of British English (and is still transcribed by McClure 2002 as [ɪ] for Buchan).[3] Its failure to undergo harmony further motivates my transcription of this vowel as [ɜ], since it does not behave as a high vowel. Apparently the change of /ɪ/ to /ɜ/ has occurred since Dieth conducted his fieldwork over the course of several visits to the region prior to 1932, and the phonetic change that centralised and lowered the vowel corresponds to a phonological featural change, from high to non-high. The scatterplot in Fig. 2 confirms that *-ing*, *him* and *it* do not undergo harmony. As shown, the F1 of /ɜ/ in the suffix/clitic

[3] As discussed by Stuart-Smith (2003: 115–117), vowel correspondences between Scots and English (presumably Scottish English) are difficult to capture, because Scots vowels tend to vary more than English vowels, probably due to dialect contact. This poses difficulty in categorising certain vowels. For example, the first vowel of *rocky* sounded like [ɔ] for one speaker in this study but like something between [o] and [ɔ] for another speaker. My decision to represent both as [ɔ], while possibly influenced by knowledge of English, did not greatly affect any aspect of the analysis to follow, since both vowels are non-high and therefore pattern together for the purposes of harmony. On the other hand, this problem could affect the analysis if the /i/–/e/ or /u/–/o/ contrasts were equally blurry, since these contrasts span the high *vs*. non-high distinction, which is critical to the process being studied. Fortunately, the choice between transcribing [i] *vs*. [e] or [u] *vs*. [o] was never terribly problematic, and the validity of the transcriptions is reinforced by the phonetic analysis to be presented in §3.

bears no relation to the F1 of the vowel in the preceding stressed root syllable; the F1 of the suffix/clitic [ɜ] vowel clusters around 600 Hz (i.e. within the non-high vowel space), whether the preceding stressed vowel of the root is high (black squares; 7 tokens; mean = 565; SD = 48·8) or non-high (grey circles; 53 tokens; mean = 617; SD = 80·8). The difference between the two groups is not statistically significant (t = 1·65; p = 0·104).

Because the pattern is apparently exceptionless in the lexicon, I assume that harmony applies to unstressed high front vowels both within the same morpheme as the trigger and across morpheme boundaries, though not from a root into a clitic, since no evidence is found for application to clitics in the modern dialect. For the phonetic study in this paper, I focus on the *-ie*/*-y* diminutive and *-y* adjectival suffixes, both of which undergo harmony, since these are highly productive suffixes where alternations are observed. This is also the domain in which we find the most evidence for the productivity of the harmony rule. Several of the diminutivised words elicited in the present study were unfamiliar to the subjects, who asked the interviewer for definitions or clarification (e.g. *hailie* 'little hail', *beakie* 'little beak'); all of these unfamiliar forms followed the same phonological pattern as more familiar words in /-i/ that might be argued to be monomorphemic lexical items. Further evidence for the productivity of the harmony and blocking pattern is provided by Wilson (1915: 55–59), who cites dozens of examples of nicknames and other words formed with these suffixes, each of which undergoes harmony in the appropriate context.

2.3 Vowel harmony

In this section, I present data exhibiting the vowel height harmony pattern. The examples to follow, except where noted, are my own transcriptions, based on auditory impression. The examples cited are from the list of elicited forms as well as from poems and stories; they therefore represent the speech of speaker ML in addition to the two participants whose speech is the subject of the phonetic study (CE and JG).

The examples in (4) show /-i/ suffixes with roots with non-high vowels. In each case, the unstressed second vowel surfaces as [e]. The forms in (4a) are monomorphemic, while the forms in (4b) are composed of a root and /-i/ suffix.[4]

[4] Words with *-ie* generally have a diminutive meaning; *Gamrie* and *Buckie* are place names, a *gamie* is a gamekeeper and a *postie* is a postman.

(4) a.	vere	*very*	lɜle	*lily*	glore	*glory*
	merse	*mercy*	mʌne	*money*	bone	*bonny*
	lenle	*lonely*	gamre	*Gamrie*	forte	*forty*
	mɛne	*many*	kafe	*coffee*	kɔpe	*copy*
	mɛre	*Mary*	stanle	*Stanley*	sɔre	*sorry*
b.	gem-e	*gamie*	hɜl-e	*hilly*	got-e	*goatie*
	her-e	*hairy*	hʌrt-e	*hurtie*	post-e	*postie*
	nel-e	*nailie*	bʌk-e	*Buckie*	mom-e	*mommy*
	hel-e	*hailie*	batʃ-e	*batchie*	tost-e	*toasty*
	nɛs-e	*Nessie*	man-e	*mannie*	sɔs-e	*saucy*
	mɛs-e	*messy*	las-e	*lassie*	rɔk-e	*rocky*

The lowering of /i/ to [e] is neutralising; this does not result in complete homophony among words elicited in this study (due to the small number of trochaic words with /e/ in the second syllable), but one very similar pair was found, in which the vowels and medial consonant sound identical: [ɛse] *essay* and [mɛse] *messy*.

As shown in (5), no lowering applies when the stressed vowel is high. (5a) shows monomorphemic examples; (5b) shows roots with /-i/ suffixes.[5] In each example, the unstressed vowel surfaces as [i].

(5) a.	piti	*pity*	rili	*really*	bjuti	*beauty*
b.	mil-i	*mealie*	dir-i	*dearie*	kuθ-i	*couthy*
	bik-i	*beakie*	bitʃ-i	*beachie*	hus-i	*housie*
	bin-i	*beanie*	ʍil-i	*wheelie*	snut-i	*snooty*

In each of the examples given so far, the word-medial consonant belongs to the NON-BLOCKING class. In the following section, I introduce the BLOCKING consonants and their effect on harmony.

2.4 Blocking

The examples in (6) have non-high stressed vowels, and therefore the unstressed second vowel in each example might be expected to undergo harmony, surfacing as [e]. However, the unstressed vowel in each case surfaces as [i]. The forms in (6a) are monomorphemic, while those in (6b) have /-i/ suffixes.[6]

[5] *Couthy* means pleasant or agreeable.

[6] *Widdie* is a place name.

(6) a.

mebi	*maybe*	wɜdi	*Widdie*	pozi	*posey*
bebi	*baby*	hʌntli	*Huntly*	dɔŋki	*donkey*
denti	*dainty*	kʌntri	*country*	bɔdi	*body*
ɛmpti	*empty*	ʌgli	*ugly*	hɔbi	*hobby*
rɛdi	*ready*	hardli	*hardly*	stoʤi	*stodgy*

b.

keʤ-i	*cagie*	kɜlt-i	*kiltie*	lod-i	*loadie*
hez-i	*hazy*	mɜnt-i	*minty*	roz-i	*Rosie*
bɛd-i	*beddie*	lʌv-i	*lovey*	dog-i	*doggie*
ɛd-i	*Eddie*	lʌmp-i	*lumpy*	dɔʤ-i	*dodgy*
bɛnd-i	*bendy*	lad-i	*laddie*	rɔb-i	*Robbie*

This effect is due to the root-final consonants that intervene between the triggering vowels and target vowels. The set of blocking consonants attested in the modern dialect conforms to the list given by Dieth (1932: 72). (7a) shows single consonants that block harmony; (7b) shows consonant clusters that block harmony.

(7) a. *Blocking consonants*

voiced stop	b	d	g
voiced affricate		ʤ	
voiced fricative	v	z	

b. *Blocking consonant clusters*

/l/ + stop		lt	
nasal + voiceless stop	mp	nt	ŋk
nasal + voiced stop		nd	
voiced stop + liquid			gl
nasal + voiceless stop + liquid		ntl ntr	
nasal + voiceless stop + liquid		rdl	
nasal + voiceless stop + voiceless stop		mpt	

Notice that the class of blocking consonants corresponds roughly to voiced obstruents and combinations of voiced obstruents with each other and with other sounds. Though not all possible consonant sequences containing voiced stops are represented, I assume based on the available evidence that any sequence containing any blocking consonant or blocking consonant sequence will itself block harmony. An interesting asymmetry in the blocking *vs*. non-blocking consonants is that although NT and lT block harmony, rT (/r/ + voiceless obstruent) is transparent to harmony. This will be addressed later in the synchronic and historical analyses proposed for harmony and blocking.

The consonants that are transparent to harmony, the non-blockers, are shown in (8).

(8) a. *Transparent consonants*

voiceless stop	p	t	k
voiceless affricate		ʧ	
voiceless fricative	f	s	
nasal	m	n	
liquid		lr	

b. *Transparent consonant clusters*

/r/ + stop		rt
/r/ + fricative		rs
nasal + liquid	mr	nl
fricative + voiceless stop		st

Note that some possible clusters are not represented in either (7) or (8), This is due, in most cases, to restrictions on root-final consonant clusters after certain vowels (although the lists in (7) and (8) are based on elicited forms with /i/ suffixes as well as on unelicited monomorphemic words, these unelicited words were not controlled and therefore do not fill in all of the gaps left by restrictions on root-final clusters). For example, no roots with final [ð mb ŋg] were successfully elicited, since they are exceedingly rare, if not non-existent, as roots eligible to take the diminutive or adjectival suffixes; these consonants/clusters are expected to be blockers. In addition, there are several other combinations involving voiced obstruents that were omitted since a voiced obstruent in any part of a cluster will block harmony. In the transparent category, [ml nr fp fk θp θt θk] do not exist as root-final clusters. I assume that any consonants that are themselves transparent should also be transparent when combined with each other, except for the combinations that are mentioned specifically as blockers (e.g. /lt/).

Based on the above description, we can schematise the pattern of harmony and blocking described above as follows:

(9) $$\begin{bmatrix} \check{V} \\ -\text{back} \end{bmatrix} \rightarrow [-\text{high}] \;/\; \begin{bmatrix} \acute{V} \\ -\text{high} \end{bmatrix} X \_\_$$

where X ≠ [−son, +voice], [+lat][−son, −cont] or [+nas][−son]

This informal rule is quite complex and involves an apparent disjunct set (X) of blockers. In §4, I propose a formal analysis in which the blockers are unified into a natural class. It is interesting to note, however, that apart from the internal complexity of the set of blocking consonants and clusters, the process in (9) is unusual from the perspective of cross-linguistic comparison. As pointed out by van der Hulst & van de Weijer (1995), vowel harmony is rarely blocked by consonants with no secondary articulation, and height harmony appears rarely if ever to be blocked by any type of consonant.

2.5 Lowering *vs*. raising

I have characterised the pattern as lowering: unstressed high vowels lower to non-high following a stressed non-high vowel. This constitutes an example of PARTIAL HEIGHT HARMONY (Parkinson 1996), since the unstressed vowel surfaces as mid regardless of whether the stressed vowel with which it harmonises is mid or low. However, the data presented above are consistent with raising as well; that is, the correct generalisation could be that the unstressed vowels in (4)–(6) are underlyingly non-high and that the unstressed vowels in (5) undergo raising following a high stressed vowel, while the unstressed vowels in (6) undergo raising following a consonant or cluster of what I have called the 'blocking' set. This is, in fact, similar to Dieth's characterisation of the process, where all unstressed vowels are expected to surface as high when following either a high vowel or blocking consonant (although Dieth does cite some forms (e.g. [obʤɛk] *object* (N), pronounced [obʤɛkt] in the modern dialect) that contradict this type of generalisation). If the harmony process were one of raising rather than lowering, this would be an example of COMPLETE HEIGHT HARMONY (Parkinson 1996), since the raised vowels would attain the same height as the triggering high vowels. The raising analysis is an important alternative to consider, because it bears on a claim of Parkinson (1996: 12), based on an extensive survey of height harmony in the world's languages:

> All height harmonies in which a vowel assimilates to the height of another vowel but does not attain the height of that vowel (i.e., partial height assimilation) involve raising. No vowel partially lowers in assimilation to the height of a lower vowel.

If the Buchan pattern is, as I maintain, partial lowering, then this contradicts Parkinson's generalisation. There are several reasons to reject a raising analysis in favour of the partial lowering analysis. The first is that while the lowering analysis involves a single process (schematised in (9)) of lowering that is blocked by voiced obstruents and certain combinations of other consonants ('blocking sequences'), the raising analysis would require two distinct rules. In order to account for the data in §§2.2 and 2.3 under a raising analysis, one would have to posit one rule raising unstressed front vowels following stressed high vowels, and another rule raising unstressed front vowels following voiced obstruents and the blocking sequences discussed above. The second rule is problematic, because, as shown in (10), it is not the case that all unstressed front mid vowels raise to high after voiced obstruents and other blocking sequences. Even if the raising rule were limited so as to apply only to tense vowels, so that the [ɛ] vowels in (10a) would not be expected to raise, the forms in (10b) would still constitute surface counterexamples to the raising rule. Although the class of words containing *-day* with a non-high vowel in the preceding syllable is not large, it is nonetheless problematic for a raising account in comparison with the lowering account, for which no counterexamples are found in the lexicon.

(10)	a. endʤɛl	*angel*	prodɛkt	*product*
	sɛvɛn	*seven*	obdʤɛkt	*object*
	b. θɛrsde	*Thursday*	kɜrkde	*Kirkday* 'church day'
	sʌnde	*Sunday*		

In order to accommodate these forms, the second raising rule would have to state that tense mid front vowels are raised to high following a high vowel and a voiced obstruent (or blocking sequence). The required addition of the high vowel to the trigger significantly weakens the raising account, since the high vowel trigger must now be incorporated into both raising rules. This duplication is avoided in the lowering account.

A second reason to favour the lowering analysis is that the raising analysis would require us to posit that the diminutive and adjectival [i] ~ [e] suffixes correspond to underlying /e/. While possible, this seems unlikely, since the vowel of these suffixes was historically /i/, and remains /i/ in other modern dialects of Scots and English, and since there is no good evidence to support a historical change from /i/ to /e/ in these suffixes. Furthermore, the behaviour of trisyllabic forms supports /i/ as the underlying form of the diminutive and adjectival suffixes. When these suffixes are added to disyllabic roots, we expect harmony not to apply since it applies only within a trochaic foot. Thus, in such forms, the shape of the suffix vowel should reflect its underlying form. As shown in (11), the suffix vowels surface as [i] in this context, which is predictable if their underlying form is /i/, but problematic if their underlying form is /e/.

(11)	bʌbəli	*bubbly*	fɜngəri	s*mall finger*
	bʌtəri	*buttery*	snɜkəri	*snickery*

A third way in which the lowering analysis is superior to the raising analysis is that while this study revealed no counterexamples to the lowering analysis, subjects did produce some forms that are inconsistent with the raising analysis. As shown in (12), the two analyses make different predictions as to what patterns should exist among trochaic words in the lexicon (here, 'D' stands for a blocking consonant or cluster, while 'T' stands for a non-blocking consonant or cluster; cases where the two analyses make different predictions are italicised).

(12)	*Form type*	*Lowering analysis*	*Raising analysis*
	iDi	predicted	predicted
	iDe	*predicted*	*not predicted*
	eDi	predicted	predicted
	eDe	predicted	predicted
	iTi	predicted	predicted
	iTe	*predicted*	*not predicted*
	eTi	*not predicted*	*predicted*
	eTe	predicted	predicted

The raising analysis predicts that there should be no forms of the type iDe or iTe, since the mid vowels would be expected to be raised in these contexts. However, as shown below, a few examples of iDe (13a) and iTe (13b) were found in modern lexical items.

(13) a. fraide *Friday* tuzde *Tuesday*
b. rile *relay* (N)

Only a few examples of these types were found, which is unsurprising since English has so few trochaic words with final /e/. However, though these problematic examples for the raising account are few, this study turned up no examples of the type eTi, which are predicted not to exist by the lowering account. Therefore, once again, the lowering account better fits the lexical data.

For the reasons outlined above, I conclude that the Buchan pattern is, in fact, lowering rather than raising, which makes it different from all of the languages discussed by Parkinson (1996) as having partial raising height harmony. This is one of several aspects of the pattern that make it an interesting subject for phonetic study.

3 The phonetics of harmony and blocking

In this section, I present the acoustic data relating to harmony and blocking. I then discuss a possible phonetic motivation for blocking and relate the pattern found in Buchan to phenomena documented in other languages.

3.1 Harmony as a phonological effect

The phonetics of harmony reveals that this is indeed a qualitative phonological effect rather than a gradient phonetic one. First, to establish the height values of the two suffix vowel allomorphs, compare the suffix vowel F1 after a root whose vowel is /i/ with one after a root whose vowel is /a/. This is shown in Fig. 3. For the female speaker CE, the F1 values of suffix vowels after roots with /i/ form a cluster whose values are below 400 Hz, with one exception out of seven tokens (mean = 368; SD = 42·7).[7] On the other hand, when the suffixes are attached to a root with the /a/ vowel, the suffix vowels form a distinct cluster with F1 values that are greater than 400 Hz, with one exception out of seven tokens (mean = 434; SD = 44·0).[8]

[7] The exceptional word is *wheelie*. One possible explanation for the exception is that the medial [l], which is velarised or 'dark' in this context, causes the stem [i] to be lowered, which in turn causes the final [i] to be lower than in the other words. However, the stem [i] is admittedly not particularly low in this token, having an F1 of 363 Hz.

[8] This exception is the word *grannie*. It is possible that the root is *grand*, with a final /d/, which is a blocker. However, no [d] is audible in *grannie*, and the root is more likely *gran*, which is common in isolation.

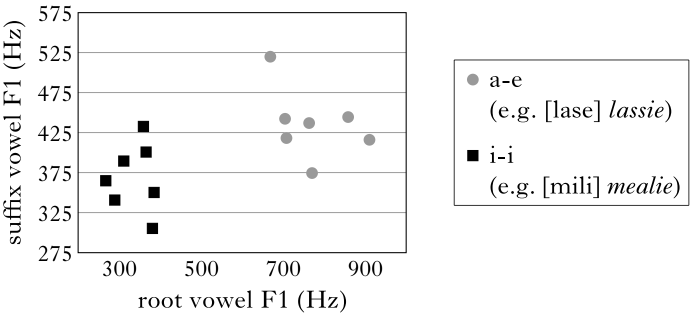


Figure 3
/-i/ suffix vowel height as a function of root vowel height (speaker CE). These data include only forms with a non-blocking medial consonant.

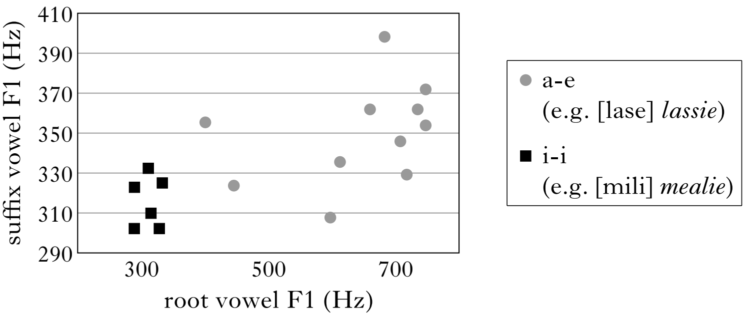


Figure 4
/-i/ suffix F1 values as a function of root F1 (speaker JG). These data include only forms with a non-blocking medial consonant.

Thus, although there is a slight overlap between the groups, the F1 values of what I have transcribed as the [i] suffix allomorph tend to be less than 400 Hz, while the F1 values of the [e] allomorph tend to be greater than 400 Hz. Application of a t-test confirms that the difference between the two clusters is significant ($t=2{\cdot}88$; $p=0{\cdot}014$).

Figure 4 shows a similar effect for the male speaker, JG. Although this speaker exhibits more overlap between the two groups isolated here, the two clusters are nonetheless statistically distinct. The mean for suffixes after /i/ is 316 ($n=6$; $SD=12{\cdot}6$), while the mean after /a/ is 349 ($n=11$; $SD=24{\cdot}9$). The distinction between the two clusters is shown to be significant ($t=3{\cdot}04$; $p=0{\cdot}008$).

I will continue to focus on F1 throughout when discussing the results of the phonetic study. This is because, first, no significant F2 effects are observed in the data. Second, even if some effect were found, it would be difficult to show that it had any bearing on the pattern being discussed here since, as was seen in Fig. 1, [i] and [e] are distinguished by F1 and not by F2.

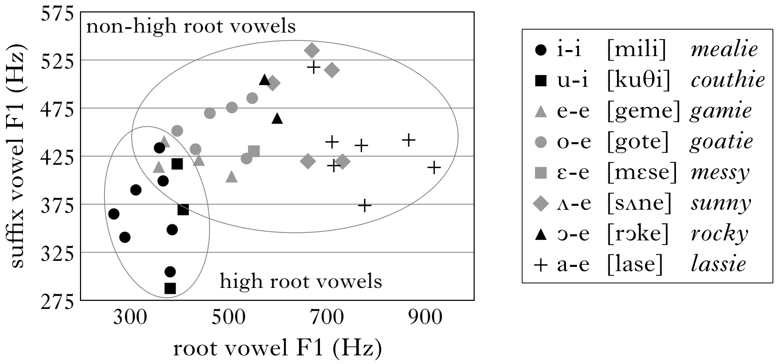


Figure 5
/-i/ suffix vowel height as a function of root vowel height (speaker CE). These data include only forms with a non-blocking medial consonant.

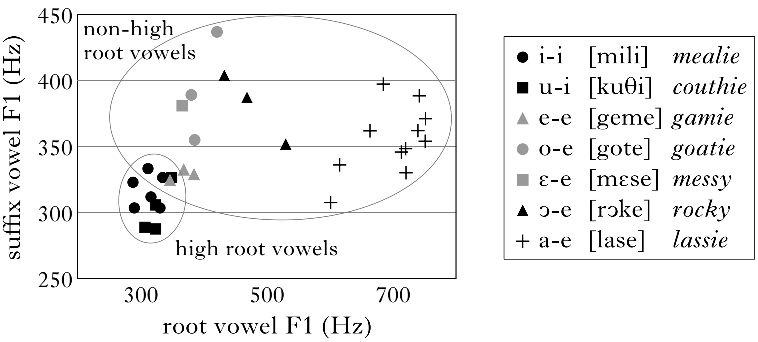


Figure 6
/-i/ suffix vowel height as a function of root vowel height (speaker JG). These data include only forms with a non-blocking medial consonant.

Having established a significant difference in suffix vowel F1 between words whose root has /i/ and words whose root has /a/, we turn now to words with other root vowels. If our characterisation of harmony is correct, we expect that all of the roots with non-high vowels will pattern with the /a/ roots, while roots with the other high vowel, /u/, should pattern with the /i/ roots. This should correspond to the same clustering that we saw in Figs 3 and 4. As shown in Figs 5 and 6, this prediction is borne out.

As shown in Fig. 5, after /i/ and /u/ roots, CE's suffix vowels tend to have F1 values of 400 or lower, although there are two exceptions out of ten tokens.[9] After all other root vowels, with one exception out of 25 tokens,

[9] One exception is the word *wheelie*, discussed above in note 7. The second is *housie*. The F1 value in question (415 Hz) is only slightly above 400 Hz, and is therefore not particularly problematic.

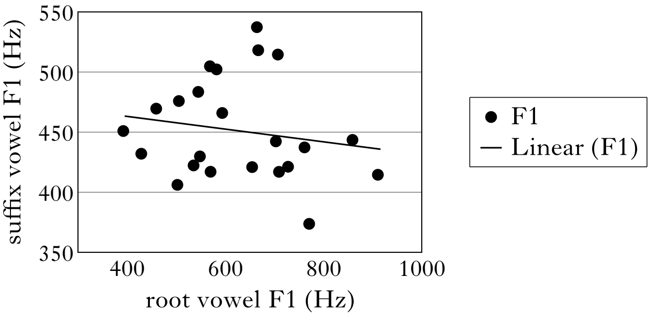


Figure 7
/-i/ suffix vowel height as a function of non-high root vowel height (speaker CE). These data include only forms with a non-blocking medial consonant.

the suffix vowels have an F1 greater than 400 Hz. Despite a slight overlap, these two groups are statistically distinct. The mean F1 after high vowels is 450 Hz ($n = 10$; $SD = 46{\cdot}6$), while the mean F1 after non-high vowels is 364 Hz ($n = 25$; $SD = 41{\cdot}0$). A t-test confirms that the distinction between these groups is significant ($t = 5{\cdot}35$; $p = 0{\cdot}000$).

As shown in Fig. 6, the same is true of speaker JG. The mean F1 value after high vowels is 310 Hz ($n = 10$; $SD = 16{\cdot}0$), while the mean F1 after non-high vowels is 361 Hz ($n = 21$; $SD = 31{\cdot}3$). Although the suffix vowel F1 values exhibit overlap between the high and non-high root vowel groups, the two groups do form distinct clusters ($t = 4{\cdot}83$; $p = 0{\cdot}000$).

Although we have established a consistent difference in F1 between what we have called the high and non-high variants of the suffix vowels, it is still not obvious that this is a categorical effect rather than a gradient one. Hypothesis A, that the effect we have seen is the purely phonetic result of perseverative tongue height coarticulation, predicts that suffix vowel F1 should vary directly with root vowel F1. Hypothesis B, that the effect is phonological and results from a categorical change from [+high] to [–high] in suffix vowels after [–high] root vowels, predicts that suffix vowel F1 should cluster into two categories depending on whether the root vowel is [+high] or [–high]. Both predict that suffix vowel F1 will be lower following [i] and [u] than other vowels, so the data we have seen so far are consistent with both hypotheses. In order to distinguish the two hypotheses, we must isolate high from non-high vowels to determine whether there is a significant effect of root-vowel F1 on suffix vowel F1 *within* the two groups. If so, the phonetic hypothesis (A) is favoured; if not, the phonological hypothesis (B) is favoured. As shown in Fig. 7 (based on 23 tokens), there is no significant effect of root vowel F1 on suffix vowel F1 when we consider only non-high root vowels ($r^2 = 0{\cdot}028$).

As shown in Fig. 8, the same is true for speaker JG (based on 21 tokens); suffix vowel F1 does not vary directly with root vowel F1 ($r^2 = 0{\cdot}0082$). This bears out the prediction of Hypothesis B above, that harmony is

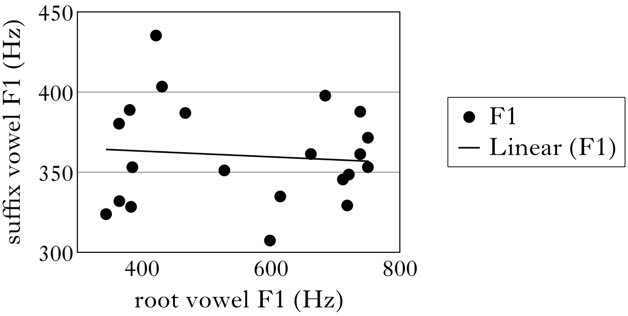


Figure 8

/-i/ suffix vowel height as a function of non-high root vowel height (speaker JG). These data include only forms with a non-blocking medial consonant.

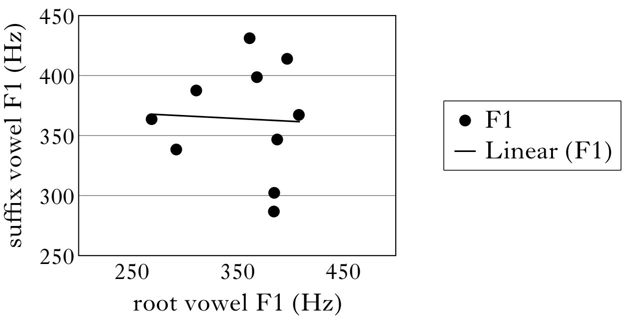


Figure 9

/-i/ suffix vowel height as a function of high root vowel height (speaker CE). These data include only forms with a non-blocking medial consonant.

not simply a phonetic coarticulation effect, but a qualitative phonological effect.

Similarly, when high vowels are isolated, we find that the F1 of high root vowels does not directly affect the F1 of suffix vowels. Figure 9 shows a plot of suffix vowel F1 *vs.* root vowel F1 for speaker CE (based on ten tokens). Again, there is no appreciable relation between root vowel F1 and suffix vowel F1 ($r^2 = 0{\cdot}0016$).

When forms with high root vowels are isolated for speaker JG, as in Fig. 10, we find again that root and suffix vowel F1 are not directly related (based on ten tokens; $r^2 = 0{\cdot}0349$). Once again, the data support the phonological hypothesis (B) over the phonetic hypothesis (A).

As was mentioned above in §2.3, harmony is neutralising, so that underlying /i/ that is lowered to [e] sounds identical to [e] from underlying /e/. This is supported by phonetic data: for speaker CE, the mean formant values of [e] from /i/ (based on 25 tokens) are 450 Hz for F1 (ranging from 373 to 536 Hz) and 2537 Hz for F2 (ranging from 2281 to 2869 Hz). The

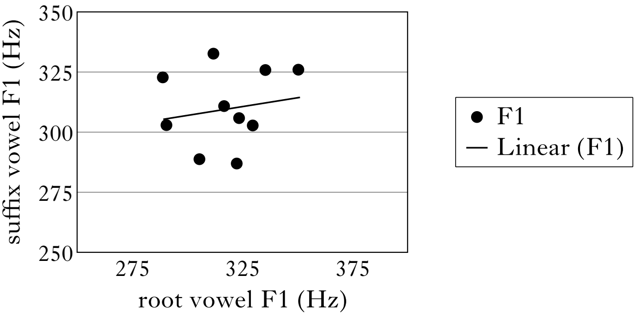


Figure 10
/-i/ suffix vowel height as a function of high root vowel height (speaker JG). These data include only forms with a non-blocking medial consonant.

values for [e] from /e/ (in stressed vowels; shown in Fig. 1) are similar (based on 17 tokens): 420 Hz for F1 (ranging from 347 to 554 Hz) and 2478 Hz for F2 (ranging from 2052 to 2652 Hz). Although the average values differ slightly, note that the F1 range of the first group is completely contained within the F1 range of the second group, and that the F2 ranges overlap considerably.

In summary, in this section I have demonstrated how phonetic measurement was used to confirm that Buchan vowel height harmony is a robust phonological pattern based on the behaviour of the diminutive and adjectival suffixes with roots ending in non-blocking consonants. Although a correlation between root/stressed vowel height and suffix/unstressed vowel height is clearly audible without the aid of acoustic measurements, these measurements are useful in demonstrating that the correlation is not a direct relationship between the F1 of stressed and unstressed vowels in a word. Rather, underlyingly high front suffix vowels cluster into two groups corresponding to [i] and [e] found in other contexts in the language. The [i] variant is found following a high root vowel, while the [e] variant is found following a non-high root vowel, even when the root vowel is the low vowel /a/. This confirms that the pattern is one of what Parkinson (1996) termed 'partial height harmony', since the /i/ suffix is not lowered all the way to [a] following /a/.

3.2 The phonetics of blocking

Now that we have examined vowel harmony phonetically, we can turn back to the blocking consonants and examine their phonetic effect. Figures 11 and 12 reproduce the data in Figs 5 and 6, except that in those charts, I showed only forms with non-blocking consonants. Here, I have added the forms that have blocking consonants, and the result confirms that the blocking effect is real and corresponds to the set of blocking consonants listed in (7). The only tokens that are expected to undergo

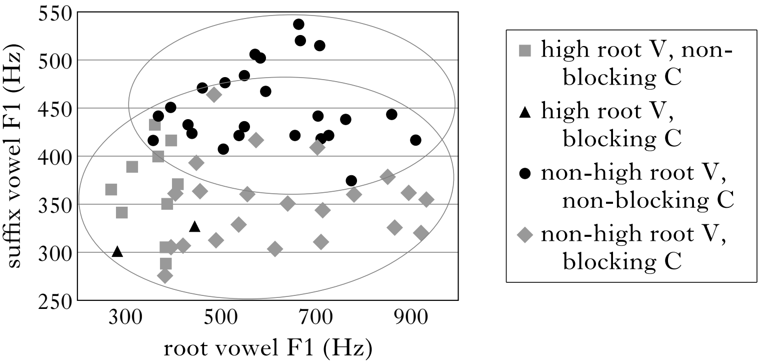


Figure 11
/-i/ suffix vowel height as a function of root vowel height and blocking *vs*. non-blocking consonant (speaker CE).

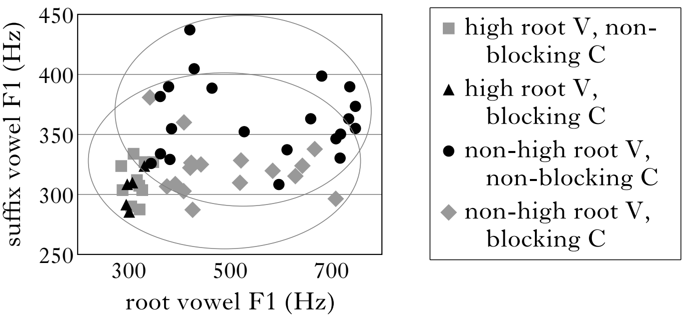


Figure 12
/-i/ suffix vowel height as a function of root vowel height and blocking *vs*. non-blocking consonant (speaker JG).

harmony are those forms with a non-high root vowel and a non-blocking root-final consonant (i.e. the tokens represented by black circles on the chart in Fig. 11). Indeed, as seen in Fig. 11, these are the only forms that undergo lowering; their F1 values are greater than 400 Hz, with one exception out of 25 tokens. Compare these with the grey diamonds, which represent forms that have non-high root vowels but blocking consonants, so that harmony does not apply. Their F1 values tend to be less than 400 Hz, confirming that harmony is not applying to these forms. Also as predicted, the blocking *vs*. non-blocking status of the root-final consonant does not appear to matter for the forms with high root vowels, though the sample size is small. The grey squares are forms with high root vowels and non-blocking consonants, and their F1 values tend to be less than 400 Hz, indicating that no lowering applies. The forms with high vowels and blocking consonants, indicated by the black triangles, have F1 values falling into the same range as those with high vowels and non-blocking root-final consonants. As stated above in the discussion of Fig. 5, the mean F1 value for /i/ suffixes after a non-high vowel and a non-blocking consonant (i.e. suffixes that undergo harmony) is 450 Hz ($n = 25$; $SD = 41{\cdot}0$). The mean F1 value for /i/ suffixes that do not undergo harmony (i.e. suffixes following a high root vowel and any consonant, and forms with a non-high vowel and a blocking consonant) is 352 Hz ($n = 34$; $SD = 44{\cdot}5$). A t-test confirms that the difference between the groups is statistically significant ($t = 8{\cdot}60$; $p = 0{\cdot}000$).

Thus the phonetic results conform to our prediction: when the root has a non-high vowel and a non-blocking final consonant, harmony applies, resulting in a non-high suffix vowel. When the root has a high vowel, and/or when it has a blocking consonant, harmony does not apply, and the result is a high suffix vowel. Figure 12 confirms that the same is true of speaker JG. The mean F1 value for /i/ suffixes in forms that undergo harmony (forms with a non-high root vowel and non-blocking consonant) is 361 Hz ($n = 21$; $SD = 31{\cdot}3$). The mean F1 value for /i/ suffixes in forms that do not undergo harmony (forms with a high root vowel and any consonant, and forms with a non-high vowel and a blocking consonant) is 314 Hz ($n = 31$; $SD = 20{\cdot}7$). The difference between the groups is significant ($t = 6{\cdot}41$; $p = 0{\cdot}000$).

Now that the phonetic description of harmony and blocking has been presented, we turn to the question of phonetic motivation for the pattern.

3.3 Effects of voicing on vowel height

Although the specifics of the Buchan pattern make it unique, a relation between voicing and vowel height has been documented in other languages, and at least one possible phonetic link has been put forward to account for such effects. Although some of the documented effects are on the vowel preceding rather than following a voiced obstruent (see, for example, Johnston 1997 for Shetlandic Scots), at least two others do involve vowel raising following a voiced obstruent: Madurese (Malayic; Stevens 1968) and Murle (East Sudanic; Arensen 1982). Denning (1989) claims that both the Madurese and Murle patterns can be explained via laryngeal lowering, which is the explanation that will be pursued in this section for the Buchan facts.

The Buchan pattern of harmony and blocking is of particular interest because consonants with no secondary articulation are not expected to interact with vowels. According to van der Hulst & van de Weijer (1995: 526–530), the most common type of consonantal interference in vowel harmony involves consonants that are vowel-like or have vowel-like features: some glides (/j/ and /w/) and consonants with secondary articulations. For example, in Bashkir, rounding harmony is blocked by /w/ (Poppe 1964, via van der Hulst & van de Weijer 1995). In other cases, where the interfering consonant does not necessarily have any vowel-like features, it has a place feature related to the harmonising vowel feature.

For example, in Finnish (Kiparsky 1981), velar consonants (sometimes specified [+back]) block [–back] harmony.

In contrast, the Buchan blockers are problematic because they do not share any one feature that is obviously related to the vowel height feature that they block. Perhaps for this reason, no researcher has successfully explained the blocking since Dieth (1932) first described it.[10] However, if we take voiced obstruents to be the central members of the blocking category, we see that there is in fact a relationship between the blockers and vowel height. Denning (1989: 81–82) notes a 'cross-linguistic tendency for voiced segments to involve lowering of the larynx' and points out that laryngeal lowering causes F1 to be lowered. Laryngeal lowering is found in American English by Westbury (1979: 199): 'normally, the larynx is lower at both closure and release for voiced than voiceless single stops. Oftentimes, too, the larynx is drawn downward during the closure intervals of most single voiced stops'. A similar effect is found in English by Riordan (1980) and in Thai, French, Hindi and English by Ewan & Krones (1974). It has been suggested that this laryngeal lowering is a strategy to maintain voicing during obstruent closure/constriction (although, as pointed out by Riordan 1980, who is critical of the interpretation of laryngeal lowering as a strategy to maintain voicing, the primary evidence in favour of this interpretation is simply the correlation between stop

[10] Other studies do not propose a satisfactory analysis of blocking. First, Fitzgerald (2002) discusses a slightly different dialect spoken in Fraserburgh (Wölck 1965), which is on the coast, to the north and east of where Dieth conducted his research (near Turriff) and where my own fieldwork was conducted (Turriff, Fyvie and Inverurie). In the dialect described by Wölck, unstressed non-high vowels reduce to [ə] except when preceded by a voiced obstruent, in which case they are raised to [ɪ]. For example, where Dieth transcribes [ʃargər] *sharger* 'person of stunted growth', Wölck transcribes [ʃargɪr]. The diminutive /i/ surfaces as [i] following a high vowel, and as [e] following a non-high vowel, with no apparent regard to the intervening consonant. Fitzgerald (2002) treats the form [ladi] *laddie* as an exception to harmony, and captures the effect of what I have called 'blocking' consonants in the dialect described by Wölck (1965) as a ban on [ə] following voiced obstruents, which do not interfere with the [i] ~ [e] alternation in the diminutive suffix. Fitzgerald's (2002) account appears to be the most straightforward available for blocking and harmony in that dialect, but her analysis does not extend to the dialect described by Dieth (1932), nor to the dialect I encountered in 2002, since in neither of these dialects do voiced obstruents trigger any change. Second, Kohler (1984) provides a short section discussing the potential usefulness of fortis/lenis in accounting for the phenomenon, but the standard use of these features would have predicted the opposite effect (blocking of lowering harmony by [+fortis], which typically refers to voiceless, rather than voiced, obstruents). Finally, Finally, Trigo (1986) proposes a raising analysis where underlyingly [–ATR] suffixes become [+ATR] after [+ATR] vowels or blocking consonants/sequences (which are assumed to be specified [+ATR]). Redundancy rules later ensure that the [–ATR] vowels are realised as [–high], while [+ATR] vowels are realised as [+high]. An [ATR]-based analysis, also suggested by Vaux (1998: 177–178), is problematic for at least two reasons. First, Trigo's analysis is a raising analysis, and therefore has all of the conceptual and empirical problems discussed above in §1.5. Second, Trigo's proposal of redundancy rules to map [±ATR] to [±high] reveals that height, rather than [ATR], is the harmonising feature. [ATR] relates the blocking consonants to vowel quality at the expense of a direct and accurate characterisation of the vowel alternation.

voicing and laryngeal lowering). In a stop, oral pressure builds up behind the closure, decreasing the pressure drop across the glottis that is required for vocal fold vibration. Although this is more problematic in initial and final position than intervocalically, devoicing is also found intervocalically in English, particularly in the context of interest here (namely, before an unstressed vowel): 'if there is a break in voicing [in English medial [b d g]], as is common for stops before non-reduced vowels, then there is more stop closure voicing before a more stressed vowel' (Keating 1984: 32). In order to maintain voicing, some 'particular additional effort' (Ladefoged & Maddieson 1996: 51) is needed to increase the supraglottal volume to maintain the pressure drop so that vocal fold vibration can continue. The studies carried out by Westbury (1979), Riordan (1980) and Ewan & Krones (1974) document laryngeal lowering in stops and do not discuss fricatives or affricates, but there is reason to believe that other voiced obstruents should involve laryngeal lowering as well. As explained by Ohala (2001), oral pressure must be as low as possible for optimal voicing in order to maintain the transglottal pressure drop required for voicing. On the other hand, for optimal fricative noise, oral pressure must be as high as possible. Since these two requirements are at odds, voiced fricatives with strong frication tend to be devoiced. Thus, laryngeal lowering in all voiced obstruents including fricatives is not unexpected.

One fact complicating the interpretation of laryngeal lowering as a strategy to maintain voicing in obstruents is that both Westbury (1979) and Riordan (1980) found laryngeal lowering not only in plosives, but in nasals as well. Nasals would not be expected to require such a strategy to maintain voicing, since they have continuous, unimpeded airflow which would prevent supraglottal pressure from building up and terminating vocal fold vibration. However, Riordan (1980) points out that the larynx lowering in nasals may relate to some different factor such as the control of pitch.

Dieth's (1932) description of the Buchan obstruent voicing contrast, based on auditory impression and on kymograph tracings, provides indirect evidence that Buchan voiced obstruents may have had a significant degree of laryngeal lowering:

> **p**, **t**, **k** … are devoid of aspiration, a trait so thoroughly ingrained in the language that it will linger on after idiomatic differences have long been obliterated. Since aspiration and no aspiration no longer divides [voiced from voiceless] stops, voice and intensity become the main discriminating factors. (1932: 85)

Dieth's claim that voiceless stops were unaspirated is supported by Grant's observation (1913: 70): 'when a breathed plosive occurs before a vowel in connected speech in Standard Scottish, the emission of breath is barely perceptible, being strongest in the case of the back plosive. It never strikes the ear in the same way as Southern English or Irish, where *pass*, **pɑs**, might be written **pʰɑs**'. Figure 13 shows kymograph tracings comparing Buchan and English voiceless stops in the word *tatez*/*tatoes*

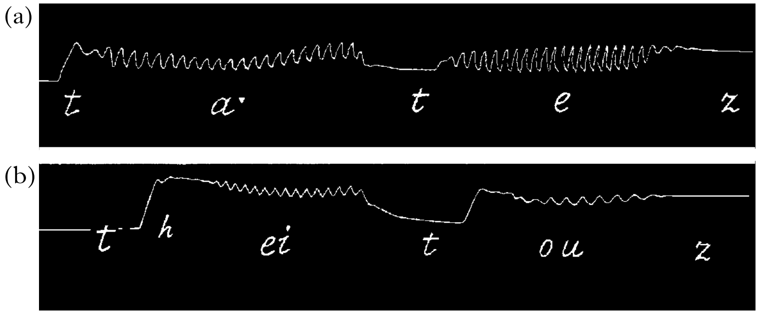


Figure 13
Kymographic tracing: (a) Standard English; (b) Buchan Scots.
Reproduced from Dieth (1932: 86).

'potatoes' (reproduced from Dieth 1932: 86), which also supports Dieth's claim. Although it is difficult to assess exactly what one is looking at in a kymograph tracing, the shape of the tracings does seem to correspond to Dieth's interpretation of it: 'the kick of the initial *t* is almost immediately followed by waves (i.e. voice, vowel) [in the Buchan example, but] in [Standard English] by a horizontal straight line (i.e. breath). The medial *t* in Buchan gives hardly any kick' (1932: 86). Because Standard English exhibits aspiration of medial voiceless stops, it is relatively easy to maintain a voicing contrast in medial position without larynx lowering. However, according to Dieth's description, supported by the kymograph tracing, Buchan Scots did not exhibit aspiration of voiceless stops in this context. Since voiceless stops lacked aspiration, the voiced–voiceless distinction was made via 'voice and intensity', which I interpret to mean robust, audible voicing of the voiced stops. Since voiceless stops were not aspirated, their VOT must have been very small, probably less than 15 ms, which would obscure the distinction between voiced and voiceless stops.[11] Without VOT, voicing (and perhaps some other factors) would bear the burden of distinguishing voiced from voiceless stops, and therefore probably had to be augmented by larynx lowering. Unfortunately, Dieth does not provide any kymograph tracings showing medial voiced stops, so we must base the discussion on inferences from what is known about the voiceless stops.

I hypothesise that in the older Buchan dialect described by Dieth, speakers produced phonologically voiced obstruents with robust vocal fold vibration throughout the closure period, i.e. with continuous, unattenuated phonetic voicing. Because vocal fold vibration is diminished by the build-up of pressure behind the closure in obstruents, speakers must have employed some strategy (the 'additional effort' mentioned by Ladefoged

[11] As will be discussed, although Dieth describes the dialect as spoken in 1932 as having unaspirated voiceless stops, the modern dialect does exhibit aspiration.

& Maddieson 1996) in order to maintain voicing in the stop closure. I claim that in this case the strategy was laryngeal lowering. Although it is impossible to test this hypothesis directly on a dialect spoken seventy years ago, there are at least two further pieces of indirect evidence for laryngeal lowering in Buchan in addition to Dieth's description presented above.

First, the set of blockers is primarily composed of voiced obstruents. No other significant category of sounds, e.g. consonants at a particular place of articulation, is a subset of the blocking class, nor does any other category capture as large a subset of the blocking class. Therefore, if any other attribute of the original set of blockers were the true cause of blocking, it would be more difficult to account for the extension of the blocking class to include all voiced obstruents plus NT and lT. For example, suppose that in order to maintain voicing during the closure of [d], rather than lowering the larynx, Buchan speakers moved the coronal articulation forward (towards the teeth) with respect to the articulation of [t]. This would have lowered F1 following [d], giving us an explanation for the blocking of harmony by [d]. However, if this were our explanation for the origin of blocking, we would then have to account for the extension of the blocking class from [d] to voiced obstruents at all places of articulation, and then to NT and lT.

A second fact in support of the laryngeal lowering hypothesis is that the effect is on the vowel *following* rather than preceding the consonant in question. Larynx lowering takes place *after* the beginning of the closure period, when pressure begins to build up behind the closure, as confirmed by Ewan & Krones (1974: 334): 'voiceless stops generally have a higher larynx position than corresponding voiced stops, *ceteris paribus*, with this difference in position being greater at or near the end of the stops'. Therefore, this explanation predicts an effect on the following rather than the preceding vowel. It is true that the perseveratory nature of the process may also be attributable to the trochaic stress pattern of the participating words, since unstressed vowels are often more susceptible to be targets of harmony than are stressed vowels (see e.g. Majors 1998), but the effect is nonetheless manifested in the predicted direction.

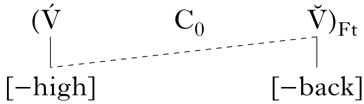
4 Synchronic analysis

Since we have determined that the pattern of harmony and blocking is phonological rather than phonetic, we turn now to a synchronic phonological analysis of the pattern. In §4.1, I present a straightforward rule-based account of harmony and blocking. In §4.2, I present a similar account formulated in OT. In §§4.3–4.5, I present possible alternative analyses based on domains, articulatory features and acoustic features, respectively. In each case, I demonstrate how the alternative analysis is inferior to the account in §4.1 and its OT counterpart.

4.1 A rule-based account of harmony and blocking

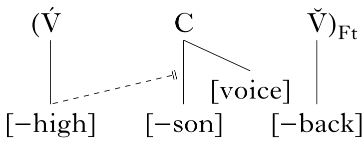
The rule in (14) captures the harmony pattern described in the preceding sections (note that V and C are placeholders for root nodes of vowel and consonant segments, respectively, and are not intended as units on a CV tier).

(14) *Lowering harmony*



The rule states that within a trochaic foot, an unstressed front vowel surfaces as non-high when preceded by a stressed non-high vowel and zero or more consonants (represented here as C_0, following Chomsky & Halle 1968). An additional condition is needed, shown in (15).

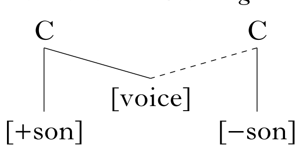
(15) *Blocking condition*



This condition stipulates that if any intervening consonant is specified for both [voice] and [–sonorant], then the spread of [–high] is blocked.

As formulated in (14) and (15), the harmony rule and blocking condition account for all of the forms presented in this paper, with the exception of the forms in which NT and lT block harmony. In order to account for these forms, I posit an additional rule spreading [voice] from a nasal or lateral to a following [–sonorant] segment:

(16) *Postsonorant Voicing*



This rule is ordered before harmony, so that a postsonorant /t/ becomes specified as [voice] prior to harmony, and therefore fulfils the blocking environment.

There is phonetic evidence for this rule. As shown in Fig. 14, which gives a representative example of a medial NT sequence, voicing is observed to 'leak' into voiceless obstruents from a preceding nasal. This gives the appearance that the rule is neutralising, but as will be discussed below, there is still a contrast corresponding to /T/ *vs.* /D/ after sonorants. Figure 15 shows the same form zoomed in during the [nt] portion.

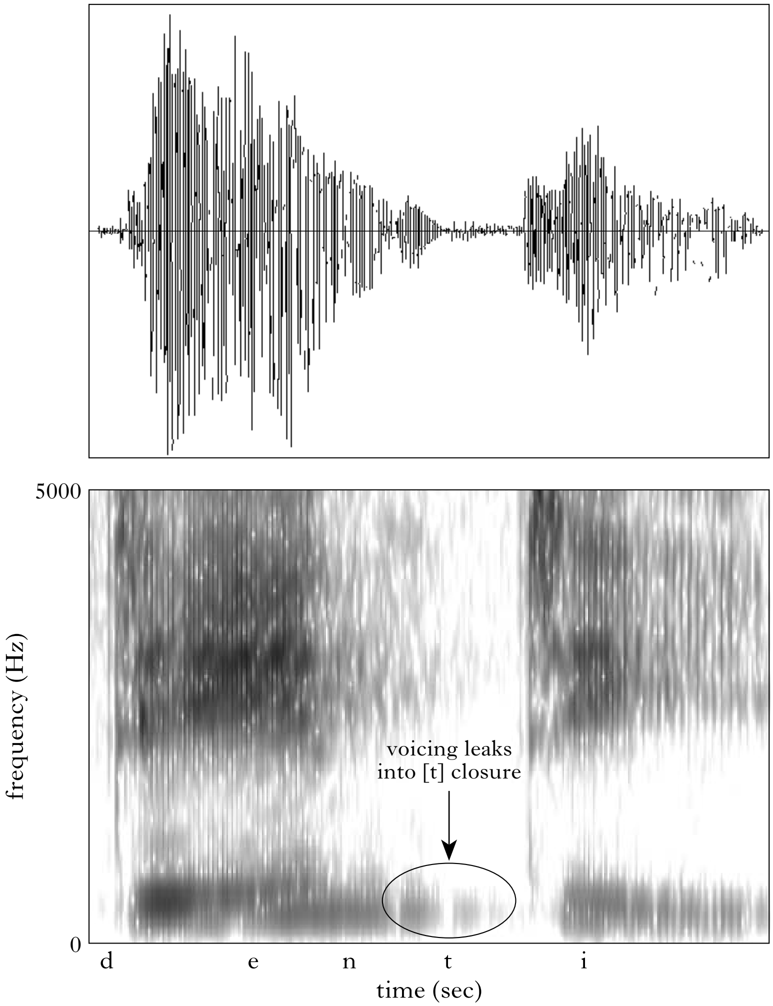


Figure 14
Waveform and spectrogram showing speaker CE's production of [denti] *dainty*.

This could be construed as an example of the so-called *NÇ̥ effect, where obstruents are claimed to be universally preferentially voiced following nasals (see Kager 1999, Pater 1999 and Hayes & Stivers 2000 for summaries of these effects and analysis in OT, and Archangeli *et al.* 1998 and Hyman 2001 for some counterexamples, and criticism of the OT approach). However, the *NÇ̥ explanation would not account for the fact that the rule in (16) applies also to lT sequences. Figure 16 shows a typical example of a medial lT sequence, and here we observe the same 'leakage' of voicing into a voiceless obstruent after [l] as after a nasal,

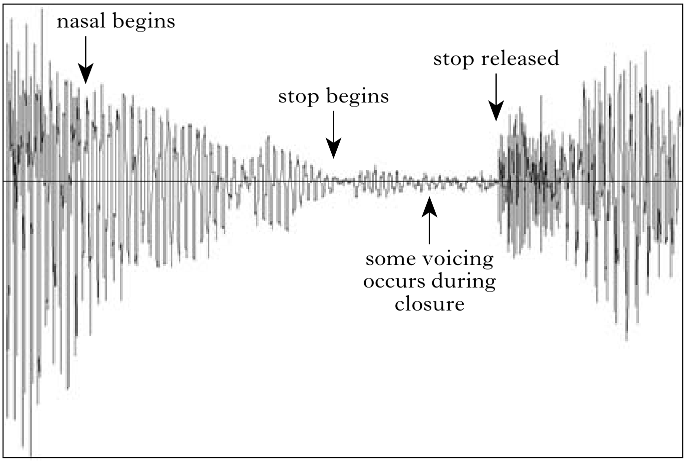


Figure 15
Medial [nt] sequence in [denti] *dainty*.

while Fig. 17 shows a waveform of the same token zoomed in at the [lt] portion.

It may seem problematic to exclude rT sequences, which, as mentioned in §2.4, do not block harmony. Based on the rule in (16), we might expect voicing to spread from /r/ into a following voiceless obstruent, yielding a [–sonorant, voice] segment that would incorrectly block harmony. However, there is phonetic evidence in favour of excluding rT from the rule in (16), since as shown in Fig. 18 (a representative token of a medial rT sequence), the pre-obstruent [r] is devoiced, and no voicing is observed to 'leak' from [r] into a following voiceless obstruent. The same token is shown in Fig. 19, zoomed in during the [r] portion of the word.

Buchan Scots /r/ is pronounced variably as an alveolar trill or a tap, and the degree of voicing varies, particularly in the trill, depending on the context. The tap is observed intervocalically, while the trill is observed in initial position, medially before another consonant (generally devoiced in this context), and word-finally. Based on its realisation and its behaviour in the phonological system, I propose that Buchan Scots /r/ is not voiced in pre-obstruent position, and that this is why it does not trigger the voicing rule in (16). This lack of a [voice] specification may be achieved via a rule whereby /r/ is devoiced before a consonant, which would be ordered before Postsonorant Voicing. Alternatively, since all of the attested examples of rT in this study are tautomorphemic, perhaps /r/ is underlyingly voiceless in this context.

A second, perhaps more serious possible objection to the Postsonorant Voicing rule is that it is not neutralising. Despite the phonetic voicing of postsonorant voiceless obstruents, speakers maintain a contrast between

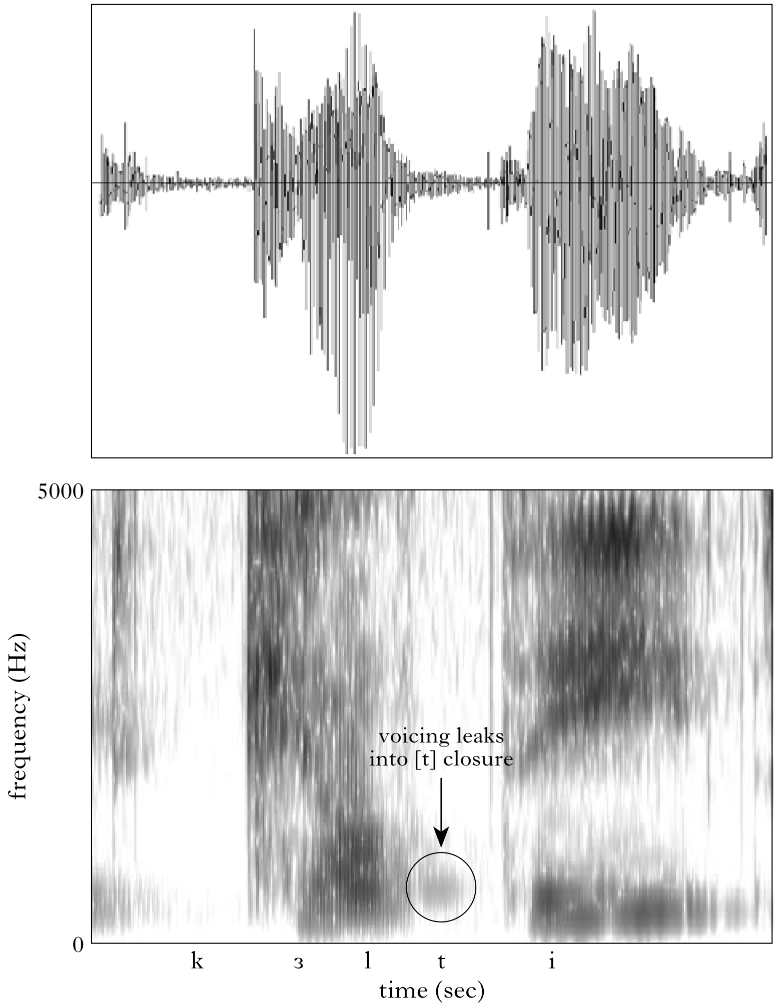


Figure 16
Waveform and spectrogram showing speaker CE's production of *kiltie*.

medial NT/lT and ND/lD. This is illustrated by such near-minimal pairs as [dent̬ɪ] *vs.* [bɛndi] (*dainty vs. bendy*) and [kɜlt̬ɪ] *vs.* [baldi] (*kilty vs. baldie*) ([t̬] indicates a coronal stop corresponding to input /t/ that has the feature [voice] in the output, but is phonetically distinct from [d]). If underlying NT and lT are altered by Postsonorant Voicing so that they are [voice], and therefore phonologically identical to ND and lD respectively, then we must still account for their surface phonetic difference. One possible explanation is that since, as discussed by Kingston & Diehl (1994: 427), there are many different cues for the voicing contrast

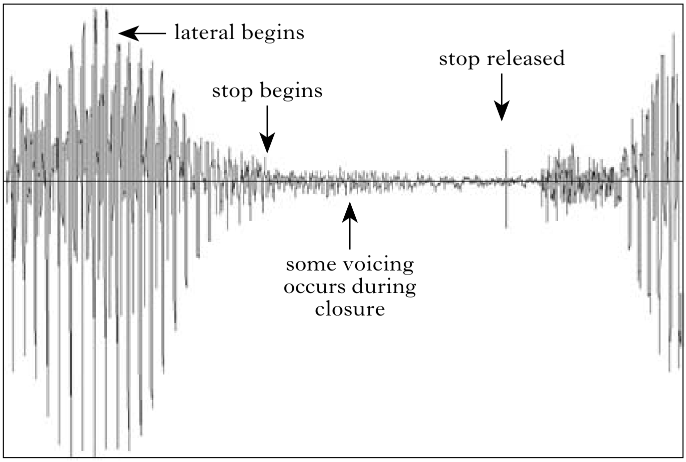


Figure 17
Medial [lt] sequence in [kalti] *kiltie*.

(including voicing, VOT, F1, F0, strength of burst, closure duration and duration of preceding vowel), perhaps the mere fact that there is voicing during the closure of [t̬] is not sufficient to cause merger with [d], since speakers can use so many other cues to distinguish the two. Whether or not this particular explanation is accepted, other instances of incomplete neutralisation of voicing have been documented in the literature (see e.g. Port & O'Dell 1985), so the Buchan Postsonorant Voicing rule does not introduce a new problem.

If we accept Postsonorant Voicing as a way of accounting for the blocking property of NT and lT sequences, a question arises as to what type of voicing is involved. Rice (1993) proposes that two different features account for voicing: Sonorant Voice (SV) for sonorants and some obstruents, and [voice] for obstruents. If sonorants in Buchan were specified for SV rather than [voice], then we would expect this to be the feature to be spread by Postsonorant Voicing. However, this is problematic because it would introduce a disjunction into the set of consonants that block harmony, which would now have to include [–sonorant, SV] segments (postnasal and postlateral voiceless obstruents that have undergone Postsonorant Voicing) as well as [–sonorant, voice] segments (underlyingly voiced obstruents). Because postsonorant obstruents that undergo voicing do not pattern with sonorants (which do not block harmony), it is more advantageous to assume that all voicing in Buchan is specified by a single feature, [voice], which is what spreads from sonorants to following obstruents in the Postsonorant Voicing rule. While this does not constitute a strong argument against the SV feature, one may conclude that although SV is available, it is not used in all languages, and in particular, it is not used in Buchan Scots.

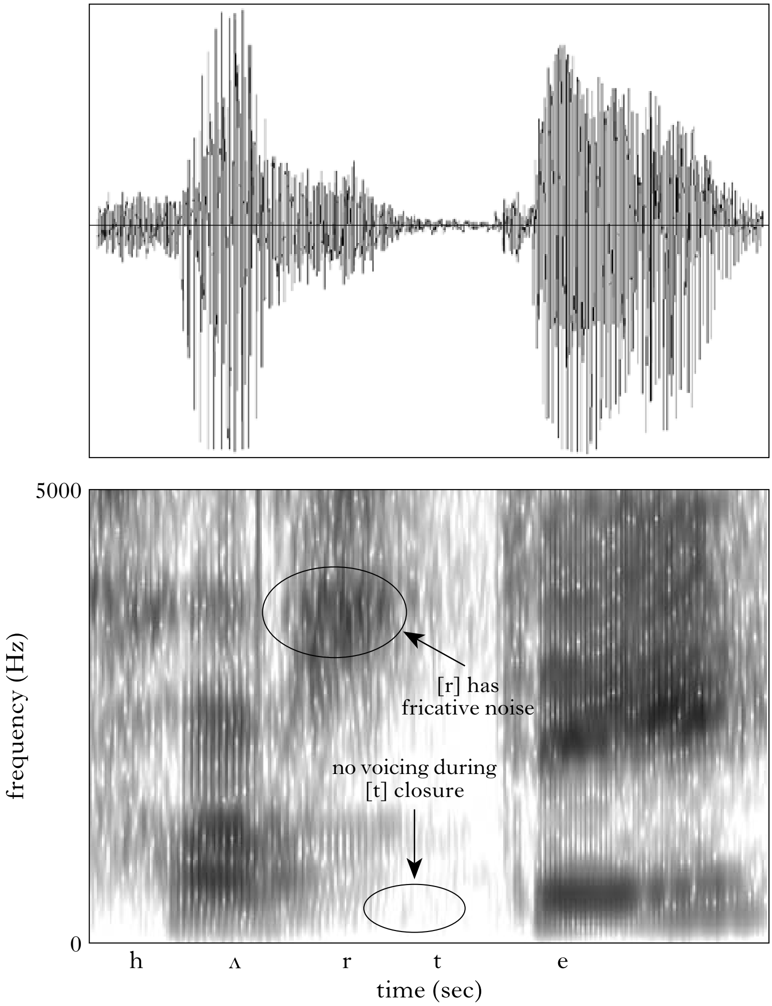


Figure 18
Waveform and spectrogram showing speaker CE's production of *hurtie*.

4.2 An optimality-theoretic account

I have described the pattern using variations of a derivational rule, but the pattern can also be captured using Optimality Theory. In one potential OT account, the constraint ALIGN-R[–hi] (17) mandates that the feature [–high] be aligned to the right edge of a word.

(17) ALIGN-R[–hi]
Align the feature [–high] to the right edge of a word.

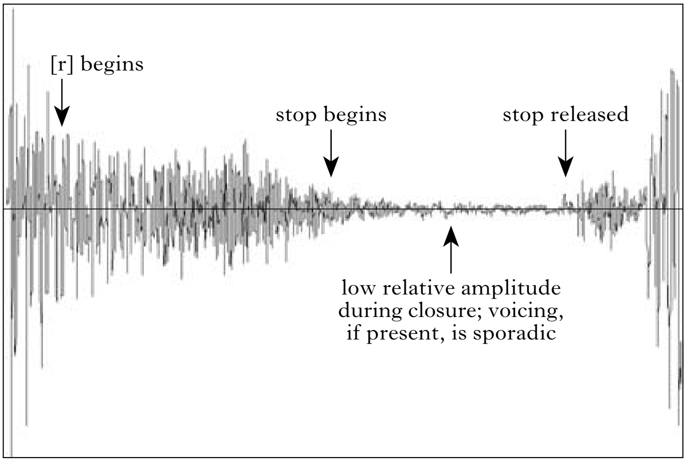


Figure 19
Medial [rt] sequence in [hʌrte] *hurtie*.

This constraint is violated by each instance of [–high] in the output that is not aligned to the right edge of the word.

Harmony is driven by the ranking of this constraint above an IDENT constraint, (18), which requires faithfulness to the input height specification of an unstressed vowel.

(18) IDENT[±hi]-V̆

An input [±high] must have an identical output correspondent in an unstressed vowel.

Under this analysis, blocking is accounted for by using the constraint *D[–hi] (19), which prevents voiced obstruents from having a [–high] specification. It is assumed that the spread of [–high] results in a [–high] domain that includes any intervening consonant rather than only the trigger and target vowels.

(19) *D[–hi]

A voiced obstruent cannot be [–high].

This constraint is language-specific and may seem unmotivated, but since we have seen a link between obstruent voicing and lowered F1, there is a phonetic principle behind the constraint.

MAX[voi] (20), a constraint against the deletion of [voice], ensures that the conflict between ALIGN-R[–hi] and *D[–hi] will not result in devoicing of an intervening voiced consonant.

(20) MAX[voi]

An input [voice] must have an output correspondent.

I use MAX[voi] rather than IDENT[±voi] because I assume, following Rice (1993) (and references therein) that [voice] is privative. The analysis can be adapted to allow for [±voice] if one prefers; in that case, the constraint IDENT[±voi] would be crucially ranked below *NT/lT to allow for post-sonorant voicing.

A highly ranked IDENT constraint, (21), prohibits stressed vowels from changing their height.

(21) IDENT [±hi]-V́

An input [±high] must have an identical output correspondent in a stressed vowel.

The constraint *NT/lT (22) prohibits voiceless obstruents after nasals and [l].

(22) *NT/lT

An obstruent may not be voiceless following a nasal or [l].

It is assumed that *NT/lT is always repaired via the spread of [voice] to the obstruent; higher-ranked faithfulness constraints would technically be required to prevent this constraint from being satisfied by deleting or changing either segment in the sequence in any other way.

Undominated MAX[+hi]-/u/ (omitted from the tableaux) prevents /u/ from lowering, since there is no evidence that /u/ undergoes harmony.

(23) MAX [+hi]-/u/

An input [+high] in /u/ must have an output correspondent.

Finally, undominated MAX[–hi] (also omitted from the tableaux) prevents ALIGN-R[–hi] violations from being resolved via raising of an initial unstressed syllable in words like *motif*. This constraint is justified by the fact that raising is never observed.

(24) MAX[–hi]

An input [–high] must have an output correspondent.

These eight constraints are sufficient to account for harmony and blocking when ranked as follows:

(25) MAX[+hi]-u, MAX[–hi], *D[–hi], IDENT[±hi]-V́, *NT/lT, MAX[voi] ≫ ALIGN-R[–hi] ≫ IDENT[±hi]-V̆

Given these constraints and rankings, we can select output forms that exhibit harmony, such as *lassie*, as shown in (26). In each of the output candidates, parentheses indicate a domain in which all segments are [–high].

(26)

las-i	*D[–hi]	IDENT(V́)	*NT/lT	MAX[voi]	ALIGN-R	IDENT(V̆)
a. l(a)si					*!	
☞ b. l(ase)						*
c. l(a)s(e)					*!	

In this example, the fully faithful candidate is eliminated because it violates ALIGN-R[–hi], since the [–high] feature of the /a/ vowel does not spread to the /i/ in the output form. The candidate where each vowel has a separate specification of [–high] is eliminated because it violates ALIGN-R[–hi].

The case where vowels are disharmonic due to a blocking consonant is exemplified by *laddie* in (27).

(27)

lad-i	*D[−hi]	IDENT(V́)	*NT/lT	MAX[voi]	ALIGN-R	IDENT(V̌)
☞ a. l(a)di					*	
b. l(ade)	*!					*
c. l(ate)				*!		*
d. l(a)d(e)					*	*!

The harmonic candidate [l(ade)] is eliminated because it violates *D[–hi]. The form that exhibits harmony and devoicing of /d/, [l(ate)], incurs a fatal violation of MAX[voi]. As shown, the fully faithful candidate violates ALIGN-R[–hi]. However, it is selected over [l(a)d(e)] because [l(a)d(e)] violates IDENT.

This ranking also correctly selects forms where medial lT acts as a blocker to harmony, as in *kiltie*.

(28)

kɜlt-i	*D[−hi]	IDENT(V́)	*NT/lT	MAX[voi]	ALIGN-R	IDENT(V̌)
a. k(ɜ)lti			*!		*	
☞ b. k(ɜ)lt̬i					*	
c. k(ɜlt̬e)	*!					*
d. k(ɜlte)			*!			*
e. k(ɜ)lt̬(e)					*	*!

In the above tableau, the faithful candidate is eliminated because it violates *NT/lT. The candidate that exhibits both harmony and postsonorant voicing, [k(ɜlt̬e)], is eliminated because it violates *D[–hi]. The candidate that exhibits harmony but not postsonorant voicing, [k(ɜlte)], fatally violates *NT/lT. Finally, the candidate that exhibits postsonorant voicing and insertion of a second [–high] specification on the unstressed vowel, [k(ɜ)lt̬(e)], is eliminated because it violates both ALIGN-R (which is also violated by the winning candidate) and IDENT (which is not violated by the winning candidate).

For completeness, I demonstrate below the selection of *easy*, which has both a high stressed vowel and a blocking consonant. As expected, the present analysis correctly selects the completely faithful candidate, with no lowering.

(29)

iz-i	*D[−hi]	IDENT(V́)	*NT/lT	MAX[voi]	ALIGN-R	IDENT(V̌)
☞ a. izi						
b. iz(e)						*!

The winning candidate does not violate any of the constraints in our inventory, while the candidate where the unstressed vowel is lowered, [iz(e)], incurs a fatal violation of IDENT.

We have seen how the OT account accurately captures the facts in a way similar to the rule-based account in §4.1. In the sections to follow, I propose three possible alternative analyses and discuss why they compare unfavourably with the rule-based and OT analyses described above.

4.3 A domain-based account

An anonymous reviewer suggests one alternative analysis that would account for the NT/lT blockers without requiring phonological Postsonorant Voicing or an OT constraint to the same effect. The alternative analysis would handle blocking via domains, following Piggott's (1996) account of umlaut in Kyungsang Korean. Under such an analysis, the domain of harmony in Buchan Scots would be a moraic trochee. In forms of the shape CVCCV, the first consonant of the medial cluster would syllabify with the first syllable and would project a mora. Therefore, the second syllable would not be in the same foot as the first syllable, and its vowel would not undergo harmony. However, as acknowledged by the reviewer, there is a significant flaw in this alternative analysis, which is that it incorrectly predicts that all medial consonant sequences should block harmony, when in fact only NT, lT and sequences containing a voiced obstruent behave as blockers. While one might be able to analyse e.g. medial [st] as an onset rather than splitting it into two syllables, it would be difficult to justify analysing other transparent clusters (e.g. [nl mr rt rs]) as onsets, since these sequences are not found as onsets in word-initial position. Therefore, though appealing on its surface as a way of avoiding having to posit non-neutralising Postsonorant Voicing, the domain-based account is untenable.

4.4 An account based on articulatory features

A second alternative way to account for harmony and blocking involves the use of articulatory features. The harmony can be characterised as the spreading of [–high] (referring to tongue height) from a stressed vowel to a following unstressed [+high] vowel. We can describe the class of blocking consonants as having the feature [lowered larynx] ([LL]), which corresponds directly to an articulatory gesture of larynx lowering that is carried out each time a blocking consonant is produced. There are at least two ways that this feature could be used to capture the blocking effect. One way is to stipulate that the features [±high] and [LL] (which I am assuming is a privative feature) are on the same featural tier, and therefore the spread of [–high] is blocked by [LL]. It seems reasonable to posit that these features share a tier, since both relate to F1. An alternative is to assume (as in the OT analysis in §4.2) that the domain of harmony includes not only the target and trigger vowels, but also the intervening consonant(s). Since blocking consonants are specified as [LL], and since the acoustic manifestation of [LL] is incompatible with that of [–high], blocking consonants are ineligible to bear [–high], and therefore the harmonic spread of [–high] is blocked by a [LL] consonant. This is schematised below.

(30) a. *Non-blocking example*

l a s - i [lase] *lassie*

[−high] [+high]

b. *Blocking example*

l a d - i [ladi] *laddie*

[−high] [LL] [+high]

One problem with this analysis is that, as mentioned in §4.1, there is a T–D contrast after [l] and nasals. One way of understanding the non-neutralising nature of the rule is to assume that while underlyingly voiced obstruents are deliberately voiced, underlyingly voiceless obstruents that undergo Postsonorant Voicing are voiced via passive continuation of voicing from a preceding sonorant. If this is the correct interpretation of the postsonorant voicing contrast, then we would not want to posit a feature like [LL] for obstruents that undergo Postsonorant Voicing, since [LL] represents an active mechanism of larynx manipulation in order to facilitate voicing. The articulatory feature account would require lT and NT to be specified as [LL] in order for them to block harmony. If NT and lT do not actually involve physical laryngeal lowering, this would make [LL] an abstract feature with no physical correlate, thus stripping the analysis of its articulatory basis. This would have been its primary advantage over the analysis in §4.1.

A second objection to an articulatory feature-based account is that there is evidence that the voicing contrast has changed since Dieth (1932) described it. This may mean that voiced obstruents no longer have sufficient laryngeal lowering to cause an F1 effect that would correspond to the incompatibility of voiced obstruents with [–high] assumed in this account. The evidence for the change is as follows: as discussed in §3.3, Dieth describes voiceless stops as unaspirated and provided a kymograph tracing in support of this description. But, as was seen in Figs 14–19, voiceless stops are aspirated in the modern dialect. This suggests that the nature of the voicing contrast could have changed completely; if voiced stops used to be produced as they are today (with voicing diminishing

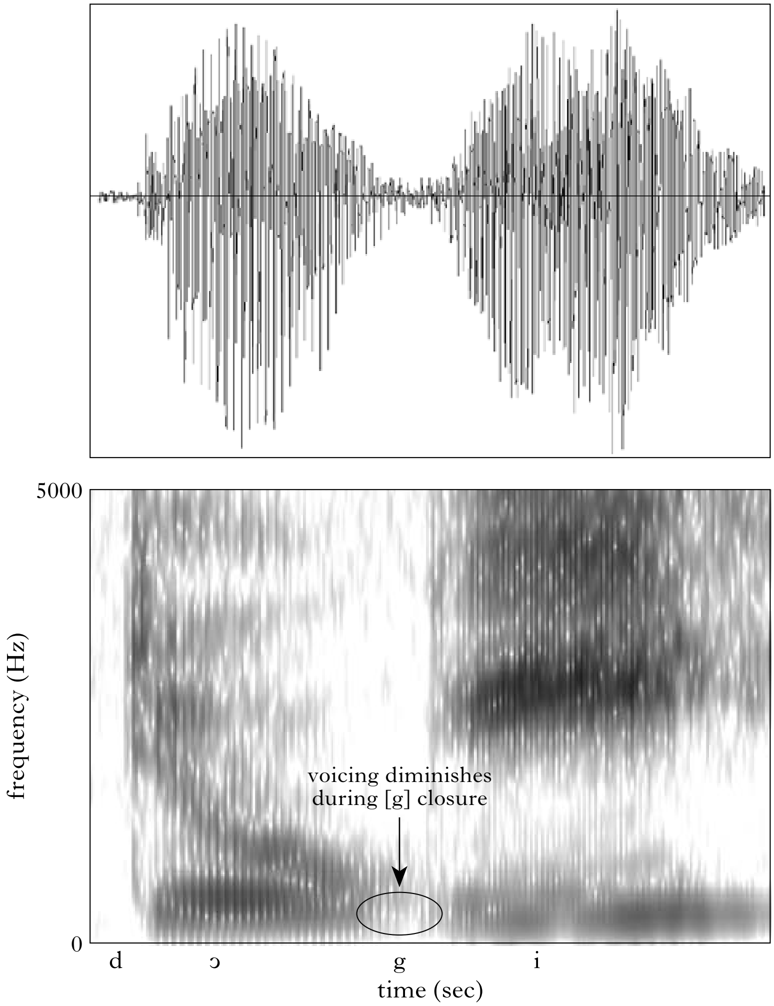


Figure 20
Waveform and spectrogram showing speaker CE's production of *doggie*.

during the closure) at the earlier stage where voiceless stops were unaspirated, then the T–D contrast would have been difficult to distinguish (unless some factor other than VOT played a more important role at that stage). Unfortunately, we will never know whether speakers of the older dialect used laryngeal lowering, and a study of larynx position and movement in the modern dialect was not within the scope of this study. However, as discussed below, we can use acoustic data to shed light on these issues in the modern dialect.

Figure 20 shows a representative example of a phonologically voiced stop in intervocalic position in the word [dogi] *doggie*. As seen in the

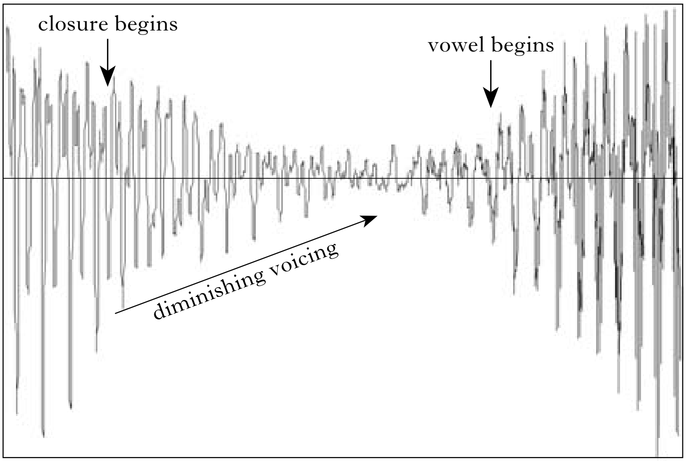


Figure 21
Closure period of [g] in [dogi] *doggie*. Note that voicing diminishes throughout the closure.

waveform and spectrogram, voicing diminishes during the [g] closure. A look a waveform of the same token zoomed in at the closure (Fig. 21) reveals a drastic decrease in the amplitude of voicing throughout the closure period. According to Ladefoged & Maddieson (1996: 50), the same is true in dialects of English, where voiced obstruents often do not have consistent vocal fold vibration throughout the closure or constriction:

> It is well known that in some languages, English being a familiar example, the vocal folds may not vibrate throughout the closure for a voiced stop. Even when surrounded by other voiced sounds, such as vowels, the vocal fold vibration often ceases shortly after the closure is made and only resumes shortly after the closure is released.

This effect can be attributed to build-up of pressure behind the closure, which eliminates the transglottal pressure drop that is needed to maintain voicing. We infer that in a language like English, where vocal fold vibration ceases or diminishes during voiced stop closure, voiced stops must involve minimal laryngeal lowering; otherwise we would expect to see a resurgence of voicing at the end of the closure. According to Riordan (1980), although the larynx could be lowered by up to 0·5 cm during stop production, the actual amount of lowering is only 0·15 cm in English intervocalic [b] (note, though, that other strategies for voicing maintenance are available for [b] than for [d] or [g], since bilabials have a larger area of compliant tissue behind the closure; Ohala & Riordan 1980). If the above interpretation is correct, then the articulatory account becomes excessively abstract since the proposed articulatory feature, [LL], may not really reflect an important aspect of the production of voiced obstruents in the modern Buchan dialect, where voiced stops were shown to be similar to their counterparts in dialects of English.

4.5 An account based on acoustic features

Another alternative is an account using acoustic features. If, rather than [–high], the feature that spreads in lowering harmony is the acoustic feature [+high F1], blocking consonants could be specified as [–high F1], thereby blocking the spread of [+high F1].

An account of this type raises objections similar to those given for the articulatory feature account. If the voicing contrast is no longer as it was in 1932, the blockers may no longer have the direct phonetic effect of lowering F1. Therefore, if we labelled the blockers [–high F1], this feature would have to be an abstract one rather than one that relates directly to an acoustic effect of the blocking segments.

Furthermore, it is unclear how this account would handle NT and lT blockers. Since sonorants are not thought to involve laryngeal lowering and are not known to cause vowel raising in other languages, they should not be specified [–high F1], so there is no source for a [–high F1] specification on the obstruent in NT/lT sequences unless one posits a rule inserting the specification [–high F1] *ex nihilo*.

4.6 Summary of synchronic analyses

The analysis presented in §4.1 and its OT counterpart in §4.2 are adequate to account for the harmony and blocking data presented in this paper. As discussed, each of the alternative analyses in §§4.3–5 is deficient in some way. First, the domain-based account presented in §4.3 fails to allow for examples with medial consonant clusters that do not block harmony; all heterosyllabic clusters would be predicted to block harmony under this account, but as we have seen, there are several clusters that do not block harmony even when we can be confident that they are in different syllables.

The account based on articulatory features (§4.4) is problematic because it would require us to assume that voiceless obstruents in NT/lT sequences are phonologically specified as having [lowered larynx], despite the fact that no study has reported laryngeal lowering in voiceless obstruents in any context. Although the preferred analysis in §4.1 does make the claim that voiceless obstruents become voiced in the NT/lT context via Postsonorant Voicing, recall that this rule was non-neutralising, so that there is still a surface contrast corresponding to underlying /t/ and /d/ after nasals and /l/. As discussed in §4.4, it seems unlikely that NT/lT involve laryngeal lowering, so the feature [LL] probably cannot have a direct physical manifestation.

Finally, the account based on acoustic features (§4.5) fails, because, like the other alternative analyses, it is unable to account for the behaviour of NT/lT blockers. There is no straightforward way to spread the proposed feature [–high F1], which unifies high vowels with voiced obstruents, onto voiceless obstruents in NT/lT sequences. This would require an ad hoc rule of feature insertion, which itself would be problematic since we have no evidence that voiceless obstruents cause lowering of F1 in any context. Both this analysis and the articulatory analysis are also problematic if, as argued, the voicing contrast in Buchan has changed so that voiced obstruents involve a lesser degree of laryngeal lowering than was present at the origin of the pattern.

It therefore appears that the analyses in §§3.1 and 3.2 are best able to capture the facts while avoiding unmotivated rules and feature specifications. In the following section, I discuss a possible historical analysis to complement the synchronic analysis.

5 The evolution of harmony and blocking

Although phonetically based alternative analyses of harmony and blocking were rejected in the previous section, this does not indicate that harmony and blocking have no phonetic explanation. On the contrary, harmony and blocking can be explained phonetically, but in the diachronic domain. In this section, I describe one potential historical explanation of the origin of harmony and blocking that is based on observed and attested phonetic patterns in Buchan and other languages. As will be discussed later, if this is indeed the correct historical analysis, then the Buchan pattern is a 'test case' for distinguishing between models of phonology that encode phonetic naturalness in the synchronic grammar and those that locate phonetic explanation in the diachronic domain. Portions of the analysis presented in this section will therefore justifiably face considerable scrutiny, but I hope to demonstrate that this is the most plausible phonetic explanation that is available.

5.1 The origin of harmony

Vowel harmony is said to result from the phonologisation of vowel–vowel coarticulation. According to Ohala (1994), the phonetic effect becomes part of the phonology when the listener fails to correct for the effect of coarticulation, and instead analyses the altered pronunciation of the target as intentional. The listener then adjusts his phonological representation of the targeted vowel in the context of the triggering vowel, resulting in phonological harmony.

Vowel height harmony results from the phonologisation of coarticulation in tongue height. Coarticulation of this type is documented in a variety of languages, including American English (Majors 1998). In the Buchan case, I hypothesise that the lowered tongue position used to produce non-high vowels coloured the pronunciation of following high vowels, so that they were produced with the tongue body slightly lower than in high vowels in other contexts, resulting in a higher F1. Speakers misanalysed this effect as intentional, giving rise to a phonological harmony process where high vowels were lowered to non-high after a non-high vowel. I assume that the phonologisation of harmony occurred simultaneously with the phonologisation of blocking by voiced obstruents, though this is not crucial to the analysis.

5.2 The link between vowel height and obstruent voicing in Buchan

As discussed in §3.3, voiced obstruents relate to increased vowel height because they involve laryngeal lowering, which lowers F1. It was shown in §3.3 that there is some indirect evidence for laryngeal lowering in Buchan. A final argument in favour of laryngeal lowering to explain blocking is that there is no evidence for any other factor that could potentially relate voicing to vowel height. For example, we do not find evidence to support the alternative hypothesis that blocking is related to tongue-tip advancement in [d] *vs.* [t]. As shown in Table I, we find no lowering of F1 in a stressed vowel after voiced coronal obstruents *vs.* other coronals (although the sample sizes are very small since this is a post hoc comparison), which would have been evidence for the origin of blocking in [d] only, rather than in all voiced obstruents. Note that these measurements, unlike those presented elsewhere in this paper, were measured at the beginning of the vowel (at the earliest point where a robust formant emerges), rather than in the middle of the vowel, in order to detect the effect of the preceding consonant.

vowel	F1 after [d z ʤ]	F1 after other coronals ([s t r l n ʃ ʧ])
i	389 (n = 1)	365 (n = 3; SD = 27·2)
u		410 (n = 1)
e	444 (n = 2; SD = 99·7)	384 (n = 1)
ɜ		566 (n = 7; SD = 95·8)
o	556 (n = 2; SD = 93·3)	415 (n = 2; SD = 46·7)
ɛ	637 (n = 1)	553 (n = 1)
ʌ		662 (n = 3; SD = 72·1)
ɔ	527 (n = 1)	593 (n = 4; SD = 72·4)
a	781 (n = 1)	813 (n = 7; SD = 125·0)

Table I

Mean F1 (Hz) after voiced coronal obstruents *vs.* all other consonants (stressed vowels in monosyllabic words; speaker CE).

A second possibility is that harmony failed to apply across consonants or clusters with long closure/constriction duration, and that these long consonants and clusters became phonological blockers of harmony. If this were correct, we should find that blockers as a group have longer closure/constriction duration than non-blockers. As seen in Table II, however, there is no evidence for a significant difference in medial consonant duration between blockers and non-blockers. It should be noted that speech rate, which may play a role in consonant length, was not controlled for in this study. However, all of the tokens included in these calculations were elicited in the same carrier phrase, thereby minimising rate differences that might occur in natural speech.

single consonants	duration of closure/constriction (ms)
voiceless stop	40·1 (n = 13; SD = 20·6)
voiced stop	42·6 (n = 11; SD = 16·3)
voiceless fricative	121·0 (n = 5; SD = 19·5)
voiced fricative	68·8 (n = 4; SD = 25·7)
voiceless affricate	82·0 (n = 1)
voiced affricate	71·0 (n = 5; SD = 17·8)

sequences	constriction	closure
voiceless fricative + voiceless stop	139·0 (n = 2; SD = 19·7)	45·5 (n = 2; SD = 0·707)

Table II

Average medial C duration (speaker CE). Duration of sonorants has been omitted, due to the difficulty of determining their onset and release.

Another potential factor is root-vowel length. If the root vowel is short, perhaps its target is not realised until late in the vowel, intensifying the coarticulation effect on the suffix vowel. If this were the correct explanation, we would expect root vowels to be shorter before non-blockers than before blockers, but as seen in Table III, we find no consistent difference in stressed vowel duration before blockers *vs.* non-blockers (though, again, sample sizes are small here since the study was not designed to test for this factor).

Nor are the documented historical vowel length changes consistent with an explanation in terms of root vowel length: Dieth (1932: 60–61, 65) noted vowel shortening before stops and voiceless fricatives, and lengthening of /e/ and /a/ (1932: 67, 69) before [r], [l], NT, tautosyllabic voiced stops (the effect before tautosyllabic voiced stops being just a historical 'tendency') and 'partly' before nasals. Some of these effects may be results of the Scottish Vowel Length Rule (Aitken 1981), which lengthened vowels before open syllables, voiced fricatives and [r]. If the blocking effect were the result of these root vowel length differences, we would expect the following to be blockers of harmony: [r/r̥], [l], NT, voiced stops in coda position and nasals. We would expect voiceless stops, intervocalic voiced stops and voiceless fricatives to be non-blockers. This does not correspond to the actual blocking and non-blocking categories, since [r], [l], nasals and intervocalic voiced stops would be predicted to be in the wrong categories.

following consonants	preceding stressed V duration (ms)								
	i	e	ɛ	ɜ	ʌ	a	u	o	ɔ
[+voice] stop (blocker)	121 n = 3	176 n = 4				100 n = 5		135 n = 3	
[−voice] stop (non-blocker)	140 n = 1				66 n = 2	125 n = 1		166 n = 2	102 n = 1
[+voice] fricative (blocker)	176 n = 2		147 n = 1	145 n = 2		145 n = 1			
[−voice] fricative (non-blocker)			124 n = 2	92 n = 1	69 n = 1	148 n = 2	84 n = 2		133 n = 1
[+voice] affricate (blocker)	167 n = 1	128 n = 2	175 n = 1	135 n = 1					
[−voice] affricate (non-blocker)	71 n = 1								
[r] (non-blocker)	174 n = 2					169 n = 1			
[−voice] fricative + [−voice] stop (non-blocker)					83 n = 2	123 n = 1		142 n = 1	

Table III

Stressed V average duration before blockers *vs*. non-blockers (speaker CE). [rt] sequences are included in the '[−voice] fricative + [−voice] stop' category. Vowels adjacent to a (non-[r]) sonorant are not included, due to the difficulty of determining the consonant–vowel boundary.

Therefore, the only apparent plausible link between vowel height and the blocking consonants in Buchan is laryngeal lowering in voiced obstruents. The laryngeal lowering analysis is complicated by the NT/lT blockers, which would not be expected to have laryngeal lowering, but behave as if they did. However, this analysis is still the best available, because it is motivated by cross-linguistic phonetic evidence, and accounts directly for a larger subset of the blocking class than any potential alternative analysis. Furthermore, though not uncontroversial, an explanation for the NT/lT blockers is possible under the laryngeal lowering account.

One important issue that was not raised in the above discussion involves the rarity of phonological patterns of vowel raising after voiced obstruents. If there is a natural link between laryngeal lowering and vowel height, and if voiced obstruents in many languages involve some laryngeal lowering, why is this not manifested as a relationship between obstruent voicing and vowel height in the phonology of a large number of languages?

One possible reason is simply that the Scots vowel inventory is large and relatively closely spaced, even in unstressed syllables (Dieth transcribed all of the vowels except /u/ in unstressed syllables; in the modern dialect, I noted distinct unstressed realisations of all vowels except /u ɜ ɔ/). This means that contextual variation in one vowel caused by an adjacent consonant is likely to make it sound like another vowel already in the inventory, leading to a phonological consonant–vowel effect. This would not necessarily be the case in languages with smaller vowel inventories, where consonant-induced vowel variation may not be significant enough to result in a categorical change in the vowel.

Another possible explanation is that the degree of laryngeal lowering required for the production of a voiced stop of the type found in Standard British and American English does not cause sufficient F1 lowering to become phonologised as raising (or, as in Buchan, blocking of lowering) of the following vowel. Denning (1989: 89) notes that typical modal voiced stops involve only a 'moderate' degree of laryngeal lowering in comparison to e.g. breathy voicing. We may therefore speculate that their production involves only a moderate degree of F1 lowering, which may be below the threshold of salience that is required for the phonologisation of a phonetic pattern.

If the above is true, however, we would not expect Buchan to have developed any phonological effect of voiced obstruents on vowel height, since we would assume, absent any evidence to the contrary, that Buchan voiced stops are similar in their production to Standard British and American English voiced stops. However, as was mentioned in §4.4, we do have some evidence, albeit indirect, that Buchan voiced stops may not always have been realised as they are today, in a way similar to Standard British and American English. If voiced stops in the older dialect of Buchan Scots had an exceptional degree of laryngeal lowering to support more robust voicing than is found in the modern dialect, this would explain why voiced obstruents do not affect vowel height more frequently among the world's languages.

5.3 A history of harmony and blocking

Below I propose a four-step process by which the modern sound pattern could have come about. At stage I, suffix vowels are influenced by the root vowel, due to perseveratory tongue-height coarticulation, so that the high suffix vowels are phonetically lowered (have raised F1) when preceded by non-high vowels. At this stage, there is no phonological harmony process, only a gradient phonetic effect. The effect of the vowel lowering (F1 raising) is negated when a voiced obstruent intervenes, because the maintenance of strong, unattenuated voicing in obstruents requires significant laryngeal lowering, which lowers F1.

At stage II, the pattern becomes categorical. The phonetic lowering of high suffix vowels after non-high root vowels (when no voiced obstruent intervenes) is 'phonologised' (Hyman 1976), resulting in phonological vowel lowering harmony that is blocked by voiced obstruents. This change is evident in the Buchan lexicon: in all of the lexical items in Dieth's (1932) word-list, as well as in the texts and word-lists collected from modern speakers for the present study, which have non-blocking medial consonants, where Standard British English has unstressed [i] following a non-high vowel, the Buchan form invariably has [e]. Examples from Dieth's word-list include [pene] *penny*, [barle] *barley* and [hʌre] *hurry*; modern examples include those cited in (4a).

Stage III involves the extension of the blocking class to include lT and NT. This occurs due to the introduction of the phonological Postsonorant Voicing rule. Once voiceless obstruents become phonologically [voice] in the postsonorant environment, they meet the description of blocking consonants, because they are both [–sonorant] and [voice]. I am assuming that this took place after the phonologisation of blocking by voiced obstruents. However, this is not crucial if one takes the view that formal simplicity can play a role in rule generalisation. Under this view, if obstruents in NT and lT sequences were already phonologically voiced at the time that blocking became phonologised, they could have been included in the blocking class from the beginning, even if blocking was not phonetically motivated for these specific sequences. This is because, regardless of whether postsonorant voiceless obstruents are included, the closest featural description of the blocking category is [–sonorant, voice]. Therefore, if underlyingly voiced obstruents caused phonetic blocking of harmony which was then phonologised, the category [–sonorant, voice] could have become the phonological blockers even if a small subset of the class (NT, lT) did not phonetically block the perseveratory phonetic vowel height effect that led to harmony.

At stage IV, the most speculative of the historical stages proposed here, the realisation of the voicing contrast changes, perhaps due to influence of neighbouring dialects and/or Standard British English, so that voiceless obstruents are aspirated, and voiced obstruent pronunciation no longer involves an extreme degree of laryngeal lowering. We know this to be the case, because, as can be seen in Figs 14–19 in §4.1, aspiration is clearly visible in spectrograms showing prevocalic voiceless obstruents. Furthermore, as was shown in §4.4, voicing in intervocalic voiced stops is diminished towards the end of the closure, a phenomenon we would not expect with a large degree of laryngeal lowering. Thus, this fourth and final step changes the voicing contrast in such a way as to obscure the original phonetic motivation for blocking. A summary of the entire process that I posit is given in (31).

(31) Stage I — High suffix vowels are lowered (have raised Fl) when preceded by non-high vowels, due to coarticulation in tongue height. The effect is negated when a voiced obstruent intervenes, because maintenance of full, robust obstruent voicing requires a large amount of laryngeal lowering, which lowers F1.

Stage II The phonetic lowering effect of Stage I is phonologised, resulting in categorical vowel lowering harmony that is blocked by voiced obstruents.

Stage III The set of blocking consonants is extended to include lT and NT sequences. Dieth (1932) describes this stage of the grammar.

Stage IV The phonetic manifestation of the voicing contrast changes. Voiced obstruents are no longer implemented with extreme laryngeal lowering. This is the state of the modern grammar exemplified by speakers CE and JG.

6 Implications

The phonological and phonetic description of Buchan vowel height harmony and blocking raises a number of theoretical and typological issues. In this section, I discuss the implications of the Buchan pattern for three of these issues: the typology of partial height harmony, the representation of vowel height and harmony, and the incorporation of phonetic naturalness into models of synchronic phonology.

6.1 Typology of partial height harmony

First, as mentioned in §2.5, the existence of this type of system contradicts Parkinson's (1996) generalisation regarding partial height harmony. Parkinson claimed that all partial height harmony is raising, but there is overwhelming evidence showing that height harmony in Buchan is partial lowering harmony. Therefore, the typological generalisation must be revised to allow for partial lowering harmony. Based on the available cross-linguistic evidence amassed by Parkinson (1996), it can still be maintained that *most* partial height harmony is raising, but this constitutes a significant weakening of the original claim.

There is further evidence from the Bantu language family indicating that Parkinson's generalisation is incorrect. Hyman (1999: 242) lists ten languages from the Bantu zones K and R where a rule lowering /i/ to [e] is triggered by /a/ in addition to /o/ and /e/. If these languages do indeed exhibit lowering rather than raising, then these are further examples of partial lowering harmony.

6.2 The representation of vowel height and harmony

A second, related issue is the phonological representation of vowel height and harmony. Based on the above typological generalisation, Parkinson proposes a model of vowel height, the Incremental Constriction Model, where each step along the vowel height continuum is represented by one instance of the feature [closed]. In a language with three vowel heights, vowels would be represented as follows (based on Parkinson 1996: 8, 12):

(32)	*Low vowel*	*Mid vowel*	*High vowel*
	Height	Height	Height
		|	|
		[closed]	[closed]
			|
			[closed]

Low vowels have no instances of [closed], mid vowels have one instance and high vowels have two. Partial height harmony is expected to be exclusively raising because if we assume that harmony involves the spread of features, and if [closed] is the only height feature, then the only possible harmony rule is one in which a vowel gains an instance of [closed], which would correspond to raising.

The Incremental Constriction Model incorrectly rules out partial lowering in Buchan, but there are at least two ways that we can account for this pattern without rejecting the model. One possibility is that vowels can be represented differently on a language by language basis, and that they are represented differently in Buchan than in the languages with partial height harmony described by Parkinson. If Buchan vowel height is represented using the features [±high] and [±low] rather than [closed], then the pattern of partial lowering described here would not force us to reconsider the way that harmony is represented in the Incremental Constriction Model. This is the approach that I have taken throughout most of this paper in order to describe the phenomenon straightforwardly using familiar vowel height features.

However, the notion that vowel height features may be language-specific runs counter to the effort to determine a universal feature geometry and may therefore be dispreferred by some. A second possible approach to reconciling Buchan partial lowering harmony with the Incremental Constriction Model is to assume that Buchan vowels are represented as in (32), but that the harmony rule is characterised by the *loss* of [closed]. This could be achieved by a rule that delinks the lowest instance of [closed] in unstressed high front vowels when preceded by a stressed low or mid vowel. In OT terms, this could be done by using a constraint that prohibits an unstressed front vowel from having more instances of [closed] than a preceding stressed vowel. While this approach stretches the concept of harmony, which typically involves spreading rather than delinking, it does allow the pattern to be represented using the Incremental Constriction Model.

6.3 Phonetic naturalness in synchronic phonology

A final, important implication of harmony and blocking in Buchan Scots relates to the location of phonetic explanation in phonology. In §4, I presented a phonological analysis of harmony and blocking that captured the facts as described in this paper. I presented possible alternative analyses, two of which incorporated phonetic naturalness. These alternatives were shown to be inferior because they could not straightforwardly account for the NT/lT blocking clusters. In addition, as was shown in §4.4, there is some evidence that the original phonetic motivation for blocking by voiced obstruents is no longer present in the modern dialect, making any synchronic analysis invoking phonetic naturalness problematic. If this interpretation is correct, this would qualify Buchan harmony and blocking as an example of a phonetically unnatural phonological system of the type described by Anderson (1981) and Bach & Harms (1972). Such systems, where the original phonetic motivation for a pattern becomes obscured through the later introduction of other rules or sound changes, are central to the question of where to locate phonetic explanation in phonology. While they can be explained using an evolutionary approach where phonetic explanation is located in the diachronic domain (see e.g. Blevins & Garrett 1998, in press, Barnes 2002, Kavitskaya 2002 and Blevins 2004), they are problematic for constrained synchronic models incorporating phonetic naturalness. Each putative case of a phonetically unnatural rule must therefore be carefully scrutinised.

The evidence for synchronic phonetic unnaturalness in Buchan Scots is indirect. The basic argument is as follows. First, voiced obstruents must have had some special property at the time when the phonological blocking pattern was introduced. Otherwise, as discussed in §5.2, if intervocalic voiced obstruents in Buchan had the 'typical' property found in dialects of English where voicing diminishes throughout the closure, we would expect many more of the world's languages to exhibit effects where voiced obstruents trigger vowel raising or block lowering. Furthermore, there is evidence for this claim in the form of Dieth's (1932) observation (supported by a kymograph tracing) that Buchan voiceless stops were unaspirated, in marked contrast to British English voiceless stops. We can infer that if the voiceless stops had a very short VOT, the voiced stops must have been different from British English voiced stops as well; otherwise, they would have been very easily confused with voiceless stops. I hypothesise that the voiced stops were distinguished via full, robust voicing throughout the closure duration, which would have required a considerable degree of articulatory effort including, I claim, significant enough laryngeal lowering to lower the F1 of following vowels to the extent that this became phonologised as blocking of vowel harmony.

The second part of the argument involves a change from the state of affairs described above into a situation more like Standard American English. In this type of system, voiced stops exhibit attenuation, and occasionally outright cessation, of voicing prior to the onset of voicing in the following vowel. This attenuation of voicing is exhibited in Buchan intervocalic voiced stops, as was shown in §4.4. Though American English speakers do exhibit laryngeal lowering during medial voiced stops (Westbury 1979), the degree of lowering is presumably less than in a language where voiced obstruents have uninterrupted, unattenuated voicing throughout the closure. Therefore, if we accept that the voicing contrast in modern Buchan Scots is similar to the American English contrast, then it is likely that the degree of laryngeal lowering exhibited by modern Buchan speakers is no longer great enough to cause lowering of F1 of the following vowel. This is confirmed by the fact that the present study found no significant F1 difference in vowels after voiced *vs.* voiceless stops. Unfortunately, we are limited to informed speculation as to the manipulation of the larynx, but the argument laid out here is consistent with all of the information that we have regarding the modern dialect as well as the dialect encountered by Dieth (1932).

To the extent that one accepts the above argumentation regarding the nature and history of the voicing contrast in Buchan Scots, one is endorsing an approach to phonology where phonetic naturalness is incorporated into the diachronic rather than the synchronic domain. If Buchan Scots does indeed exhibit a phonologically unnatural sound pattern due to a historical change in the manifestation of the voicing contrast, this constitutes evidence in favour of the evolutionary approach, which predicts that patterns of this type may arise any time a sound change obscures the original phonetic motivation for another already existing sound pattern.

7 Conclusion

In this paper, I have presented the unusual pattern of vowel height harmony and blocking found in Buchan Scots. I have described the pattern both in phonological and phonetic terms, concluding that the pattern is a robust part of the phonology of modern Buchan Scots. A synchronic analysis was proposed, and contrasted with three competing analyses, including two analyses encoding phonetic naturalness. Each of the alternatives was shown to have considerable shortcomings with respect to the favoured analysis. A history of the pattern was proposed to explain the origin of harmony and of blocking, which was argued to result from laryngeal lowering in voiced obstruents. Finally, three important theoretical and typological implications of this study were discussed, of which perhaps the most controversial is the argument advanced here that the pattern of harmony and blocking in Buchan Scots is phonetically unnatural, due to a historical change in the manifestation of the voicing contrast. If this is true, then the blocking of harmony in Buchan is a phenomenon of a type that supports the evolutionary approach to phonology: a phonetic explanation, while available in the diachronic domain, is problematic when one attempts to incorporate it into the synchronic grammar. The characterisation of Buchan Scots vowel height harmony as an unnatural process is consistent with its status: partial height harmony with blocking by voiced obstruents appears to be unique typologically.

REFERENCES

Aitken, A. J. (1981). The Scottish Vowel-length Rule. In Michael Benskin & M. L. Samuels (eds.) *So meny people longages and tonges*. Edinburgh: Middle English Dialect Project. 131–157.

Anderson, Stephen R. (1981). Why phonology isn't 'natural'. *LI* **12**. 493–539.

Archangeli, Diana, Laura Moll & Kazutoshi Ohno (1998). Why not *NC̥. *CLS* **34:1**. 1–26.

Arensen, Jon (1982). *Murle grammar*. Juba: University of Juba & Summer Institute of Linguistics.

Bach, Emmon & Robert T. Harms (1972). How do languages get crazy rules? In Robert P. Stockwell & Ronald K. S. Macaulay (eds.) *Linguistic change in generative theory*. Bloomington: Indiana University Press. 1–21.

Barnes, Jonathan (2002). *Positional neutralization: a phonologization approach to typological patterns*. PhD dissertation, University of California, Berkeley.

Blevins, Juliette (2004). *Evolutionary Phonology: the emergence of sound patterns*. Cambridge: Cambridge University Press.

Blevins, Juliette & Andrew Garrett (1998). The origins of consonant–vowel metathesis. *Lg* **74**. 508–556.

Blevins, Juliette & Andrew Garrett (in press). Analogical morphophonology. In Kristin Hanson & Sharon Inkelas (eds.) *The nature of the word: essays in honor of Paul Kiparsky*. Cambridge, Mass.: MIT Press.

Chomsky, Noam & Morris Halle (1968). *The sound pattern of English*. New York: Harper & Row.

Denning, Keith (1989). *The diachronic development of phonological voice quality, with special reference to Dinka and the other Nilotic languages*. PhD dissertation, Stanford University.

Dieth, Eugen (1932). *A grammar of the Buchan dialect (Aberdeenshire): descriptive and historical*. Vol. 1: *Phonology – Accidence*. Cambridge: Heffer.

Ewan, William G. & Robert Krones (1974). Measuring larynx movement using the thyroumbrometer. *JPh* **2**. 327–335.

Fitzgerald, Colleen M. (2002). Vowel harmony in Buchan Scots English. *English Language and Linguistics* **6**. 61–79.

Grant, William (1913). *The pronunciation of English in Scotland*. Cambridge: Cambridge University Press.

Hayes, Bruce & Tanya Stivers (2000). Postnasal voicing. Ms, UCLA.

Hulst, Harry van der & Jeroen van de Weijer (1995). Vowel harmony. In John A. Goldsmith (ed.) *The handbook of phonological theory*. Cambridge, Mass. & Oxford: Blackwell. 495–534.

Hyman, Larry M. (1976). Phonologization. In Alphonse Juilland (ed.) *Linguistic studies offered to Joseph Greenberg on the occasion of his sixtieth birthday*. Vol. 2: *Phonology*. Saratoga: Anma Libri. 407–418.

Hyman, Larry M. (1999). The historical interpretation of vowel harmony in Bantu. In Jean-Marie Hombert & Larry M. Hyman (eds.) *Bantu historical linguistics: theoretical and empirical perspectives*. Stanford: CSLI. 235–295.

Hyman, Larry (2001). On the limits of phonetic determinism in phonology: *NC revisited. In Elizabeth Hume & Keith Johnson (eds.) *The role of speech perception in phonology*. San Diego: Academic Press. 141–185.

Johnston, Paul (1997). Regional variation. In Charles Jones (ed.) *The Edinburgh history of the Scots language*. Edinburgh: Edinburgh University Press. 433–513.

Kager, René (1999). *Optimality Theory*. Cambridge: Cambridge University Press.

Kavitskaya, Darya (2002). *Compensatory lengthening: phonetics, phonology, diachrony*. London & New York: Routledge.

Keating, Patricia A. (1984). Physiological effects on stop consonant voicing. *UCLA Working Papers in Phonetics* **59**. 29–34.

Kingston, John & Randy L. Diehl (1994). Phonetic knowledge. *Lg* **70**. 419–454.

Kiparsky, Paul (1981). Vowel harmony. Ms, MIT.

Kohler, Klaus J. (1984). Phonetic explanation in phonology: the feature fortis/lenis. *Phonetica* **41**. 150–174.

Ladefoged, Peter & Ian Maddieson (1996). *The sounds of the world's languages*. Cambridge, Mass. & Oxford: Blackwell.

McClure, J. Derrick (2002). *Doric: the dialect of North-East Scotland*. Amsterdam & Philadelphia: Benjamins.

Majors, Tivoli (1998). *Stress-dependent harmony: phonetic origins and phonological analysis*. PhD dissertation, University of Texas, Austin.

Ohala, John J. (1994). Towards a phonetically-based theory of vowel harmony. *Proceedings of the 1994 International Conference on Spoken Language Processing*. Vol. 2. Yokohama: Acoustical Society of Japan. 491–494.

Ohala, John J. (2001). The phonetics of phonology. LSA Summer Institute course lecture. PowerPoint slides available October 2004 at http://www.billnet.org/ucsb/aerodynamics.ppt.

Ohala, John J. & Carol J. Riordan (1980). Passive vocal tract enlargement during voiced stops. *Report of the Phonology Laboratory, UC Berkeley* **5**. 78–88.

Parkinson, Frederick B. (1996). *The representation of vowel height in phonology*. PhD dissertation, Ohio State University.

Pater, Joe (1999). Austronesian nasal substitution and other NC̥ effects. In René Kager, Harry van der Hulst & Wim Zonneveld (eds.) *The prosody–morphology interface*. Cambridge: Cambridge University Press. 310–343.

Piggott, Glyne (1996). Reconfiguring harmony. *McGill Working Papers in Linguistics* **12**. 61–98.

Poppe, Nicholas (1964). *Bashkir manual*. Bloomington: Indiana University.

Port, Robert F. & Michael L. O'Dell (1985). Neutralization of syllable-final voicing in German. *JPh* **13**. 455–471.

Rice, Keren D. (1993). A reexamination of the feature [sonorant]: the status of 'sonorant obstruents'. *Lg* **69**. 308–344.

Riordan, Carol J. (1980). Larynx height during English stop consonants. *JPh* **8**. 353–360.

Stevens, Alan M. (1968). *Madurese phonology and morphology*. New Haven: American Oriental Society.

Stuart-Smith, Jane (2003). The phonology of modern urban Scots. In John Corbett, J. Derrick McClure & Jane Stuart-Smith (eds.) *The Edinburgh companion to Scots*. Edinburgh: Edinburgh University Press. 110–137.

Trigo, Loren (1986). Voicing and pharyngeal expansion: ATR harmony in Buchan and Madurese. Ms, MIT.

Vaux, Bert (1998). *The phonology of Armenian*. Oxford: Clarendon Press.

Westbury, John R. (1979). *Aspects of the temporal control of voicing in consonant clusters in English*. PhD dissertation, University of Texas, Austin.

Wilson, James (1915). *Lowland Scotch as spoken in the Lower Strathearn district of Perthshire*. London: Oxford University Press.

Wölck, Wolfgang (1965). *Phonematische Analyse der Sprache von Buchan*. Heidelberg: Winter.