DOCTOR OF PHILOSOPHY

Preaspiration in phonological stop contrasts : an instrumental phonetic study

Chasaide, Ailbhe Ni

Award date:
1985

Awarding institution:
Bangor University

PREASPIRATION IN PHONOLOGICAL STOP CONTRASTS:

An Instrumental Phonetic Study.

by

Ailbhe Ní Chasaide

A thesis submitted to the University of Wales
for the degree of Doctor of Philosophy

Department of Linguistics
University College of North Wales
Bangor

1985

TABLE OF CONTENTS

CHAPTER 3

The Effects of Differing Stress Levels on Contrasts which Involve Preaspirated Stops

CHAPTER 4

Diachronic Aspects of Preaspiration and of Voicing Contrasts

ACKNOWLEDGEMENTS

I am deeply indebted to Mr. R.A.W. Bladon for his perceptive criticism and invaluable guidance in supervising this thesis, not to mention his unfailing welcome to the Phonetics Laboratory of Oxford University. I would also like to express my sincere gratitude to Dr. F. Gooding for his encouragement and assistance in jointly supervising the later stages of this research.

My warmest thanks are also due to Dr.F.J. Nolan and Dr.C.O Dochartaigh for detailed discussions on various aspects of this study, and to Dr. D. Scott for invaluable assistance with statistical preparation.

My sincere thanks also to Profesor Roger Lass for stimulating discussions which directed my attention towards the subject matter of the second half of Chapter 4.

I am very grateful to Drs. Ameen Al-Bamerni and Cynthia Shuken for their willingness to discuss and advise on aspects of my work, and to Proffesor M. Barnes and Mr. Kjell Gustafson for their help in matters concerning the translation and interpretation of Norwegian material.

I would like to thank for their comments, the participants of the Experimental Phonetics Symposium of Leeds University, the Speech Group of the Institute of Acoustics, and the Colloquium of British Academic Phoneticians, at which preliminary work on this thesis was presented. Valuable suggestions were also obtained when preliminary results were presented to seminars in the Universities of Cambridge, Edinburgh, Oxford, Sussex and University College, Dublin.

Due to the choice of languages and the range of experimental techniques used in this thesis, research was carried out in a number of establishments. For their generous assistance with recording and with the preparation of stimuli for perception experiments, I would like to thank the following individuals and institutions: Dr. J. Anthony (Royal Hospital for Sick Children, Edinburgh); Dr. B. Rosner (Experimental Psychology Laboratory of Oxford University); and the Phonetics Laboratories of the Universities of Oxford, Cambridge, Edinburgh, University College, London, and Trinity College, Dublin.

Tá mé fíor bhuíoch do Chris Ní Choisdealbha agus d'Fhionnuala Ní Chasaide, a bhí chomh foighdeach sin le cló-scríobh an tráchtais seo, agus do Bhetsy Ungar is do Chíaran Ó Casaide a chuidigh le cúrsaí eagarthóireachta.

This research project was commenced while on a Studentship from Instituid Teangeolaiochta Eireann (Dublin), and was subsequently assisted by a Studentship from the University of North Wales, Bangor. This generous financial assistance is gratefully acknowledged.

Finally, a central role in any study of instrumental phonetics is performed by one's informants. Not only did they cooperate enthusiastically in experiments which were, at times, physically uncomfortable, but meeting and working with them was one of the most pleasurable aspects of this study. Of the many who assisted with either production or perceptual experiments, I would like to mention, in particular, Mòrag MacLeod, Páll Hersteinsson, Donald Mac Donald, Sigurlina Magnusdottir, John McInnes, Jean McKenzie and Ásta Pállsdottir.

ABSTRACT

This study is an experimental phonetic investigation of phonological voicing oppositions - specifically, those involving preaspiration as found in Icelandic, Scottish Gaelic, and Irish. Three main aspects of these oppositions are dealt with.

The first involves the production of these contrasts. Productions by native speakers of the three languages were monitored using techniques including electroaerometry and photoelectric glottography. Specific attention is directed to the durational correlates of the opposition, and how these vary across languages and for different phonetic environments, including stress variation. The differences and similarities between contrasts which involve preaspiration and those which involve postaspiration are discussed in some detail. In considering production aspects of these oppositions, interest focusses also on the laryngeal mechanisms which control voicelessness and aspiration (pre- and post-). Glottographic data presented suggests that the nature and the amplitude of glottal gesture for a voiceless or aspirated stop is very precisely tailored to the prevailing aerodynamic conditions.

The second aspect considered is that of the historical development of these contrasts. Past hypotheses are discussed in some detail, and a more phonetically-based alternative is proposed. The general tendencies of change which affect voicing oppositions and which have traditionally been termed lenition processes are also considered. Suggestions are made regarding the phonetic motivation of such changes, suggestions based on existing research as well as on certain results of this study.

Thirdly, the perception of these oppositions is considered. Perceptual experiments are reported using synthetic and computer-edited natural speech stimuli. In the first instance, these tests bear on specific questions regarding the perception of preaspirated stops, which arise out of the production data in the earlier chapters. In addition, the broader question of the perception of voicing contrasts is discussed. A serious problem facing the researcher in this area (and in the area of linguistic contrasts generally) is that of how the simple binary linguistic percept is arrived at from the large number of potentially relevant cues. The question arises as to whether there is a single dominant cue or whether voicing detection involves separate monitoring of the various cues which have been postulated in the literature. A hypothesis is proposed to the effect that the linguistic percept depends on a judgement regarding the relative ratio of two properties of a larger, Vowel+Consonant unit. The multiplicity of postulated cues may be an artifact of an excessively segmental approach; these seemingly disparate cues may be seen instead to be feeding into a cumulative decision based on a syllable-type unit.

INTRODUCTION

This study deals with phonological stop contrasts which involve preaspiration. The languages looked at are Icelandic, Scottish Gaelic and Irish. The topic is approached from three main perspectives:

1) Production aspects (Chapters 2 and 3)
2) Diachronic considerations (Chapter 4)
3) Aspects of the perception of preaspirated stops and of two way stop oppositions (Chapter 5)

Oppositions involving preaspiration are considered rare (Maddieson, 1984) and have been relatively little studied (though see concluding paragraph). There is, however, a vast amount of data available for other two way stop contrasts, such as are found in English or French, which are usually described as voicing or aspiration contrasts. In this work, although the object of examination is the "preaspirating" opposition, this is done within the framework of what is known about these "other" two way phonological stop contrasts. The scope of many of the findings reported, questions raised and hypotheses proposed go beyond the specific topic of preaspiration and are relevant to the production, perception and historical evolution of two way stop contrasts in languages generally.

Chapters 2 and 3 deal with aspects of the production of "preaspirating" oppositions. The intent of Chapter 2 is descriptive; it sets out to describe the durational correlates of the contrast. Specifically, it attempts to determine whether, and to what extent the temporal adjustments characteristic of other two way stop oppositions also characterise "preaspirating" contrasts. Similarities and differences between preaspiration and postaspiration are discussed.

Chapter 3 broadens the scope of Chapter 2 by looking at the consequences of stress variation for the "preaspirating" opposition. The durational effects of changes in stress level are described first of all. In addition, the question of the glottal control of voicelessness and aspiration is considered. Photoelectric glottographic data on voiceless and preaspirated stops are considered in the light of two models of glottal control proposed by Kim (1970) and Löfqvist et al. (1981). The first suggests that the presence/absence and duration of aspiration are regulated by controlling the degree of glottal opening at stop release. As opposed to this, Löfqvist et al. (1981) have argued that speakers may not in fact have much (fine) control of the degree of glottal opening, and that the presence and duration of aspiration is determined primarily by the timing of the glottal opening/closing gesture. The electroglottographic data presented in this chapter suggest that, athough timing differences can and do occur, control of glottal amplitude (specifically at stop closure and release) may indeed be a crucial articulatory target for the voiceless or aspirated stop. It is, furthermore, hypothesised that differences in laryngeal adjustment observed across stress level for the data presented are necessitated by the altered aerodynamic conditions which correlate with stress variation in these cases. It is, therefore, proposed that the glottal gesture for a voiceless or aspirated stop is tailored to the prevailing aerodynamic conditions, and that the duration of aspiration will be a function of degree of glottal opening in conjunction with the prevailing respiratory level.

Diachronic questions form the subject matter of Chapter 4. In the first half of the chapter, an account of the derivation of preaspiration is proposed for the languages of this study. This account suggests that preaspiration arose as a means of maintaining an unstable opposition of voiced and voiceless geminates, unstable because of production constraints on voicing, particularly in stops of long duration. Other, rather different derivations of preaspiration in these languages have been offered by past scholars, and these possible alternative accounts are discussed in some detail.

In the second half of Chapter 4, the scope of the discussion is broadened to consider the types of changes which generally affect voiced/voiceless stops. These changes have been traditionally treated as instances of the phonological process of lenition. Although it is most frequently assumed that such lenition processes are phonetically motivated, surprisingly few attempts have been made to characterise what the phonetic content of lenition might be. A preliminary schema is proposed which attempts to identify the main areas of phonetic motivation of lenition processes. This proposal incorporates some of the findings of this study, as well as other existing insights reported in the literature, and may serve as a step towards the development of a composite theory of lenition.

The final chapter concerns issues of perception, and here again the interest is twofold. The first topic of interest concerns the perception of preaspirated stops, and the first half of the chapter deals specifically with questions arising out of the production data of Chapters 2 and 3. The first two perception experiments reported were primarily designed to address these questions.

The second part of the chapter concerns the broader issue of the perception of stop contrasts in general. The literature on stop contrasts reveals a large number of production correlates, most of which seem to be relevant to the perception of the opposition. This poses the problem of how, from the large number of potentially relevant cues, the simple binary linguistic percept is arrived at. Are these cues integrated, and if so, in what way? A hypothesis is proposed here, prompted largely by production data in Chapter 2, which suggests that the multiplicity of cues may only be a product of an excessively segmental approach, and that the linguistic percept may depend on a judgement on the relative weighting of two properties of a larger Vowel+Consonant unit. Thus, the apparently disparate cues are simply feeding into a cumulative decision based on a syllable-type unit. The proposed hypothesis and the predictions it entails, are discussed in relation to reported findings in the literature on the perception of stop contrasts. Experiment 3 of this chapter, as well as aspects of Experiment 1, test some of these predictions.

To conclude, a final point must be made regarding the rarity of preaspiration, as mentioned at the beginning of this Introduction. The inclusion of Irish in this study on preaspiration will appear surprising to anyone acquainted with phonetic descriptions of that language. Stops in Irish have traditionally been described as voiced, or voiceless aspirated, but never as preaspirated (see Chapter 1.2.3). Yet, as the production data of chapters 2 and 3 show, the voice offset pattern in the Irish data is frequently very similar to that of Lewis Gaelic for which preaspiration has been described. It is therefore quite possible that a similar degree of preaspiration may characterise other languages, which are presently simply described as having a voicing or aspiration contrast. Preaspiration, at least to the degree found in Irish may not be as rare as is commonly thought to be the case. Furthermore, as shown by the perceptual experiments of Chapter 5, even this amount of preaspiration would appear to be highly relevant perceptually. Therefore, it may well be that more attention could usefully be directed at the voice offset patterns of "voiceless" stops in other languages.

CHAPTER 1

PRELIMINARIES

1.0 INTRODUCTION

This chapter covers three main areas as a background to the following chapters. The first section outlines some of the main correlates of two-way stop oppositions and especially those features regarded as temporal adjustments. The correlates of voicing oppositions are of interest for two reasons: first of all, the production data presented in Chapters 2 and 3 focus mainly on those temporal aspects of preaspirating oppositions; interest here is to see whether and to what extent these temporal features are relevant to these contrasts. A discussion of these correlates is also relevant to Chapter 5 which deals with perception and with the question of how the multiplicity of seemingly relevant cues lead to the binary linguistic percept.

The second section outlines briefly the sound systems of the three languages included in this study, Icelandic, Scottish Gaelic and Irish. The sketch map of Figure 1.1 shows the language areas dealt with and the approximate locations of the informants for whom production data are presented in Chapters 2 and 3.

The third section details the instrumental techniques used in the thesis. A summary is given of the production data presented and details of segmentation are discussed.

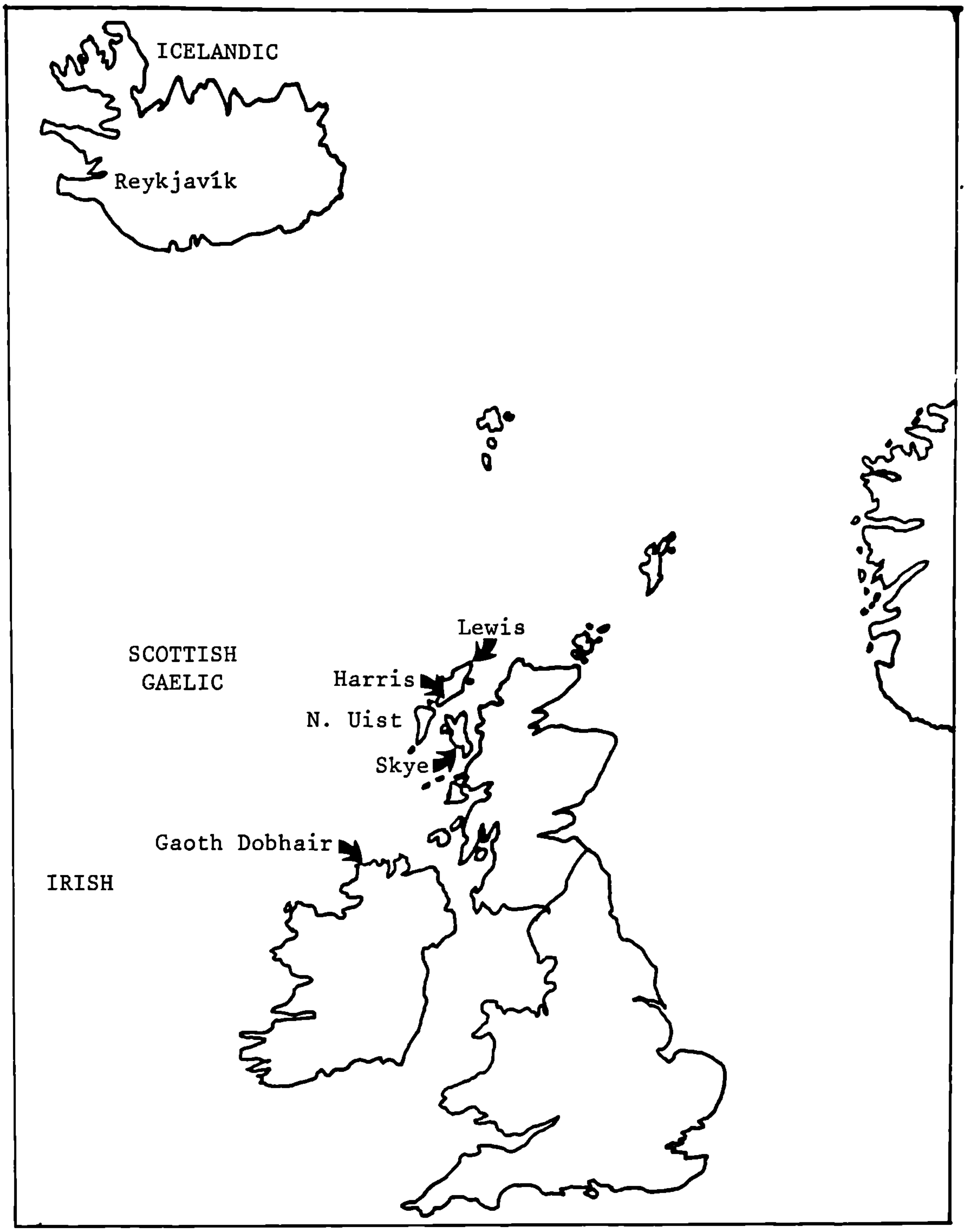


Figure 1.1 Languages investigated with approximate provenance of informants for whom production data is presented

1.1 TWO-WAY CONTRASTS OF STOP COGNATES: THE PHONETIC CORRELATES

1.1.0 Introduction

A simple binary linguistic opposition between stop cognates is characterized at the phonetic level by a number of different measurable correlates, or sub-features. These have usually been unearthed in the phonetic laboratory from production data, and many of these have also been claimed as perceptually relevant cues to the opposition. The occurrence, and the relative importance of any one feature, depends on a number of factors, such as the language in question, the phonetic environment, etc... The list which follows gives some of the main features associated with the opposition and is by no means exhaustive.

1. Vocal-fold vibration synchronous with supralaryngeal articulation.
2. Presence or absence of postaspiration.
3. VOT - a conflation of the temporal aspects of 1 and 2.
4. Presence or absence of preaspiration.
5. Differences in closure duration between the two members of the opposition.
6. Differences in the duration of a preceding vowel.
7. F1 transition to the adjacent vowel.
8. Transitions of other formants to the adjacent vowel.
9. Fo perturbations in the onset of a following vowel.
10. Intensity of the release burst.
11. Larynx height differences - i.e. larynx lowering with the voiced stop.
12. Expansion of the oro-pharynx with the voiced stop.

The first ten of these are relevant to perception as well as to production. The last two, when they occur, would seem to be physiological mechanisms which may facilitate the maintainance of vocal fold vibration in a voiced stop. The first ten can be crudely subdivided into two groups, as being derived from measurements made in the temporal or in the spectral domain. Features 1 to 6 tend to be largely regarded as matters of timing. As regards the first two features, voicing and aspiration, although they have an obvious acoustic content, it is their duration which has usually been measured and considered perceptually relevant. This probably results largely from the fact that they have normally been studied under the VOT paradigm. In any case, grouping them here as "temporal" features is not intended as a denial of the possible perceptual relevance of their spectral content, a point which will become clear in chapter 5 which deals with perception. Discussion in the following subsections 1.1.1. to 1.1.6. will be of these "temporal" features, as these are the object of investigation in Chapter 2.

The specifically spectral features, 7 to 10, could be argued to be secondary for the following reasons. First of all, they are unavoidable production by-products of a voicing contrast and are not independently controlled. For example, the fundamental frequency perturbations in the onset of a following vowel would appear to be most likely a consequence of the different aerodynamic conditions pertaining to voiced and voiceless stops.

To quote Ladefoged (1972:78) :

> "Quantitative data (Ladefoged, 1967) on the relation between subglottal pressure, airflow, and frequency of vibration of the vocal cords, indicate that the decrease in transglottal flow which occurs in voiced obstruents can be sufficient to account for the entire decrease in pitch which is observed in these sounds, without having to presume that there are any adjustments of the positions of the laryngeal structures. Similarly it is probable that the increase in pitch which occurs in a sound after a voiceless stop is mainly due to the increased Bernouilli effect"

A simple aerodynamic explanation would also account for feature 10: differences in the intensity of the release burst. As the vocal folds are abducted for the voiceless stop, pressure behind the oral constriction is higher, yielding a higher intensity burst.

Furthermore, some of these specifically spectral features might be considered secondary in terms of their perceptual importance. In the case of Fo, its importance as a perceptual cue may have been grossly overestimated. Abramson and Lisker (1983) have pointed out that stimuli used in the earlier perceptual experiments involved Fo differences which were much greater than those found in natural speech. They note that Haggard, Ambler and Callow (1970) used a range of 163 Hz. This range is very much greater than that described by Hombert (1978:87-98) for the production of English and French stops.

Differences in the release burst intensity may not constitute an important perceptual cue either. This has been shown for intervocalic stops by Lisker (1975). Utterance finally, it would also seem to be a rather weak cue (Raphael 1981). This last is perhaps not surprising given that in the dialect of English studied final stops may often be unreleased in any case. One would expect the most important role for a release burst cue to be in initial prestressed position. But even here, in spite of earlier suggestions to this effect by Slis and Cohen (1969) and by Summerfield and Haggard (1974), recent investigations by Repp (1979) seem to indicate that the contribution of this cue is a relatively weak one in #CV.

The apparent lack of importance of this cue may not be all that surprising for oppositions which contrast voiceless unaspirated and voiceless aspirated stops. In both of these types of stops the vocal-folds are open prior to stop release, and oral pressure is high. Perhaps one should expect a more important cueing role in oppositions in languages which contrast a truly voiced and a voiceless stop. Experimental evidence by Kohler (1979, and 1981) would seem to offer some support for this suggestion .

As for the F1 transition, whose perceptual importance has been amply demonstrated, it has nevertheless been pointed out by Lisker (1975) that the lack of a measurable acoustic transition can be regarded as a simple consequence of the articulators having reached their target positions by the end of aspiration. This means that F1 transition differences are only likely to be found as cues in a language where the voiceless series is aspirated. And F1 transitions are only likely to be clearly in evidence when a stop is followed by an open vowel, i.e. a vowel which in any case has a high F1 (see Lisker, 1975 and discussion therein of an earlier paper by Fischer Jørgensen, 1954).

Furthermore, even in languages which have aspiration, there is evidence to show that the F1 cue is acquired through association, whereas the temporal aspects of VOT would seem to operate at a very early age. A study by Simon and Fourcin (1978) tested the perceptual relevance of VOT and F1 transitions on English and French children between the ages of 2 and 14. The English-speaking children in the younger age group of up to 5 or 6 years of age, seemed to be primarily sensitive to the temporal aspects of the distinction; after that age, F1 transitions seemed a more important factor. The fact that the French children did not appear to be sensitive to F1 transitions adds support to the point made in the previous paragraph, as there is not usually much aspiration of voiceless stops in French.

The main focus here is on the temporal features 1 to 6. Chapter 2 sets out to describe to what extent these features are used in phonological oppositions where preaspiration is found. From past descriptions we know that feature 1 (voicing) is relevant for some of the languages and dialects looked at (see section 1.2). In initial position the contrast of stop cognates in the languages of this study seems to depend on feature 2 - postaspiration. For features 5 and 6, it is not known whether these play a role in "preaspirating" contrasts: in the voicing oppositions of other languages which do not involve preaspiration, they are widely attested as being particularly important for medial and final positions respectively.

1.1.1 <u>Voicing: presence or absence of vocal fold vibration</u>

The phonetic realisation of phonological oppositions of stop cognates (usually described as "voicing" or "aspiration" contrasts) may, but need not necessarily involve the presence or absence of vocal fold vibration. Whether it does or not seems to depend on such factors as the language in question, the phonetic environment and the manner of articulation.

Lisker and Abramson (1964) distinguished between a category of languages which in #CV contrasts voiced and voiceless stops, of which French and Spanish are examples (which will be called Group 1) and a category which contrasts voiceless unaspirated and voiceless aspirated stops, exemplified by English (Group 2). These categories are based on the behaviour of prestressed initial prevocalic stops, and other environments may not be thus aptly characterised. For example, in VCV in English, the role of aspiration is much reduced and voicing proper is present in the cognate stop. A third group of languages exemplified by Thai (Group 3), which have a three way opposition, distinguish between voiced, voiceless unaspirated, and voiceless aspirated stops. Further details on the three groups of languages are given below in section 1.1.3.

Of all the manners of articulation, stops present the aerodynamic conditions most unfavourable to voicing initiation or maintenance, and the most favourable to devoicing. To sustain vocal-fold vibration, it has been estimated that a transglottal pressure drop of approximately 2cm aq is required (see Catford, 1977:29); to initiate voicing would seem to require an even higher transglottal pressure drop (Westbury & Keating, 1980). As during a stop the vocal tract is completely occluded, oral pressure (Po) rises and so the transglottal pressure drop decreases. Keating et al. (1983) point to the fact that across languages there is an overwhelming preference for voiceless unaspirated stops (i.e. stops with a short VOT lag). In an aerodynamic modelling study of stop voicing, Westbury and Keating (1980) have shown that the voiceless unaspirated stop is aerodynamically the most likely, easiest type. Developmental studies by Zlatin and Koenigsknecht (1976) also seem to point in this direction. Children's first productions seem to be of this type, and the adults' contrasts would seem to be acquired through learning at a later stage. Some counter-evidence to the findings by Zlatin and Koenigsknecht might seem to be offered in Grunwell (1982). She reports context-sensitive voicing in young children's first productions, with lenis stops in all but final prepausal position (:181). However, the contradiction may be only apparent; Grunwell's study is an auditory description of the speech of English speaking children, and what she refers to as "lenis" stops may perhaps be identified with voiceless unaspirated.

However, when speaking of the most "natural" or "easiest" type of stop, it is important to bear the phonetic environment in mind. Westbury and Keating (1980) have estimated in their aerodynamic study that for voiced stops in postvocalic position, if one allows for "passive" expansion of the vocal tract only, vocal fold vibration should last approximately 60ms before the glottal pressure drop is neutralised. Ohala (1983:197) gives a very similar estimate of 64ms. The fact that voicing can, and does commonly continue for longer than this in languages which have voiced stops, can be attributed to:

(a) passive expansion of the vocal tract, due mainly to the compliance of the cheeks, and,

(b) active enlargement of the vocal tract, such as oro-pharynx expansion and larynx lowering (see, for example, Bell-Berti, 1973 and 1975). The possibility of velar lowering during voiced stops, to allow a small amount of nasal leakage, was also investigated by Westbury (1979), who however did not find evidence for it.

It seems very likely that the physiological correlates of voiced stops, listed above as features 11 and 12 are simply strategies used to allow vocal fold vibration to continue under the otherwise adverse conditions of oral closure. One should note here that these effects and the explanation given to them are not unambiguously attested and accepted (see Riordan 1980).

Although less attention has been given to it in the literature, the target of voicelessness may to some extent also present a difficult production target, in medial intervocalic position at least. This fact emerges fairly clearly in the descriptive work in Chapters 2 and 3 and is discussed in some detail in Chapter 3.

Quite apart from the possible production constraints on voicing and voicelessness in stops, one must note the perceptually relevant fact that the acoustic strength of the voicing buzz is greatly attenuated due to oral closure. The perceptual importance of voicing as a cue may depend on language type (i.e. Groups 1 or 2) and may correlate with the extent to which it characterises stops in production. For example, phonologically "voiced" stops in French in utterance final position have considerable voicing during closure (Kohler, 1981) and voicing would seem to be an important perceptual cue (Van Dommelen, 1983). In English, which is more prone to final devoicing, closure voicing would seem a less powerful cue (Lisker, 1978). Nevertheless, even for the English stops, it would appear that a reduction in the duration of the voiced portion of the stop will entail a reduction in voiced percepts (Raphael, 1981). Watson (1983) suggests that the periodic and aperiodic portions of the stop may be measured perceptually as a ratio.

Given the production difficulties which may accompany stop voicing production, and given the fact that voicing amplitude is not acoustically strong due to oral closure, it is perhaps not too surprising that the phonological "voicing opposition" is so frequently carried, not, or not only, by presence or absence of vocal fold vibration, but by a number of other features.

Nor is it surprising that stops in languages exhibit diachronic tendencies of voiced --> voiceless or voiceless --> voiced change, depending on the environment. The physical phonetic constraints and conditions which may underlie these tendencies are the subject matter of Chapter 4.2.

1.1.2 Postaspiration

In some languages or environments, the opposition of stop consonants may involve, not presence or absence of vocal fold vibration during the stop, but rather presence or absence of aspiration. Aspiration is frequently defined as a "delay in the onset of voicing" (after stop release). During that delay, airflow through the vocal tract is high as the vocal folds are separated, and so aspiration is acoustically characterised by glottal and/or cavity friction. As pointed out by Catford (1977:250) for [h], the relative degrees of glottal/oral cavity friction will depend on the oral configuration; local cavity friction is more likely with high vowels; glottal friction with low vowels. To this one could add that a greater degree of local cavity friction is probably more likely in the early part of aspiration for those places of articulation for which the active articulations are relatively sluggish.

Aspirated sounds are produced by abduction of the vocal folds during the stop. At the release of the stop, the vocal folds are still abducted, and voicing begins only when the vocal folds are sufficiently adducted for the Bernouilli effect to occur (see Catford, 1977:32).

The precise mechanism whereby aspiration (but also preaspiration and voicelessness generally) is controlled forms the chief topic of discussion in Chapter 3.2. A study of Korean stops by Kim (1970) shows an almost linear relationship between the area of glottal opening during the stop and the duration of aspiration following the stop. The implication of his work is that the control of aspiration and of glottal opening at stop release, is effected by controlling the degree of glottal opening for the stop. Thus, a voiceless aspirated stop should exhibit a greater degree of glottal opening than a voiceless unaspirated or weakly aspirated one.

More recently, Löfqvist et al.(1981) have argued that speakers may not be able to exert a fine degree of control on the amplitude of glottal opening, and that the control of aspiration resides instead in the timing of the glottal opening gesture. Löfqvist (1980) has shown that in aspirated stops the peak glottal opening occurs later than in voiceless unaspirated stops.

These two proposals are of course not mutally exclusive and will be mentioned again in Chapter 3.2 where the question of glottal control of voicelessness is explicitly addressed.

Since the seminal study on VOT by Lisker and Abramson (1964), discussion of aspiration has tended to be phrased in VOT terms. Furthermore, the majority of researchers working on VOT have tended to emphasize the temporal aspect of the phenomenon and to disregard or minimize the role of aspiration noise. Results of the first perceptual experiment in Chapter 5, along with some other experimental findings reported in the literature, suggest a need for a model of "voicing" perception which would take both temporal and spectral features into account. And this is partly what the proposals in Chapter 5.2 attempt to do.

1.1.3 VOT

VOT is a measure which conflates the durational aspects of voicing (feature 1) and aspiration (feature 2) by measuring the time between the onset of voicing and the release of the stop. The moment of oral release counts as time value zero; voicing during a stop (= voice lead) is measured as a negative value; aspiration (= voice lag) is indicated as a positive value.

The literature on the production and perception of voicing oppositions has been dominated by VOT. The concept of VOT, and some of the results of perceptual experiments on VOT were to form the basis for some wider theoretical discussions concerning speech perception in general. For this reason, and because of the obvious relevance to a study of oppositions involving preaspiration (which one should expect to be able to characterise along similar lines in terms of voice offset time, VOFFT,) some of the main findings concerning VOT production and perception are summarised here in some detail.

Production

As demonstrated in the study by Lisker and Abramson (1964), VOT as a production measure allows comparison on a single continuum of oppositions which involve + or - voice, and + or - aspiration. It is useful not only in characterising two-way phonological contrasts, but also handles three way oppositions as between voiced, voiceless unaspirated, and voiceless aspirated stops, as these are well differentiated by VOT (at least in #CV). Contrasts in some languages are less well differentiated by a VOT measure. In a language such as Hindi which has a fourth breathy-voiced stop cognate, the voiced and breathy-voiced stops are not well differentiated on a VOT continuum. Another language for which VOT does not give a useful separation of stop categories is Korean, where there is an opposition between three sets of voiceless stops in initial position, and some overlap in the VOT values of two of these. (See also Hardcastle (1973) and Han and Weitzman (1970) for a description of the Korean oppositions).

The study by Lisker and Abramsom showed that across languages the distribution of VOT values for initial prevocalic stops is tri-modal, i.e. stop categories fall into three ranges:

a) from -125ms to -75ms, with a median value at -100ms.

b) from 0 to +25ms, with a median value at +10ms.

c) from +60ms to +100ms, with a median value at +75ms.

The VOT measure is sensitive to place of articulation, velars having consistently higher VOT values than the other stops.

Another observation made by Lisker and Abramson was that none of the two category languages located its categories at the opposite ends of the VOT continuum, a fact which Lisker and Abramson interpreted as "evidence for the view that in the phonetic "realisation" of phonemic contrasts, human beings fall considerably short of utilising all the phonetic space available to them" (1964: 407).

This effectively means that the contrast in languages with a two way phonological opposition usually involves either voicing, or aspiration, but not both. For this reason, languages can be fairly readily classified into the groups below, according to the type of contrast exhibited by their initial stops. (The classification given here omits those languages for which VOT does not give good separation of category).

Two category languages

Group 1, which contrasts stops in ranges a) and b) above, i.e. + versus - voice. Spanish and Romance languages would represent this group.

Group 2, which contrasts stops in ranges b) amd c) above, i.e. + or - aspiration. English and most Germanic languages would be representative of this group.

Three category languages

Group 3, which contrasts stops in ranges a), b), and c) above, i.e. + voice, - voice, and + aspiration. Thai would belong to this group of languages.

Perception

The first important finding to emerge regarding VOT perception was that it appeared to be perceived categorically. This means that judgements on, for example, a "da" -"ta" continuum exhibited, rather than a gradual increase in "ta" responses with VOT increase, a sharp increase at a given VOT value. This phenomenon has also been termed "the category boundary effect" (see Pastore, 1981:183). The VOT value at which the sharp increase occurred coincided fairly well with where the VOT boundaries fell in subjects production of stops in their own language. Thus, whereas speakers of English had a category boundary in the +25ms to +45ms region, speakers of Thai (a three category language) had an additional boundary at approximately 0 VOT (Lisker and Abramson, 1970 and Abramson and Lisker, 1970). The perceptual category boundaries also seemed to reflect the place of articulation effect found in production; in English, for labials the boundary was at +25ms, for alveolars at +35ms, and for velars at +45ms (Lisker and Abramson 1970). Further studies of VOT perception in adults and infants seemed to indicate that a heightened discrimination ability in the region of the "English" boundary was present not only for speakers whose language did not have an "English" type contrast, but also for very young infants regardless of their linguistic background (see Streeter, 1976). It was therefore proposed by Eilers et al. (1979) that a boundary in the "English" boundary region might therefore appear to be an innate ability.

The finding of categorical perception was first thought to be unique to the perception of speech, and explanations of the phenomenon invoked the concept of speech specific specialized processors. These were vizualised either in terms of higher level abstract categorisation processes (Studdert-Kennedy et al. 1970) or in terms of phonetic feature detectors (Eimas 1975). Feature detector theory, an influential recent model of speech perception, explained the category boundary effect for VOT as the reflection of the operation of feature detectors. The proposed feature detectors were pairs of specialised neural cells, oppositely tuned to detect phonetic/ phonological features (see Abbs and Sussman 1971). The voiced/voiceless decision would depend on which detector had the higher output. Neurological research had demonstrated the existence of visual and auditory detectors in a number of animals (see Lettvin et al., 1959; Hübel and Wiesel 1962; and Kuhl, 1979). Selective adaptation experiments purported to demonstrate such detectors in humans, by explaining for example, the VOT boundary shifts towards the adapted VOT stimulus, in terms of the fatiguing of that detector (see Eimas and Corbit,1973). Recent experimental findings have however seriously undermined feature detector theory[1] and have raised questions regarding the generality of categorical perception in speech perception ; these are alluded to below.

VOT perception: detection of temporal order or aspiration noise?

Surprisingly perhaps, the perception of VOT has nearly always been presented as a task involving a judgment on the relative timing of two events, oral release and voice onset. Thus the listener was presumed to be doing something analogous to what the linguist was doing in measuring production data. The early experiments on VOT perception did in fact present VOT continua with aperiodic excitation in the positive VOT range (Lisker and Abramson, 1967, 1970; Abramson and Lisker 1970) but this was not considered particularly relevant to its perception. Summerfield and Haggard (1974) concluded that the addition of aperiodic noise to synthetic stimuli did not necessarily enhance (and could even sometimes reduce) their effectiveness as cues. In the 1970's the

------

1 see for example, Remez (1980), Carney et al.(1977), Kuhl (1981), Kuhl and Miller (1978) and also discussion and further references pp.31-33.

debate on VOT versus F1 cues was presented very much as a "temporal" versus "spectral" cue debate (e.g. Stevens and Klatt, 1974; Lisker, 1975), and the evidence seemed to favour the latter (e.g. Summerfield and Haggard, 1974). The conceptualisation of VOT detection as a judgment on temporal separation of two events is still current, as evidenced by such work as the recent experiments carried out by Darwin and Pearson (1982) to characterise more precisely what constitutes the second "event" - voice onset.

A psychoacoustic explanation has been put forward to explain the apparently innate heightened discrimination ability in the short lag VOT region - i.e. the boundary for languages such as English. This explanation reflects the common visualisation of VOT as a temporal separation cue, and suggests that the VOT boundary effect, mentioned above, is determined by an auditory constraint on temporal-order resolution. Experiments by Pisoni (1977), based on earlier work by Hirsch (1959), showed that if the onsets of two coterminous tones of 500 Hz and 1500 Hz were varied, listeners had best discrimination when the relative onsets differed by about 20ms. The tones were categorised as simultaneous when the relative onsets fell within a range of -20ms to +20ms; larger differences were perceived as successive. This line of explanation of course undermined earlier assumptions that the phenomenon of categorical perception was specific to speech, and a reflection of specialised speech specific processors at work.

The common assumption that VOT perception is a temporal-order perceptual task can however be questioned. In quite an early study of Danish stops, Fischer-Jørgensen (1968) concluded that aspiration noise constituted a more important perceptual cue than the temporal separation of stop release and voice onset. Recent work by Repp (1979), together with one aspect of Experiment 1 reported here in Chapter 5, suggest that aspiration noise level affects our judgment and VOT and VOFFT stimuli. Repp in fact argues that VOT perception in a language which has aspiration, might more accurately be conceptualised as a task requiring the detection of the presence/absence of aspiration, rather than a judgement on the relative timing of two events.

If one conceptualises VOT as a positive detection of aspiration noise, a second type of proposed psychoacoustic explanation for the VOT category boundary effect would seem more appropriate, i.e. an explanation in terms of masking. The "masking" explanation was suggested by Miller et. al. (1976) who also demonstrated the "boundary effect" with nonspeech stimuli, intended as analogous to VOT continua. The stimuli they used had two coterminous components; a buzz of fixed 500ms. duration, and Gaussian noise of 15 dB less intensity whose relative onset time varied relative to that of the buzz. Differences in noise lead times here were most easily discriminable at about a relative onset time of +16ms. The authors concluded that this value represented a psychophysical threshold, where the noise lead is sufficiently long to evade masking by the buzz. The implication for speech and for VOT detection is that the "category boundary effect" would similarly be the result of aspiration duration crossing the same masking threshold, - with subthreshold stimuli having no detectable noise.

One further psychoacoustic finding should be mentioned in this context. It has been pointed out by Pastore (1981) and mentioned by Repp (1979), that for stimuli ranging from 10ms to 200ms the auditory system integrates energy, so that manipulations of the duration of a stimulus will affect its perceived intensity.

Any theory which attempts to explain the perception of the "phonological voicing opposition" must take account of temporal/acoustic interaction just mentioned, and the hypothesis put forward in Chapter 5.2 attempts this. Rather than argue as Repp has done, that VOT detection may involve aspiration detection rather than a temporal order judgment, a hypothesis will be proposed which allows for acoustic weighting of an essentailly temporal integrated cue.

Limitations of VOT

As mentioned in the introduction to this section, the concept of VOT has been very pervasive in the literature. In a great number of perceptual experiments, it has been the (frequently unspoken) assumption that the perception of the voicing contrast may be simply equated with VOT detection. However, whether as a production measure, or as a perceptual cue, there are a number of ways in which VOT may be of limited use.

VOT does not handle different positional variants equally well, but seems most useful for initial, prestressed, prevocalic stops. Probably for reasons of ease of handling, most of the work in the field has concentrated on the #CV environment. This is not very representative of most of the stops in running natural speech; medial stops might provide a more widely applicable starting point. And VOT is much less useful in distinguishing stop categories in non initial position (see for example Lisker,1978). For stops other than prestressed initial prevocalic ones, a number of other features would appear to be more relevant; for example, features 5 (consonant closure duration), and 6 (preceding vowel duration) may well be more useful for VCV and VC# respectively.

The problem of positional variation one should expect not to be a problem for oppositions which involve preaspiration. Actually, it should be eminently possible to describe these in terms of an inverse VOT measure, voice offset time, VOFFT. Indeed one would expect languages with preaspiration to illustrate a rather exceptional group, where the VOT/VOFFT measure is a particularly useful characterisation of the phonological opposition across positional variants.

Apart from the fact that VOT is usually considerably less useful in characterising the production or perception of stops in non-initial positions, it is also affected by factors such as tempo and stress. Lisker and Abramson (1967) point out that stops are less well distinguished by VOT, and that there is some overlap between voiced/voiceless categories when speech tempo is increased. For discussion of the consequences of stress variation on VOT see Keating et al. (1983). As will be seen in Chapter 3, VOFFT is also greatly affected by stress variation.

Another problem with VOT is that it may not be as useful when generalised to manners of articulation other than stops. (This particular point does not directly relate to preaspiration as such, but rather to a more general discussion which arises again in Chapter 5.2, and which concerns the perception of phonological "voicing" oppositions, and the limitations of models phrased in terms of VOT detection.) The production/perception of fricatives, for example, may not be as easy to characterize in VOT terms. In production, the lack of a well delimited release burst would make a VOT measure somewhat difficult to ascertain accurately. This difficulty is presumably not insurmountable; in principle, fricative production can still be measured under a VOT paradigm. In a study of the phonological "voicing" contrast of initial fricatives, Massaro and Cohen (1976) presented VOT results. It is worth noting however that their VOT measure was not analogous to that used for stops, and indicated instead the time between the onset of frication and the onset of vocal fold vibration. However, as they point out, there is no reason why results might not be formulated for fricatives in a way that would be analogous to stops.

An account of the perception of the phonological contrast in fricatives in terms of VOT detection seems less likely for fricatives than for stops, at least if one accepts the common formulation of VOT detection as a judgement on the relative timing of two events. This formulation seems most suited to voiceless aspirated stops where voice onset and consonant release are likely to represent more delimited and auditorily salient "events" than for fricatives and other manners of articulation.

One of the attractions which made VOT such a popular object of study was the finding of categorical perception. As mentioned above, VOT and categorical perception provided much of the inspiration for theories of speech perception such as feature detector theory. However, the hypothesis that categorical perception is unique to the perception of speech and evidence of speech specific processors was disproved by later research which demonstrated similiar categorical perception in animals such as chinchillas (Kuhl and Miller 1978). Other experiments also showed categorical perception of non-speech stimuli in humans. (For a useful review and discussion of this question, see Watson, 1983.)

Furthermore, in the perception of linguistic contrasts, it would appear that the phenomenon of categorical perception may not be all that widely applicable. Stops in VCV have been shown to be less categorically perceived than initial ones (Libermann et al.,1961), and this seems to hold regardless of the cueing feature used. Fricatives also appear to be less categorically perceived than stops (Healy and Repp,1982).

Even if discussion is restricted to prestressed stops in #CV, there are grounds for suspecting that categorical perception may only strongly characterize languages of the Group 2 type, i.e. languages which have a contrast involving + or - postaspiration. Perceptual studies on Group 1 type languages, where the contrast involves + or - voicing proper, suggests that VOT perception is not really categorical (see Carramazza et al. (1973) on French Canadian and discussion in Watson, 1983). The evidence is fairly confused, as some other studies do point to categorical perception in Spanish bilinguals (Williams, 1977) and in French speakers (Carramazza and Yeni-Komshian, 1974). For the latter studies the VOT boundary is at about 0 ms. In a study on children by Simon and Fourcin (1978), it appeared that the categorical perception of VOT was a function of age; The younger children did not reveal categorical perception, the older ones did.

But quite apart from difficulties arising out of categorical perception as such, a serious problem for feature detector theory lies in the fact that the perception of voicing contrasts can not be equated with VOT detection in any case. As noted above, VOT is not broadly generalisable as a voicing cue; furthermore, numerous other cues have been shown to be relevant to the perception of voicing contrasts. As pointed out by Simon and Studdert-Kennedy (1978), the concept of feature detectors loses its appeal where one considers that it would logically be necessary to postulate as many features detectors as there are potential voicing cues.

The sheer multiplicity of relevant and apparently disparate voicing cues presents a problem not just to feature detector theory. Any model of voicing perception (and of the perception of phonological contrasts in general) seems doomed to failure until it tackles the question of whether and how the multiple cues to the contrast might be perceptually integrated to yield a binary linguistic percept.

This discussion is resumed in Chapter 5.2, where a hypothesis is proposed which addresses this problem, and suggests how a number of these apparently disparate cues may in fact be feeding into a cumulative binary decision, based on the syllable.

1.1.4 Preaspiration

Preaspiration, as the name implies, is generally regarded as the inverse of postaspiration: a typical definition would be as a "time-lag between the offset, or cessation, of voicing and the formation of the stop" (Catford, 1977: 144). Preaspiration is described as occurring in a number of Northern European languages, including Icelandic, Scottish Gaelic, Faroese, Lappish, Finnish and a few Norwegian and Swedish dialects (see

Liberman, 1982). It would appear to be comparatively rare and exotic, and is typically given only a cursory mention in phonetics textbooks. It has not been the subject of much instrumental investigation, but Shuken (1980) for Scottish Gaelic, and Pind (1982) for Icelandic are notable contributions which help to remedy this deficit. Furthermore, as mentioned earlier, one might expect that the findings from the vast literature on postaspiration and especially on VOT production/perception would be relevant to preaspiration and VOFFT.

A study which did include preaspirated stops was the glottographic investigation by Löqvist and Yoshioka (1981). In the preaspirated stops it was found that peak glottal opening occurred earlier than in postaspirated or unaspirated stops. This was partly the basis for Löfqvist's contention, mentioned in 1.1.2, that glottal control of voiceless and aspirated stops involves control of the timing of the vocal fold abduction gesture, rather than the control of the degree of glottal opening per se. His basic viewpoint would seem to be that the glottal opening/closing gesture is a fairly fixed cycle which occupies a roughly constant amount of time. The point at which it is put into operation determines the difference between voiceless preaspirated, unaspirated, and postaspirated stops.

Following this line of argument, Löfqvist (1980) also claims that a stop can have either postaspiration or preaspiration, but not both. As will be seen, data from Irish and Lewis Gaelic presented in Chapter 2 does not in fact support this particular claim of Löfqvist's ; pre- and postaspiration co-occur in these languages.

The question of the glottal control of pre- and postaspiration (and of voicelessness in general) is addressed in Chapter 3.2. Electroglottographic data presented there suggests that although the glottal opening/closing gesture is a fairly fixed ballistic cycle, a double cycle is a possibility when necessary, for the production of such pre- and postaspirated stops.

1.1.5 Consonant Duration

In non-initial positions the duration of the consonant may play a role in the contrast; phonologically voiceless stops tend to be longer than their voiced counterparts (see for example Lisker, 1957). The perceptual relevance of the consonant duration differences noted in production was demonstrated by Denes (1955) and Liberman et al. (1961). It seems to be most relevant for VCV; in VC# it counts as a rather weak cue (Raphael, 1981).

Clearly for consonant duration to play a role in cueing the opposition of stop cognates, it must be available to our perception. This is clearly not the case with #CV, where duration of consonant closure is not identifiable. In final stops, closure duration may be only intermittently available, and stops are frequently unreleased in the dialects of English relevant to the studies mentioned above. One could perhaps suggest that stop closure duration would play a more important role in CV# for dialects and languages where stops are always released. Interestingly for fricatives, where consonant duration is available even in #CV, it does seem to affect the voiced/voiceless percept in this environment (Cole and Cooper, 1975). Summerfield (1981) has also demonstrated that closure duration may affect the perception of the contrast for word initial stops which have been medialised by insertion into a frame.

1.1.6 Vowel Duration

There seems to be a universal tendency for vowels to have longer durations before the phonologically "voiced" stops than before the voiceless cognates. Javkin (1979) gives references for a large number of languages where these differences have been attested including English, Hungarian, French, Spanish, Norwegian, Danish, Hindi, Russian and Korean. The extent of the difference would appear to be greater for English than for the other languages studies, but even in American English, the more recent studies (Umeda, 1975; Klatt, 1975) have shown the differences to be relatively small except in utterance final position. Scully (1974), quotes Chen as suggesting that the universal difference would be in the region of 20-30ms. The perceptual role of vowel duration differences has been demonstrated by Denes (1955) and Raphael (1972). They also showed that the cue was operational irrespective of whether there was closure voicing or not. Not surprisingly perhaps, there are cases where voicing proper has been lost, and the distinction maintained by the vowel duration differences - "in certain environments, English and Latin have replaced the voicing distinction of the consonant following the vowel with a vowel duration distinction" (Javkin, 1979:52).

A number of hypotheses have been proposed to account for the vowel duration differences, and these are reviewed and discussed by Javkin. The two most interesting ones are Javkin's own and one by Scully.

Javkin suggests that the root cause may lie in a misperception: as vowels may be perceived as longer when they precede voiced than when they precede voiceless segments, he proposes that "listeners made consistent and systematic errors in their perception" which in time led to the observed difference in production. The claimed "misperception" was demonstrated in an experiment where English listeners matched the duration of a tone to the durations of vowels before voiced and voiceless fricatives. Vowels preceding the voiced fricatives were consistantly matched with longer tones. This experiment and its conclusions will be discussed again in Chapter 5, which deals with perception.

Scully's proposal is in the nature of a prediction from a computer aerodynamic model, namely that vowel amplitude will drop sooner before, and rise later after, an intervocalic voiceless consonant, even though the supraglottal closing gestures are timed identically.

If in natural speech, vowel amplitude does decay sooner with a following voiceless consonant, it would seem reasonable enough to suggest that listeners judgment of vowel duration might be affected by this. The fact that the amplitude of a signal will affect its perceived duration has already been alluded to. This has further been demonstrated by recent experimental work, e.g. by Repp (1979), showing that the perception of aspiration duration is affected both by the amplitude of the frication noise and by the amplitude of the adjacent vowel. Similar consequences of aspiration level for the perception of preaspiration are reported in Experiment 1 of Chapter 5. A probably related finding is that reported by Darwin and Pearson (1982), who propose that vowel onset may best be defined as the point in time at which the vowel reaches a given intensity, rather than the onset of periodicity as such. These findings are discussed again in Chapter 5.2, which deals with the perception of voicing contrasts.

To return to the proposed causation of the vowel duration differences, the line of explanation which would follow from Scully's prediction does not actually explain Javkin's results where synthetic stimuli were used for a given amplitude. In any case, the two types of explanation need not be mutually exclusive, and in both cases the universal tendency in production would be the result of heightening a perceived difference in vowel duration.

It is not intended to propose a counter hypothesis, but one could perhaps add to the above by suggesting that the development of a vowel duration difference may be intimately linked to the tendency for languages to lose voicing proper in VC#. Therefore one could regard it as an alternative and perceptually equivalent strategy which may reinforce, or eventually take over, an unstable opposition (involving voicing proper). The phonetic factors which lie at the root of the instability in such voicing oppositions form the topic of discussion in Chapter 4.2.

1.2 AN OVERVIEW OF THE SOUND SYSTEMS OF ICELANDIC, SCOTTISH GAELIC AND IRISH

1.2.1 ICELANDIC

1.2.1.0 Introduction

Descriptions of the sound system of Icelandic are to be found in works such as Haugen (1958) and Einarsson (1945); for a brief review see also Árnason (1980).

1.2.1.1 Vowels

pure vowels:

i		u
ɪ	y	ɔ
ɛ	oe	a

diphthongs: ɛi oey au ou
ai

In this description, as in the description of the other languages, the vowel system in the stressed syllable is given. Both the pure vowels and diphthongs can occur in either long or short form, depending on the quantity rule (see below). The quality of the vowel varies somewhat with vowel length (for more on this, see Garnes, 1976).

1.2.1.2 Consonants

The consonantal system is set out in the table below. The symbols in brackets indicate segments whose phonemic status is a matter of some dispute. The length of consonants will be dealt with separately below.

	labial	alv-dent.	palatal	velar	glottal
aspirated stops	p	t	(c)	k	
unaspirated stops	b	d	(ɟ)	g	
voiceless fricatives	f θ	s	(ç)	x	h
voiced fricatives	v		j	ɣ	
nasals	m	n	ɲ	ŋ	
liquids		l r			

Stops

There are two series of stops, both voiceless in all environments (thus the choice of phonemic symbols can be misleading). One series, traditionally described as "hard" hörð lokhljóð is characterised by aspiration: postaspiration in initial prevocalic position, and preaspiration in medial intervocalic and final postvocalic positions. The other series, traditionally described as "soft" lin lokhljóð is voiceless unaspirated. In the postvocalic positions, the opposition is not simply a matter of presence or absence of preaspiration. After short vowels the preaspirated stop (which functions phonologicaly as a long consonant: see the discussion on quantity below) alternates with an unpreaspirated geminate. Preaspiration in Icelandic (as in the other languages described) affects not only a preceding vowel, but also causes devoicing of a preceding nasal or liquid.

After initial /s/, only unaspirated stops occur. Neutralisation of the opposition also occurs after long vowels, or when the stop is followed by /j, v, r/. (In the latter environment the vowel is in any case always long). The direction of the neutralisation depends on the dialect. In the north (a dialect called <u>harðmaeli</u> "hard speech") an aspirated (i.e. postaspirated) stop is found. In the south, an unaspirated stop is used; this dialect is called <u>linmaeli</u> "soft speech".

According to Liberman (1971:271), "Icelandic preaspiration is realised not only as [h], but also as [x], [ç], and perhaps even as [f], depending on the preceding vowel and the following consonant". This suggestion was apparently based on early descriptions by Goodwin (1905 and 1908) and is generally dismissed by other and more recent researchers in the field (e.g. Pétursson 1972, Garnes 1976, and Thraínsson 1978). In the speech of all the Icelandic informants used in this study, the realisation of preaspiration would most appropriately be described as having the quality of a glottal fricative, although inevitably, a small amount of local cavity friction may also be detectable during part of the oral closing gesture.

As regards the number of distinct places of articulation, there is some dispute as to whether the palatal stops are separate phonemes, or allophones of the velar stops (see Árnason, 1978). For the purposes of this study, examples of both palatals and velars were included in the word lists, regardless of their phonemic status.

Fricatives

The phonemic status of some of the fricatives is also not unproblematic. [ç] can be analysed either as a separate phoneme, or as derived secondarily from /hj/. The voiced velar fricative has a limited distribution as it does not occur in initial position. /θ/ has a voiced allophone [ð] which occurs in complementary distribution with [θ].

Liquids and Nasals

Voiced and voiceless varieties of the liquids and nasals occur. The voiceless segments occur before the "hard", i.e. preaspirating stop series, and also in initial position. The latter cases can be regarded as deriving from underlying /h/ plus liquid or nasal.

Quantity

Stress on non compounds falls on the first syllable in Icelandic. All stressed syllables have approximately the same quantity, and the syllable rhyme will contain either a long vowel or a long consonant (or consonant cluster) but not both. This yields the following possible types of syllable rhyme:

V:(C)

VCC (CC is a long consonant or a cluster).

It is clearly not necessary to regard length as distinctive on both vowels and consonants, and phonologists vary in their treatment. Some authors (e.g. Bergsveinsson 1941; Garnes 1976) have opted for an analysis where length is considered distinctive on the vowel and predictable on the consonant. An alternative suggestion has been to regard consonant length as distinctive with vowel length predictable (e.g. Benediktsson, 1963) A further possible solution, discussed by Haugen (1958), is to abstract length from the segments and make it part of what he terms an "accent", which may be placed on consonant or vowel. For a discussion of the merits and demerits of various types of analyses, see Árnason (1980).

Historically, long and short vowels and consonants could combine freely so that the following types of syllable rhymes were possible:

VC	short
V:C VC:	long
V:C:	overlong

The evolution of a single quantity in stressed syllables involved a number of changes in the phonology usually referred to as the "quantity shift". First of all, long vowels before long consonants or consonant clusters began to shorten, thus eliminating the overlong syllable. Short syllables were then eliminated by lengthening of the vowel. The former of these changes would seem to have predated the latter; Haugen (1982) suggests that it had already begun before 1150 AD, whereas he would date the second change as beginning considerably later, c. 1550 AD. On the basis of metrical evidence from dróttkvaett and rímur poetry, Árnason (1980) also dates the second change as being of relatively recent origin, and suggests that it may not have been fully stabilised until the eighteenth or nineteenth century. Similar quantity shifts have also occurred in other Scandinavian languages, such as Faroese, Norwegian and Swedish, leaving them rather different from languages such as Danish, English and German which do not have a uniform quantity in stressed syllables.

One apparent exception to the "quantity rule" in Icelandic is the fact that long vowels are found before stop or/s/ plus /j/, /v/ or /r/ in polysyllabic words. This problem is dealt with by Árnason (1980), by suggesting a phonotactic constraint forbidding such clusters in syllable final position, and assigning the second consonant to the onset of the following syllable. As mentioned earlier, the "voicing" opposition among the stop consonants is neutralised in this position.

It has also been mentioned that preaspirated stops in Icelandic function as long (or geminate) consonants and can only occur following short vowels, where they are contrasted with an unpreaspirated geminate stop. After long vowels the opposition is neutralised. In summary, the phonetic realisation of stops in, say, the <u>linmaeli</u> dialect of Icelandic can be represented as follows, using the bilabial symbols to exemplify.

Initial	Medial		Final	
#CV and #CV:	VCV	V:CV	VC#	V:C#
p^h	^hp		^hp	
		p		p
p	p:		p:	

1.2.2 Scottish Gaelic

1.2.2.0 Introduction

The sound system of Scottish Gaelic closely resembles that of Irish, with probably the most striking feature being the opposition in the consonantal system of velarised and palatalised segments.

Gaelic, or to be precise, Old Irish, was first introduced into Scotland in the 5th century A.D., when the kingdom of the Dál Riada situated in the North East of Ireland (Co. Antrim) colonised neighbouring Scottish territories. This kingdom spread, and the language with it, so that by around 1000 A.D. it was spoken over the greater part of present day Scotland. Although the political unity of the Scottish and Irish territories had ceased by the 7th century, a strong cultural unity persisted for much longer, down to c.1700 A.D. The training of Scottish litterati would probably have involved lengthy stays in Ireland, until political defeat in Ireland during the 17th century led to the demise of the Gaelic social system and to a loss of patronage of the bardic schools. Jackson (1951) dates the linguistic emergence of the two distinct dialects from approximately 1200 A.D.

The Scottish Gaelic informants whose speech is described in this study come, broadly speaking from two main dialect areas. The first is represented by Lewis; the second is represented by speakers from Harris, Skye and North Uist. For the location of these dialects, see Figure 1.2.

Descriptions of the sound system of the Lewis dialect are to be found in Borgstrøm (1940) and in Oftedal (1956). The dialects of Harris and North Uist are also described in Borgstrøm (1940); the dialect of Skye is described in Borgstrøm (1941). Further detailed phonemic analyses of other Scottish Gaelic dialects are the description of the Gaelic of Applecross in Ross-shire, by Ternes (1973), and of East Sutherland Gaelic by Dorian (1978).

The two dialects studied here differ in their realisations of preaspiration. Differences in the realisation of the opposition of stops in the Scottish Gaelic dialects will be described below, following a brief general outline of the phonological system of Scottish Gaelic.

1.2.2.1 Vowels

pure vowels

i(:)	ɯ(:)	u(:)
e(:)	ə(:)	o(:)
a(:)	ɑ(:)	ɔ(:)

diphthongs

closing		opening	
ei	ui	iə	uə
əi	ɑi	iɑ	uɑ

The pure vowels can be either long or short, whereas the diphthongs are always long. Oftedal (1956) mentions that the /ui/ diphthong has a very limited distribution, and that generally, the closing diphthongs are most frequently found before the consonants [m], [n̴̪], [n̡], [ɫ̪] and [l̡], where the opening diphthongs are rare. Due to the strongly velarised or palatalised secondary articulation of the consonants, the pure vowels are often not exactly "pure" and may exhibit diphthongal glides. For more on this, see the description of Irish below.

1.2.2.2 Consonants

The striking feature of the consonant system is the opposition of velarised and palatalised segments. More precisely, there is an opposition between segments whose primary articulation is in the palatal region or which have the secondary articulation of palatalisation, and segments articulated in the velar region or which have a secondary articulation of velarisation. The alternation of palatalised and velarised segments plays an important function in the morphology of Scottish Gaelic and of Irish. For example, in word final position, the alternation can signal case; [ɛx] and [ɛç] are nominative and genitive cases respectively of the word <u>each</u> "horse" in Scottish Gaelic.

For the bilabial place of articulation the contrast of a palatalised and velarised pair has been lost in Scottish Gaelic, as it has also been for the glottal fricative and for the alveolar nasals and laterals.

	Lab.	Dent.	Alv.	Pal-alv.	Pal.	Vel.	Glot.
aspirated stops	p	t̪		t̠ʲ	c	k	
unaspirated stops	b	d̪		d̠ʲ	ɟ	g	
voiceless fricatives	f	s̪		ʃ	ç	x	h
voiced fricatives	v				j	ɣ	
nasals	m	n̪	n	n̠ʲ			
laterals		l̪	l	l̠ʲ			
trills/taps			r ɾ	ɾʲ			

Stops

The aspirated stops are voiceless and strongly aspirated in initial position. In medial intervocalic and in final postvocalic positions they have been described as preaspirated. The extent and the phonetic realisation of the preaspiration varies between the two dialect areas dealt with here, and this will be touched upon below. The unaspirated stops are voiceless in initial position. In medial intervocalic and final postvocalic positions, they have been described as voiceless or partially voiced, depending on the dialect. This will also be dealt with below. Following voiceless consonants there is neutralisation of the opposition and only unaspirated stops are found. Preaspiration of the preaspirating segments affects not only a preceding vowel, but any preceding voiced segment.

Fricatives

Alternations between stops and fricatives in word initial position are also important in the morphology of Scottish Gaelic (and Irish). The fricatives arose historically through the phonetic lenition of single stops, and the stop : fricative alternation seems to have replaced an earlier alternation of geminate and single stops. The alternation carries some important grammatical functions, e.g. as a tense marker on verbs; [kuð̆] and [xuð̆] are imperative and past tense forms of the verb cuir "put".

Liquids and nasals

Palatal and velar nasals occur before the palatal and velar stops, and would normally be regarded as allophones of /n/. In some parts of Skye these segments occur without the following stops (see Borgstrøm 1941), and would be regarded as independent phonemes.

Another striking feature of the consonantal system of Scottish Gaelic (and Irish) is the number of contrasts in the dental alveolar and palato-alveolar region. Historically there was a four-way opposition between laterals and liquids made at these places of articulation. Taking the nasals to illustrate, and in so far as one can surmise on the phonetics of Old Irish, it would appear that the velarised dental and the palatalised palato-alveolar segments [n̴̪] and [ȵ̠] alternated with palatalised and velarised alveolar segments respectively. This alternation parallelled the alternation of non-lenited and lenited stops in the system, and carried the same grammatical load. The loss of the four-way contrast seems to be a relatively recent development in Irish and Scottish Gaelic dialects and traces of the older system are still to be found in some dialects of both languages (see Oftedal, 1956 and Quiggin, 1906). However, for the nasals and laterals in most Scottish Gaelic dialects, the distinction between the alveolar pair (i.e. the "lenited" pair) has disappeared, leaving a three-way contrast. In the case of "r" sounds, the opposition seems (again, in so far as one can guess at the phonetics of the past) to have involved a distinction between a (velarised and palatalised) pair of trills, i.e. the non- lenited varieties and a pair of taps, i.e. the lenited counterparts. The present system seems to involve a three way contrast, with the reflexes of the old non-lenited palatalised and velarised trills having fallen together as a velarised trill.

Although symbolised as a tap on the chart above, the palatalised /ɾ̡/ has a variety of realisations depending on the dialect. In Lewis it is realised as a voiced palatalised dental fricative [ð̡]; in Skye, it is realised as [j]; In Harris and North Uist it is realised as a voiced palatalised alveolar fricative, best symbolised as [ᶎ].

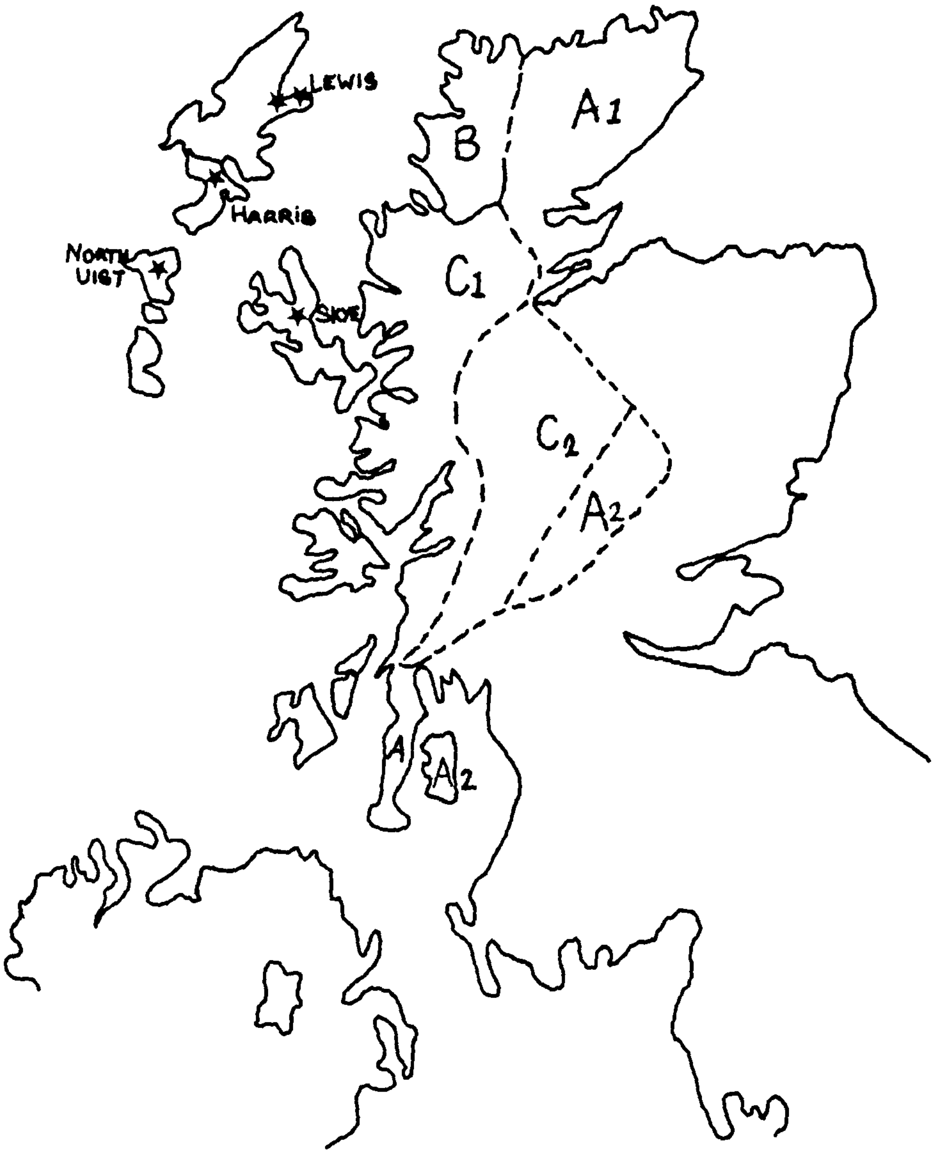


Figure 1.2 Scottish Gaelic dialect areas, and approximate location of informants for whom production data is presented

1.2.2.3 Dialect differences in the realisation of preaspiration and of the phonological opposition of stops.

Borgstrøm (1974) classifies the Scottish Gaelic dialects into three main areas on the basis of their realisations ot preaspiration. His classification is summarised here, and the illustration of the geographical location of these dialects in Figure 1.2 is adapted from Borgstrøm (1974) and Ó Baoill (1980).

A Areas which lack preaspiration. These areas lie outside the present study and can be further subdivided into two parts.

A1 In the first of these, i.e. eastern Sutherland, the apparently older system of voiced versus voiceless stops is described as persisting.

A2 The second sub-area is represented by the Isle of Arran in the south and a small part of Perth-shire in the East. In these the two stop series would appear to have merged completely, yielding what Borgstrøm describes as voiceless or half-voiced stops. Holmer's (1957) description of the Arran dialect, suggests a disappearing rather than a completely neutralised contrast among the stops.

B Areas where preaspiration tends to be shorter and weaker (i.e. with less audible friction present), described by Borgstrøm as "a voiceless breathing between the vowel and the stop" (:97). These areas include Lewis (one of the dialects studied here), northern and western Sutherland, and the greater part of Ross-shire on the mainland. The preaspiration in this area Borgstrøm considers as "the simplest and presumably oldest form of preaspiration". This suggestion is further discussed in Chapter 4, which deals with the historical development of preaspiration. Borgstrøm further suggests that before the alveolo-palatal and the palatal stops the preaspiration is "normally palatalised and may resemble a very short [ç]" (1974:97).

For this dialect, the unaspirated series of stops is described in Borgstrøm (1940) as being "mainly voiceless" in initial position (and the opposition therefore depending on the presence or absence of postaspiration). In medial and final positions after a stressed vowel the opposition is described as involving the presence or absence of preaspiration, although the unaspirated series are here described as "unaspirated lenes, frequently half voiced (:20)". Voicing of the unaspirated series in Lewis is not mentioned by Oftedal (1956).

C Areas where preaspiration is more prominent and longer. The unaspirated series in these dialects are voiceless (Borgstrøm, 1940). As regards the realisation of preaspiration, these areas can be further subdivided:

C1, where palatal and velar stops are preaffricated, i.e. are realised as [$^{\text{ç}}$c] and [^{x}k] rather than as [^{h}c] and [^{h}k]. The Harris, Skye, and North Uist informants all represent this group). Infrequently, the preaspiration of the velar stop may in fact have the quality of glottal frication rather than homorganic cavity friction; stops other than the palatal and velar ones may also occasionally have realisations of preaspiration with palatal or velar frication (depending on the palatalised or velarised nature of the stop).

C2, where preaspiration for every place of stop articulation is realised as a strong velar or palatal fricative. This covers wide areas in the Central Highlands, and is not included in the present study.

1.2.3 Irish

1.2.3.0 Introduction

The dialect of Irish included in this study is that of the Gaoth Dobhair Gaeltacht in West Donegal (see Figure 1.1). Detailed phonetic descriptions of neighbouring West Donegal dialects are to be found in Quiggin (1906) and Sommerfelt (1922).

1.2.3.1 Vowels

pure vowels

ɨ(:)	u(:)
e(:)	o(:)
a(:)	ɔ(:)

diphthongs

closing	opening	
au	ɪa	ua

In a relatively recent article (1965) based on his earlier work on the neighbouring Donegal dialect of Torr, Sommerfelt includes two further vowels in the phonemic system. These appear to be high and mid unrounded vowels with a rather back quality. In Gaoth Dobhair Irish these two vowels seem to have fallen together with the front high and mid vowels. For more discussion on this see Ní Chasaide (1977).

For the pure vowels length is distinctive. The diphthongs are always long. As already mentioned in the outline of the Scottish Gaelic system the quality of the "pure vowels" varies considerably according to the palatalised or velarised nature of the adjacent consonant, and will frequently exhibit strong diphthongal onglides or offglides. Figure 1.3, from Ní Chasaide (1977) illustrates how a preceding velarised or palatalised consonant affects the auditory quality of the main allophones of these vowels. In addition to diphthongal on- or offglides, the steady state quality of the vowel allophones may also vary. For some spectrographic measurements which illustrate this point, see also Ní Chasaide (1977).

following a velarised consonant　　　　following a palatalised consonant

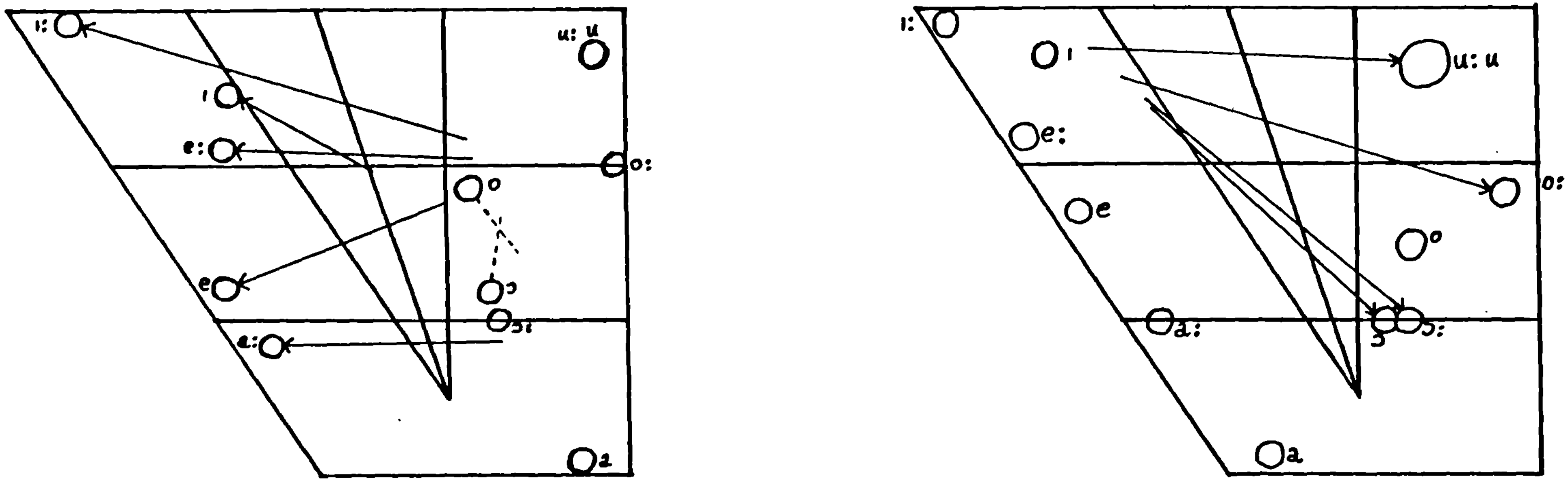


Figure 1.3 Some main allophones of vowels in stressed position following velarised and palatalised consonants. Symbols used are phonemic

——→ Direction of onglide from preceding consonant

-------- Allophone quality varies along dotted line

Consonants

Unlike the situation pertaining to Scottish Gaelic, labial segments in Irish retain the opposition of velarised and palatalised varieties. The velarised labial segments series are also fairly noticeably labialised. On the chart below, segments in brackets are of rather marginal phonemic status.

	Lab.	Dent.	Alv.	Pal.-alv.	Pal.	Vel.	Glot.
aspirated stops	pˠʷ pʲ	t̪ˠ		t̠ʲ	c	k	
unaspirated stops	bˠʷ bʲ	d̪ˠ		d̠ʲ	ɟ	g	
voiceless fricatives	fˠʷ fʲ	s̪ˠ		ʃ	ç	ɣ	h
voiced fricatives	w vʲ				j		
nasals	mˠʷ mʲ	n̪ˠ	nˠ (nʲ)	n̠ʲ			
laterals		l̪ˠ	(ɫ) lʲ	l̠ʲ			
trills/taps			rˠ	ɹʲ			

Stops

Both Sommerfelt (1922) and Quiggin (1906) describe one series of stops as being fully voiced, compared to the second series which is strongly aspirated except after [s ʃ x]. Further positional variation of voicing or aspiration is not discussed by either author; however, Ó Dochartaigh (1979) describes for another, more northern, Donegal dialect, a tendency towards devoicing of the voiced series in VC#.

Liquids and Nasals

Compared to other Irish dialects, Donegal Irish is conservative in that it retains traces of the four-way opposition of non lenited versus lenited palatalised and velarised nasals and liquids in the dental, alveolar and palato- alveolar region. Even here, however, the status of the fourth alveolar segment is somewhat marginal. For a discussion of this topic, see Ní Chasaide (1977 and 1979). In the case of r-sounds, the historical four-way opposition has collapsed to two, leaving what would appear to be the reflexes of the lenited variants. In initial position these phonemes are realised as postalveolar approximants. In postvocalic environments the palatalised member /ɽ / is most frequently is realised as [j] in this dialect. Palatal and velar nasals have full phonemic status in Irish.

1.2.4 ORAL FRICATIVE REALISATIONS OF PREASPIRATION

As just described, there are realisations of preaspiration whereby the quality of the preaspiration is that of oral rather than of glottal frication. Such realisations are the predominant ones for velar and palatal stops in the second Scottish Gaelic dialect studied here (that of area C1 represented by the Harris, North Uist and Skye informants). A weaker tendency in the same direction may exist for Lewis Gaelic, judging by Borgstrøm's comments, cited above, on palatalisation of preaspiration with palatal and palato-alveolar stops in this dialect, so that it resembles a short [ç]. Similarly, in Icelandic, the observations of Liberman (1971) based on work by Goodwin (1905 and 1908) could indicate some such similar trend, although probably not very widespread; as mentioned above, other scholars have queried these suggestions. It has also been pointed out above that the Icelandic informants encountered in this study had a quality of preaspiration most appropriately described as glottal frication. However, even here a small amount of local cavity friction can frequently be detected in the final closing phase of the preaspiration.

The presence of what one might term "preaffricated" realisations of preaspiration, especially with velar and palatal segments, is not very surprising if one considers the source of the fricative noise in [h]-type segments. The vocal folds are spread and there is a high rate of airflow through the glottis. The vocal tract has the configuration appropriate to the adjacent vowel, or for invervocalic [h], the vocal tract configuration shifts from that of the first to the second vowel. For postaspiration there is movement from the configuration of the consonant stricture to that of the vowel (the reverse is true for preaspiration). At any one instant in time, the relative apertures of the glottal and oral strictures will determine the source of frication noise. When the oral stricture exceeds the glottal one, the audible frication noise will be predominantly local cavity friction; when the greater stricture is at the glottis, a predominance of glottal friction should result. For preaspiration in the languages described here, one would expect the factors to be the following, which would influence the degree to which preaffrication tendencies would be found:

(a) the quality of the adjacent vowel;

(b) the place of articulation of the consonant;

(c) secondary articulations; and

(d) the duration of preaspiration.

(a) The quality of the adjacent vowel

In a discussion concerning the interpretation of [h] as a glottal fricative or a voiceless vowel, Catford (1977: 250) remarks:

> "Any voiceless vowel with an articulatory stricture narrower than the glottal stricture (certainly [i]- and [u]-type vowels, and possibly [e]- and [o]-types) will be an (oral) approximant and will have turbulent flow through the oral channel. Any vowel with an oral channel more open than the glottal channel will not generate turbulent flow at that

point. What one hears ... is glottal turbulance modulated by the oral-shaping for the vowel."

(b) The place of articulation of the consonant

Regardless of vowel height, during the closing or opening phase of the stop there will be an interval for which the oral stricture exceeds the glottal one in pre- and postaspiration respectively. The duration of this interval is likely to be longest for segments where the active articulator is large and relatively sluggish. This effectively means tongue body articulations (as opposed to tongue tip or labial ones) i.e. stops articulated in the velar or palatal region. This difference is illustrated schematically in Figure 1.4. Hence, it does not seem too surprising that these are the places of articulation for which "preaffricating" realisations of preaspiration are usually found in dialect Cl. Corroborating data are presented in Chapter 2.2.3 which suggest that the slowest oral closing times and the longest preaspiration durations are found with velars and palatals. This particular question is broached again in Chapter 4.1, where the historical evolution of preaspiration is discussed.

(c) Secondary articulations

Regardless of the primary place of articulation, all, or virtually all of the consonants of Scottish Gaelic and Irish are articulated with a high tongue body, due to the opposition in the

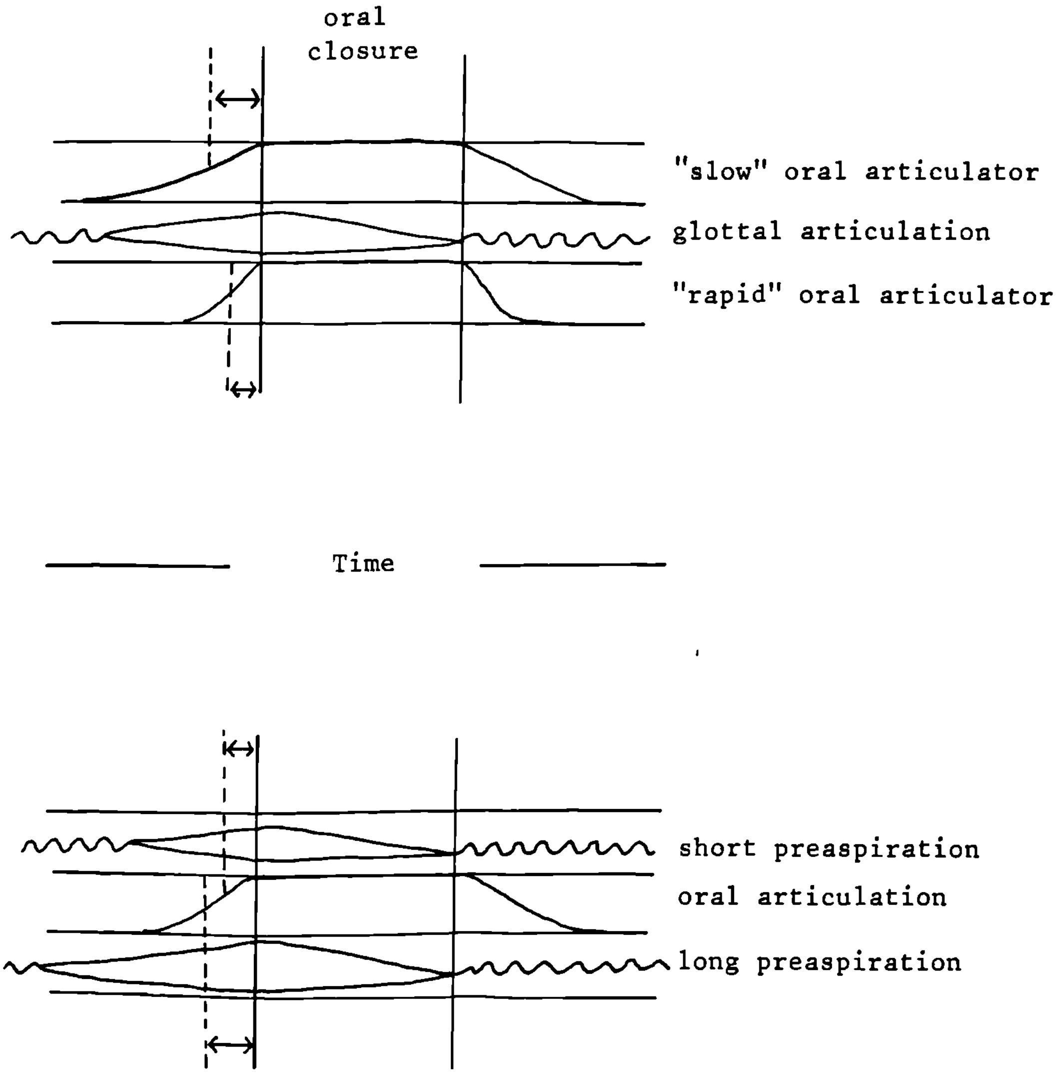


Figure 1.4 ⟵⟶ duration of interval for which oral stricture exceeds glottal stricture, as a consequence of articulator mobility (above) and preaspiration (below), shown schematically

system of velarised and palatalised segments. As was also mentioned above, the secondary articulation affects, not only the segments themselves, but also the transitions to the adjacent vowels. Hence one would expect the final phase of preaspiration, and the initial portion of postaspiration to contain substantial amounts of cavity friction, with a velarised or palatalised quality. This may explain the greater tendency towards "preaffricated" realisations of preaspiration in Scottish Gaelic than in Icelandic. It may further explain why in dialect C 2, preaspiration realisations of a velar or palatal quality is found with stops in places of articulation other than velar or palatal.

(d) The duration of preaspiration

The duration of preaspiration may indirectly affect the extent to which audible preaffrication is likely to develop. This is because there is a positive correlation between the duration of preaspiration and the degree of glottal abduction in the closing phase of the stop (see Chapter 3.2), and this should in turn correlate with the rate of airflow through the glottis and through the oral cavity.

A wider glottal aperture during the oral closing phase, should extend the interval during which local oral friction should predominate over glottal friction. This is illustrated schematically in Figure 1.4. The higher rates of airflow through the oral cavity should increase the amplitude of oral friction (see Catford, 1977: 33-46). As shown in perceptual experiment 1 of Chapter 5, an increased amplitude of frication noise enhances its perceptibility.

1.2.5 The phonological interpretation of preaspirated stops: single phoneme or cluster?

The description and discussion so far of preaspiration in these languages implicitly assumes that preaspiration is to be analyzed phonologically as a property of the stop. From this viewpoint the preaspirated stop is seen as partaking of a phonological contrast with an unpreaspirated one. An alternative analysis has also been suggested by authors describing both Icelandic and some of the Scottish Gaelic dialects, whereby the preaspirated stop is analyzed as a sequence of two phonemes. According to the bi-phonemic analysis the opposition of stop cognates is neutralised is all but initial positions.

For Icelandic, both interpretations have been suggested. Haugen (1958) used a monophonemic analysis. On the other hand, Pétursson (1972 and 1974:106) has argued that preaspiration should be regarded as an instance of the phoneme /h/ which otherwise occurs for that language in initial position. The basis of Pétursson's analysis involves the argument that preaspiration is phonetically similar to [h] (and dissimilar to postaspiration). More precisely, this phonetic similarity would seem to consist in:

Durational similarity The considerable duration of preaspiration resembles more the duration of a segment than the duration of postaspiration.

Articulatory similarity As for [h], preaspiration has a spread glottis and a vocal tract configuration appropriate to the adjacent vowel.

Pétursson (1972) further speculates that preaspiration may differ from postaspiration in terms of glottal articulation, or more precisely in terms of the degree of glottal opening. Indeed, he suggests that this may explain the observed durational differences

> "Notre hypothèse est donc que la différence physiologique entre la préaspiration et l'aspiration des occlusives est une différence du degré d'ouverture glottale, ce que expliquerait la grande différence de durée observée chez nos sujets pour ces deux segments." (:68)

This hypothesis is prompted by the work on Korean stops by Kim (1970) who demonstrated a positive relationship between the degree of glottal opening at stop release and the duration of postaspiration (see Chapter 1.1.2).

In Scottish Gaelic the analysis by Borgstrøm (1940 and 1941), argued again in (1974), has been to treat the stops with shorter preaspiration of the Lewis dialect (and area B) as single phonemes, and to regard the longer preaspiration of the more southern islands and the mainland (areas C1) as clusters of [h], [ç], or [x] plus stop. To recapitulate briefly on the realisations of preaspiration in the latter dialect, which varies with place of articulation: with velars and palatals the realisation is nearly always a homorganic fricative, but a glottal fricative may also occasionally be found. With other places of articulation, a glottal fricative is the usual realisation, but realisations with velar or palatal fricatives can also occur (for a detailed description, see Borgstrøm, 1940: 167-169, and 1941: 43-44).

Principal reasons for the differential treatment of the two dialects, and specifically for the biphonemic analysis of the Cl dialect, would seem to be:

Durational: The rationale here is similar to Pétursson's. When preaspiration is longer it is more separately perceptible in its own right. Lewis preaspiration is shorter than [h], and shorter than the preaspiration of the southern dialects.

Variability of realisation: As velar, palatal and glottal fricatives occur also as separate phonemes in Scottish Gaelic, there is a reluctance to have their appearance as realisations of preaspiration derived from a different underlying source.

Palatalisation of preaspiration in Lewis Gaelic: For palatal and palato-alveolar stops in Lewis Gaelic, Borgstrøm notes that "preaspiration is normally palatalised and may resemble a very short [ç]" (1974: 97). In his earlier work (1940:21) he describes the quality of preaspiration with these segments as "distinctly palatal without being as narrow as [ç]". The phoneme /h/ is normally analyzed as neutral in Scottish Gaelic, i.e. as not partaking of the opposition of palatalised and velarised segments (see section 1.2.2.2). The palatalisation of preaspiration in the Lewis dialects, with segments articulated in the palatal region, is viewed by Borgstrøm as setting it apart from the "ordinary h".

<u>Preaspiration in the English of Lewis Gaelic speakers:</u>
Lewis speakers are more likely to preaspirate stops in English than are speakers of the more southern dialects, e.g. Harris.

With regard to the phonemic status of preaspirated stops I would tend to favour the "single phoneme" interpretation for the languages and dialects looked at. My reasons for preferring a monophonemic analysis, and the counterarguments I would suggest to the grounds suggested above for the bi-phonemic analysis would be as follows:

1. Arguments on <u>phonetic similarity</u> involve durational and articulatory characteristics, which must be dealt with separately.

1a) <u>Durational</u>. Although preaspiration can be of very long duration in certain environments (e.g. following short vowels) in other environments it can be very short indeed. For example, in Scottish Gaelic it is never very long with long vowels (see Chapter 2). Its duration is also comparatively shorter in medial than in final prepausal position (see also Chapter 2) and in positions with relative lack of stress its duration is strikingly shorter (see Chapter 3).

One might add here that the perception experiments reported in Chapter 5 would seem to indicate that only a short duration of preaspiration is required in order for stops to be perceived as preaspirated. VOFFT (voice offset time) perception is durationally very similar to VOT perception.

1b) Articulatory similarity. This is, as far as I can see a non-argument. Bearing in mind the discussion of the previous subsection 1.2.3, there are similarities of oral and glottal configuration between [h] and pre- and postaspiration, and no particular justification for grouping [h] and preaspiration as distinct from postaspiration. More plausible grounds for arguing a phonetic dissimilarity between pre- and postaspiration could conceivably be found in the fact (already mentioned in section 1.3. below and discussed in some detail in later chapters) that preaspiration has, in comparison to postaspiration, a relatively slow breathy voiced transition between the vowel and the aspiration. However, as is argued in Chapter 2 the breathy voiced transition is probably an unavoidable aerodynamic/mechanical artefact of postvocalic devoicing when the vocal tract is open. As such, one would be reluctant to suggest it as a differentiating feature.

Pétursson's suggestion that preaspiration may have wider glottal opening than postaspiration and that this would explain the durational difference, seems to miss the point of Kim (1970). The width of glottal opening at stop release may serve to explain postaspiration duration, because, all else being equal, it determines how long it will take for the vocal folds to reach the point where voice is initiated. With preaspiration, there is no reason to suspect that the degree of glottal opening determines the point at which preaspiration terminates (or oral occlusion occurs). Although one should expect preaspiration duration to correlate with width of glottal opening at oral closure, this would simply be a consequence and not a cause of the longer preaspiration duration. It would be a reflection of the fact that a greater proportion of the glottal opening was achieved before the point of oral closure.

2. Variability of realisation.

The fact that realisations of preaspiration vary as between glottal and oral frication, has been used by Liberman (1972) as an argument against treating preaspiration as a sequence of two segments.

The variability of preaspiration realisation is only phonologically a problem if one adheres to a strict classical phonemic model of phonology where similar surface segments have to be derived from the same underlying form. This requirement of classical phonemics has retrospectively become known as the bi-uniqueness condition (see Chomsky, 1964: 94-95). As [h], [ç], and [x] occur as separate phonemes in Scottish Gaelic, an analysis whereby [xk] is derived from an underlying [hk] in the Cl dialect would contravene the bi-uniqueness condition. (It is worth pointing out here that the work by Borgstrøm is within the classical phonemic model, or is in some cases prephonemic.)

However, in the Cl dialect, velar and palatal stops have usually (but note, not always) velar or palatal fricative realisations of preaspiration, and furthermore, other places of articulation may occasionally have velar or palatal fricative realisations of preaspiration rather than the more usual glottal fricative variety. This means that a phonemic analysis as clusters would be untidy (with lots of overlapping) and would miss out an important generalisation. If there are "preaffricating" dialects or idiolects in Icelandic, this point would also hold. Within more recent phonological thought, the bi-uniqueness condition has not been considered a primary consideration. The capturing of generalisations is on the other hand of primary importance.

3. Phonological and morphological generalisations

Other important generalisations are lost if one adopts the biphonemic analysis. One example concerns the devoicing of liquids and nasals. In all the languages looked at (including Irish) voiced liquids and nasals are devoiced preceding the "preaspirating" stop series. This, one feels, really does point to the preaspiration as being genuinely a characteristic of the stop. If one were to adopt a cluster analysis, this further generalisation would be lost. Clearly, the devoicing of liquids and nasals preceding preaspirated stops is analogous to the devoicing commonly found in liquids following postaspirated stops. In Scottish Gaelic, one would further have to postulate a voiceless series of liquid and nasal phonemes, if one were to adopt the cluster analysis.

In fact, recent works on Icelandic phonology by Árnason (1980:24) and Thráinsson (1978:21) have (although as phonologists deferring to Pétursson's "phonetic" line of argument that preaspiration should be regarded as a separate segment) pointed out that, in terms of phonological and morphophonemic processes in the language, this interpretation does not make much sense. Alternations between preaspirated and unpreaspirated stops occur in Icelandic and carry important grammatical functions, for example as past versus present tense marking on verbs or as neuter versus feminine marking on adjectives (<u>ljót</u> [ljout:] versus <u>ljótt</u> [ljou^{h}t] are feminine and neuter forms of the adjective "ugly"; for more on this, see Árnason, 1977). These cases would have to be dealt with as cases of [h] infixing, if the biphonemic analysis is adopted.

4. <u>Palatalisation of preaspiration with palatal stops in Lewis Gaelic points to a similarity rather than a dissimilarity with the southern C1 dialect.</u>

The situation described for Lewis palatal and palato-alveolar stops is clearly analogous to that of the more southern dialect of C1. The tendency revealed is clearly the same, it is only the degree that differs. The weaker preaffrication exhibited by Lewis probably correlates with the overall shorter duration of preaspiration in this dialect, for the production reasons outlined in subsection (d) of section 1.3 above. The fact that Lewis Gaelic exhibits tendencies similar to those of dialect C1 militates rather for grouping them together, and can hardly serve as grounds for a separate treatment.

According to Borgstrøm the palatalised realisation of preaspiration for palatal stops in Lewis renders it different from the /h/ phoneme which is neutral. The fact that the /h/ phoneme is phonologically analysed as neutral, i.e. does not contrast velarised and palatalised varieties, indicates rather that the quality of the glottal fricative tends to, and is free to coarticulate in quality with adjacent segments. In this respect it is not essentially any different from either pre- or postaspiration.

5. The pronunciation of English by Gaelic speakers.

On this, I would tend to agree with a viewpoint expressed by Cathair Ó Dochartaigh (personal communication) that this is not necessarily a criterion that should be used when deciding on the internal structure of a language or dialect.

6. Perceptual integration of preaspiration and stop closure

One final piece of evidence, which seems to favour the monophonemic interpretation of preaspirated stops, comes from perception Experiment 3 in Chapter 5.2. In that experiment it was found that stop duration contributes positively to the percept of the preaspirated stop. This suggests some kind of perceptual integration of the two elements of stop closure and preaspiration. If it were the case, that preaspiration functions as a separate segment, then one should expect an increase in the following stop closure to decrease its perceptibility. The type of trading relationship observed for preaspiration and stop closure would seem highly unlikely it these two were perceived in contrast to each other.

On balance therefore, the monophonemic interpretation of the preaspirated stop seems preferable, and is the one opted for in this study.

1.3 INSTRUMENTATION, SEGMENTATION AND LINGUISTIC DATA RECORDED

1.3.1 Instrumental Techniques used

1.3.1.0 Introduction

Instrumental techniques were used in this study to elucidate aspects of the production and perception of preaspiration.

The production data presented in Chapters 2 and 3 involved primarily fairly extensive measurements of the possible durational correlates of "preaspirating" oppositions. These correlates and their importance in stop cognate oppositions have been outlined in section 1.1 above. The durational measurements were based on a comparison of oral airflow and audio (or in some cases laryngographic) signals. In addition to this, some (much more limited number) of recordings included electroglottographic and subglottal pressure measurements, which afforded insights into glottal activity in the production of the stop oppositions of the three languages studied. The findings and insights regarding glottal behaviour are also discussed in Chapters 2 and especially 3. Finally, in Chapter 5, which deals with the perception of preaspiration, a small amount of additional production data is included, from which durational measurements were made. These data were obtained to illustrate or clarify certain points relevant to the discussion in this chapter. Details concerning the equipment used follow here below. In section 1.3.2, there is a discussion of the segmentation used. The linguistic materials recorded are tabulated in section 1.3.3.

The results of experiments concerning the perception of preaspiration are presented in Chapter 5. There were two techniques used for the preparation of stimuli for these experiments. The first involved computer manipulation of previously recorded natural speech. The second technique involved speech synthesis, i.e. the synthetic construction of speech-like stimuli, on the basis of parameters measured from spectrograms. Some details concerning the equipment used for the preparation of stimuli are included here below. More specific information is given in the relevant parts of Chapter 5, outlining the nature of the parameters manipulated for each series of stimuli as well as details concerning the subjects and the presentation of stimuli.

1.3.1.1 Instrumentation used in production measurements:

The recordings of production data were carried out at a number of establishments. In addition to the phonetics laboratory of the University College North Wales, Bangor, where the author was based, recordings were made in:

The Phonetics Laboratory, Edinburgh University,

The Royal Hospital for Sick Children, Edinburgh and

The Phonetics Laboratory, Oxford University.

The spread of establishments was mainly dictated by where informants could be found, as speakers of the languages

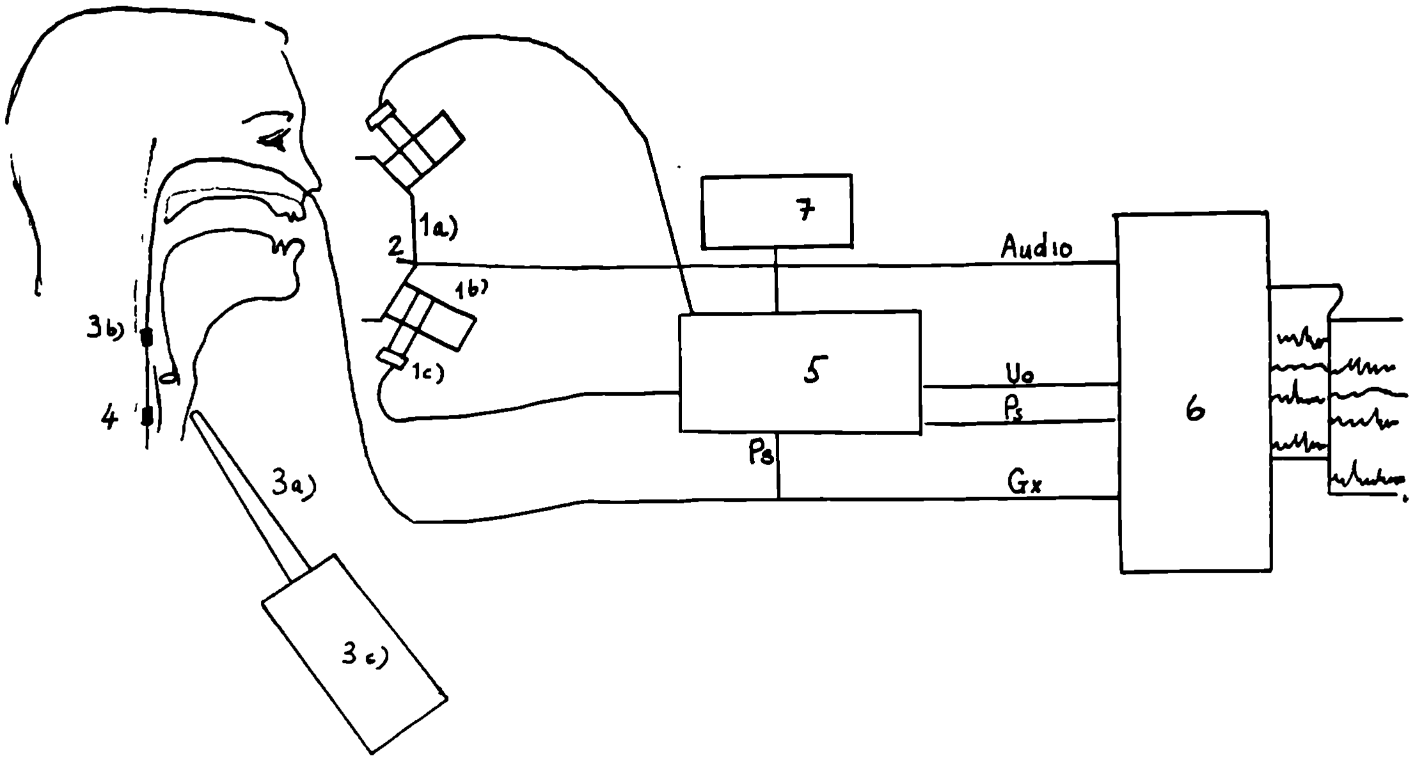


Figure 1.5

Experimental arrangement for a recording which includes:

1. Airflow (see text for different types of devices used)
   a) mask
   b) flowheads
   c) differential pressure transducers
2. Audio microphone
3. Photo electric glottograph
   a) cold light source
   b) light sensor
   c) amplifier
4. Subglottal/oesophageal pressure transducer
5. Amplifying unit for 1c) and 4
6. Inkwriter - oscillomink
7. Tape recorder

investigated are often difficult to find. On the whole, similar instrumentation was used in the various laboratories; what slight differences there were in intrumental set-up is mentioned below. The instrumental technique of electroglottography was only available in the phonetics laboratory of Oxford University, and therefore all such data was recorded there.

Figure 1.5 illustrates the experimental arrangement for a recording where signals were obtained for (1) oral airflow, (2) an audio microphone, (3) an electroglottograph, and a transducer which measures (4) subglottal pressure (strictly speaking oesophageal pressure - see below). The outputs of (1) and (4) were (5) amplified, and along with the other signals were recorded on an (6) oscillograph ink writer. Figures 1.6, 1.7 and 1.8 illustrate the oscillographic tracings for a typical recording of the above signals, with the exception of subglottal pressure. In most recordings (i.e. all but the earliest recordings made) the audio microphone was also simultaneously fed to a (7) tape recorder. This is useful when transcribing the data, and as it permits later recovery of errors, breaks etc., enables a larger quantity of data to be recorded without stopping to annotate where one is at.

(1) Oral Airflow: Depending on the establishment, one of two devices were used to record oral airflow. Figure 1.5 illustrates the second of these.

The first, used in the phonetics laboratories at Bangor and Edinburgh is the electro-aerometer (F-J Electronics). For a detailed description of this device, see Scully (1969). The subject speaks into the specially-designed face mask, which fits over the nose and mouth, and separates oral and nasal flow by means of a soft rubber partition which rests above the upper lip. In the oral and nasal chambers, there are two one-way valves, with lights behind them, through which ingressive and egressive flow can pass separately. The opening and closing of the valves is registered by photoelectric cells.

In the phonetic laboratory of Oxford University, and the Royal Hospital for Sick Children, Edinburgh, the pneumotachographic method was used to register oral airflow (see Figure 1.5). This device involves a flowmeter in which there is a wire mesh screen and a differential pressure transducer. As air flows across the wire mesh screen, a pressure drop results and is recorded by the transducer, via pressure taps on either side of the screen. The pressure drop, which is linearly related to the volume rate of airflow, is converted to an electrical voltage and amplified. The particular configurations used in the two establishments were designed by Dr J. Anthony of Edinburgh University and consisted of the following: (1a) a surgical face mask, converted so that a soft rubber partition, resting on the upper lip, separates oral from nasal flow. To the exits of the oral and nasal chambers are attached (1b) flowheads (Type F2, 19mm bore, manufactured by Mercury Electronics Scotland Ltd.). The differential pressure transducers (Gaeltec 8T) and amplifiers, (1c) and (5), respectively in Figure 1.5, form part of the Gaeltec Aerodynamic unit manufactured by Gaeltec Ltd., Skye, Scotland. For some comments on this system of airflow measurement, see Anthony (1982).

Of the two systems for measuring airflow, the latter has the advantage of being more linear and is more easily calibrated.

(2) <u>Audio Microphone</u>

Again systems were not identical in each estalishment. In Edinburgh University and in Bangor, a larynx microphone (F-J Electronics) was placed at the subject's larynx on the outside of the throat by means of a collar. In these recordings, needless to say, no glottography signal was included and hence the larynx was "free". In Oxford University, a microphone (type Eagle PRO M5) was mounted in the oral chamber of the airflow mask. This is the version illustrated in Figure 1.5. In the Royal Hospital for Sick Children, Edinburgh, the audio microphone was mounted on a stand external to the mask. The audio signal in this last configuration is extremely noisy, as it picks up other external noises, such as that of the machines. However, this configuration featured a laryngograph, a device which measures the electrical impedence across the vocal folds (not part of the illustration in Figure 1.5). The Laryngograph records the waveform of vocal-fold vibration, and replaced the function of the audio-microphone in these recordings, for determining voice

The glottograph can not be calibrated, and factors such as the placement of light source and light sensor affect the amplitude of the waveform obtained. Although information regarding onset of glottal abduction/adduction can be obtained with accuracy, caution is required in interpreting glottal opening amplitudes. Inferences concerning amplitude of glottal opening are made only in cases where there is evidence of

- abduction versus no abduction of vocal folds (as in Chapter 2.3.4), or of

- large and consistant differences in glottal opening amplitude (as in Chapter 3.2). Care has also been taken in these recordings to minimise factors which could cause artefacts in the results (see discussion in 3.2.3).

on- and offset. Some differences in measurements resulting from the use of laryngograph as opposed to the microphone signal are discussed where relevant in the text of Chapter 3.

(3) Photo-electric glottograph

The F-J electronics, type LG 900 photo-electric glottograph was used. This device consists of (3a) a light source, (3b) a photo-transistor, and (3c) an amplifier. A cold beam of light from the light source is directed through an acrylic cone whose tip is held in contact with the subject's skin below the thyroid cartilage. The photo-transistor is mounted in a polyethylene catheter, which is introduced transnasally, and lowered into the subject's pharynx to a point where it lies above the glottis. The tip of the catheter is swallowed, and this stabilises the position of the photo-transistor in the pharynx. The amount of light picked up by the transistor will depend on the opening and closing of the vocal folds. It is converted into an electric current which is amplified and then recorded.[1]

(4) Subglottal/oesophageal pressure

The catheter containing the photo-transistor had two further transducers mounted in it (Gaeltec 3CT), suitable for the recording of oral and oesophageal pressures. This "multi-transducer" catheter was manufactured by Gaeltec Ltd., Skye, Scotland, to the design of Mr R.A.W. Bladon. In recordings which contained glottographic signals it was usually possible to include one and sometimes two of the pressure recordings. The fixed distances between transducers did not necessarily "fit" every subject. When this was the case, oral pressure (Po) was considered dispensible as it was least essential for the purpose of this study. In illustrations of recordings, the signal resulting from an incorrectly positioned oral-pressure transducer is marked with an asterisk. Only subglottal/oesophageal pressure is referred to in the thesis and discussion will be restricted to it here.

The transducer which records subglottal/oesophageal pressure is positioned below the photo-transistor, and is swallowed so that it lies in the oesophagus behind and just beneath the glottis. For short utterances of the kind used in this study, oesophageal pressure correlates well with subglottal pressure and will henceforth be referred to as such; (for a discussion of this topic, see Ladefoged 1967:6-10). The output from the transducer is amplified in the aerodynamic unit (5) before being recorded.

(5) Amplifiers for airflow and pressure signals

The aerodynamic unit supplied by Gaeltec Ltd., Skye, Scotland, contains amplifiers for both airflow and pressure signals. It also allows low pass filtering of the airflow signals in the range of 60Hz to 270Hz. Both filtered and unfiltered outputs were recorded on separate channels of the inkwriter.

(6) Oscillograph

The ink writers used were in every case by Siemens. In Oxford, in Bangor, and in the Royal Hospital for Sick Children in Edinburgh, an eight channel model was used. In Edinburgh University both four and sixteen channel models were used. The recording speed was 100mm per second, excepting recordings made in the Royal Hospital for Sick Children, Edinburgh, where the recording speed was 250mm per second.

1.3.1.2 Instrumentation used for perceptual experiments

The stimuli used in the perceptual experiments described in Chapter 5 were prepared in:

The Phonetics Laboratory, Cambridge University, and

The Department of Experimental Psychology, Oxford University.

In Cambridge, stimuli were produced from computer-editing natural speech. A studio recorded speech sample was first low pass filtered to 5 Khz, and then digitised at a sampling speed of 10 Khz on to a Computer Automation 'Alpha' LS1-2/40 minicomputer, and stored on disk. The stored, digitised speech was then displayed on a CRT screen. A software editing program SEDIT allows for up to 1.6 seconds of speech at a time to be transferred from disk to memory, and to be displayed and manipulated in various ways. Manually controlled cursors permit durational measurements to be carried out on the displayed speech, and can further be used to designate the position on which specific operations are to be carried out. The waveform manipulations which were carried out on the speech samples for these experiments involved deletion, reduplication, amplification and attentuation. The precise details regarding the stimuli are given in Chapter 5.

Stimuli prepared in the Experimental Psychology Department of Oxford University involved synthetic speech. The particular synthesis model used was the Klatt software synthesis, implemented on a PDP-11. This is described in detail in Klatt (1980), and featured additionally an executive system written by Diane Kewley-Port. Details regarding the actual stimuli prepared on this system are given in Chapter 5.

Stimuli for the perceptual experiments were presented to subjects in the following establishments:

The Phonetics Laboratory, University College London

The Phonetics Laboratory, University of Edinburgh, and

The Phonetics Laboratory, Oxford University.

As was the case in obtaining production data, the spread of establishments used was a reflection of the difficulty in finding subjects. The stimuli were presented to subjects using headphones (HD 414X). The tape recorder used in each establishment was a Revox (A 77).

In Experiments 1 and 3 of Chapter 5, it was thought that the level at which subjects heard the stimuli might affect their responses. For this reason, steps were taken to ensure that the tape was presented to subjects at the same level, and these are also described in Chapter 5. In Experiment 2, this factor was not taken account of, and subjects were instructed to set the volume at a level which they found comfortable.

All further details regarding the presentation of stimuli (e.g. numbers of stimuli, interstimulus intervals, etc.) are described in the relevant sections of Chapter 5.

1.3.2 SEGMENTATION

Figures 1.6, 1.7, and 1.8 are of typical recordings which include the traces for : oral airflow rate (Uo) filtered on channel 1 and unfiltered on channel 2, the photo-electric glottograph on channel 3 (Gx), and the audio microphone signal on channel 4. These recordings will serve to illustrate points concerning segmentation and show the three types of stops which can occur in medial intervocalic position in Icelandic.

Information on supraglottal articulation was ascertained from the oral airflow trace.[1] Stop closure is indicated by the sharp dip of oral airflow and would correspond for example to time points D in Figures 1.6, 1.7 and 1.8. The subsequent sudden rise again from zero marks the moment of oral release - time points E in these figures. The drop in oral airflow which marks oral closure is rather dramatic for the preaspirated stops. This is because airflow prior to closure is very high, due to the

------

1 Note that as the filtered channel lags between 5 and 10ms behind the unfiltered, the latter has been used for segmentation purposes.

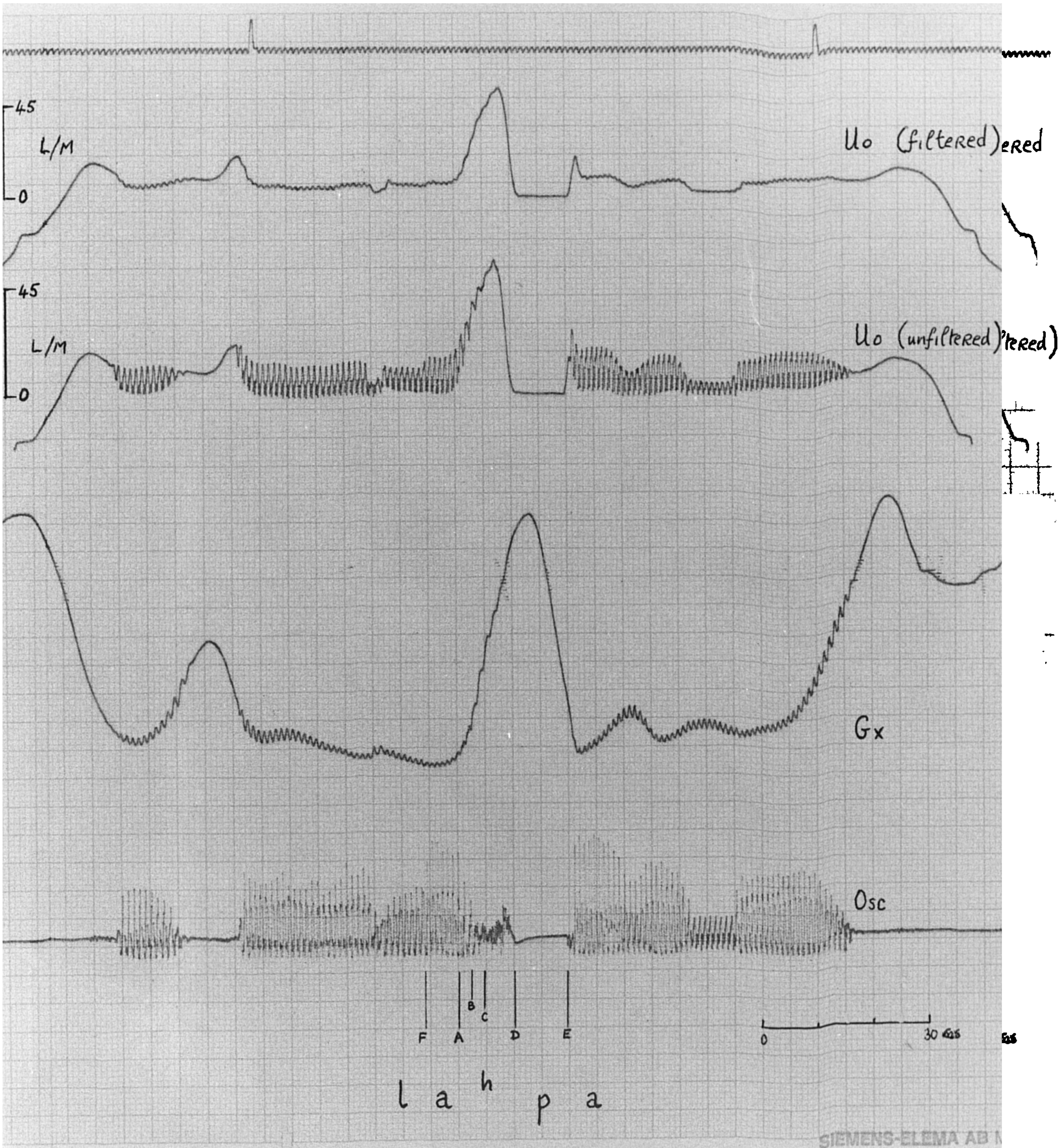


Figure 1.6

Mingogram of the Icelandic word [la^{h}pa] in the carrier frame: "Hann sagði -- wið mig." Time points A to F are explained in text.

Uo = oral airflow
Gx = photoelectric glottogram
Osc = audio oscillogram

ms = cs

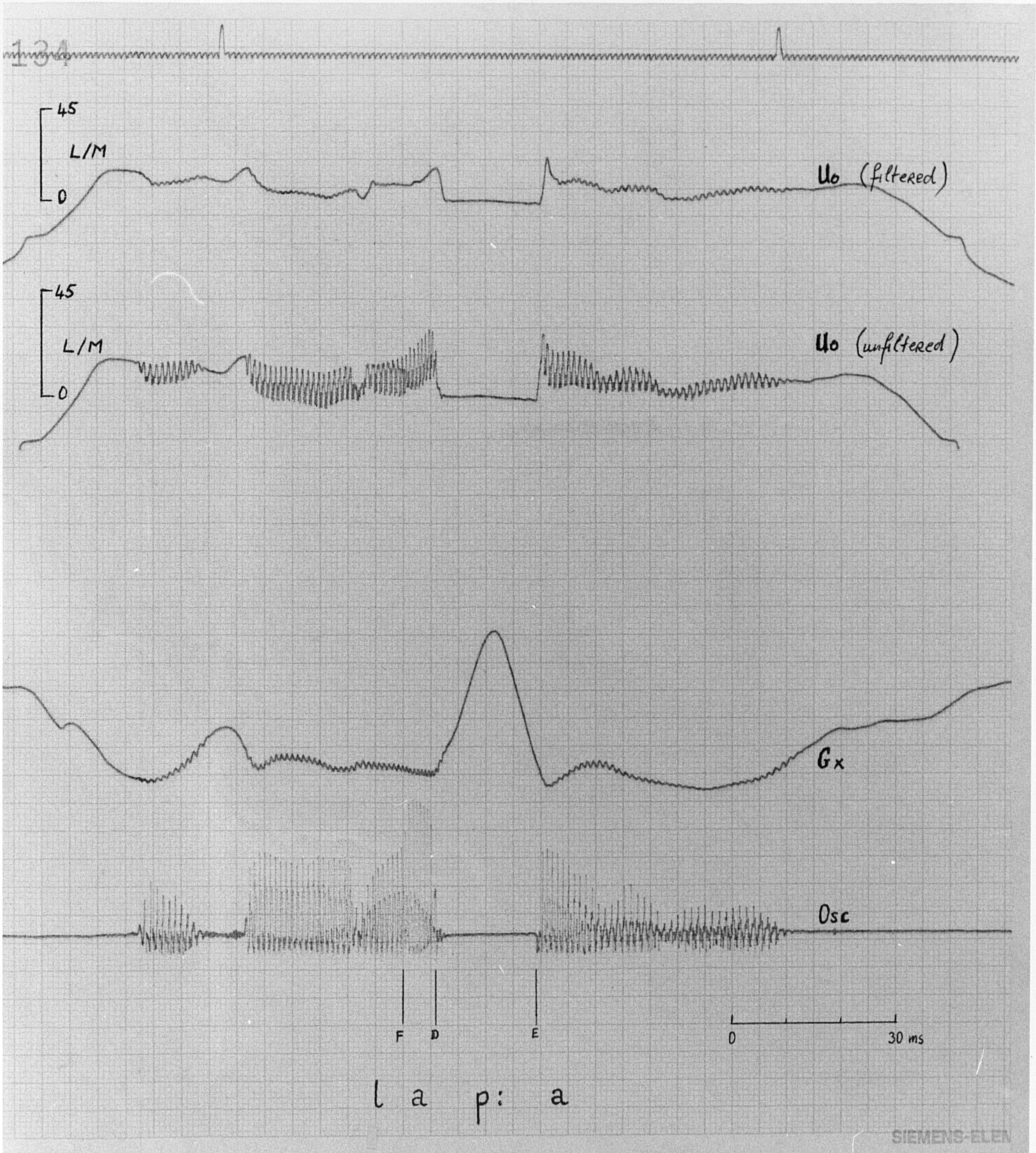


Figure 1.7

Mingogram of the Icelandic word [lap:a] in the carrier frame: "Hann sagði -- við mig." Time points D to F are explained in text.

Uo = oral airflow
Gx = photoelectric glottogram
Osc = audio oscillogram

ms = cs

Move D marker ½ mm to right

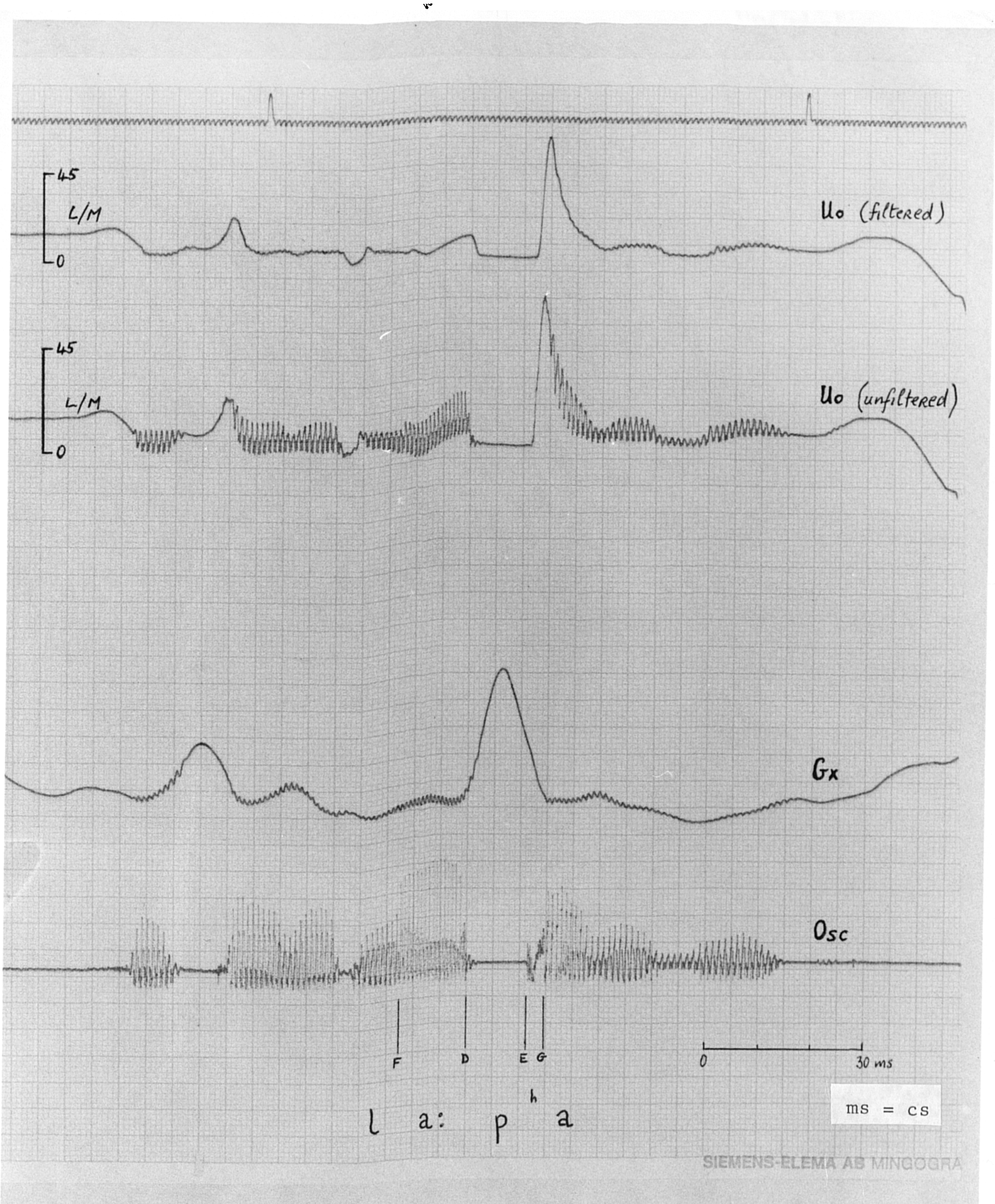


Figure 1.8

Mingogram of the Icelandic word [la:pa] in the carrier frame: "Hann sagði -- við mig." Time points F, D, E and G are explained in text.

Uo = oral airflow
Gx = photoelectric glottogram
Osc = audio oscillogram

abduction of the vocal folds. For stops which are not preaspirated the dip in oral airflow is less dramatic, but segmentation is aided here by the very sudden and severe damping of the "voicing" striations, which can be observed on the audio microphone signal and on the unfiltered oral airflow trace (time points D in Figures 1.7 and 1.8).

Time point F marks the beginning of the preceding vowel. It might be noted here that the principal measurements and the statistical results presented for vowel duration in Chapter 2 come from data set 3 (as described in Table 1.1 and section 1.3). In this data set the initial consonant did not vary and was in every case an unaspirated bilabial stop. This enabled easy segmentation; the vowel was measured as beginning with the onset of voicing after the stop.

Postaspiration, or Voice onset time was taken to be the interval from stop release, ascertainable from the oral airflow trace, and the beginning of the "voicing" striations on the audio microphone signal, (for example time point G in Figure 1.8).

The segmentation of preaspiration posed the greatest problem. The initial expectation had been that it could be measured in a way analogous to postaspiration and voice onset time, that is as the interval between voice offset (i.e. the end of the "voicing" striations on the microphone signal) and oral closure as determined from the oral airflow trace.

However, contrary to these expectations, preaspiration is not the mirror image of postaspiration in one important way which was crucial to our measurements. Preaspirated stops are characterised by a sudden sharp increase in oral airflow prior to stop closure, corresponding to timepoint A in Figure 1.6. This coincides with early glottal opening, as can be seen from the electro-glottographic trace. Vocal fold vibration continues, however, for quite some time after the oral airflow trace has indicated glottal opening, at a considerable amplitude for an interval, and then diminishing to a low residual ripple. It seems, therefore, that voice offset time (if strictly interpreted to mean the end of periodicity in the waveform) occurs quite some time after vocal fold abduction has commenced. What appears to be happening is that there is a slow transition from voice to voicelessness, yielding an interval when there is both voicing and aspiration present. This interval has also been remarked upon by Shuken (1980), who described it as breathy-voice, a label which seems appropriate and which will be adopted here, abbreviated to BV. From the audio oscillogram one can, within the BV interval, very often differentiate without too much difficulty between a portion for which vocal fold vibration is at a rather high level, not very different from that of the vowel (for which the mnemonic NV will be used) and a portion where the periodicity in the waveform is at a very low level (which will be termed LAV here). In Figure 1.6, NV corresponds to the interval A --> B and LAV to the interval B --> C.

The slow, sloppy transition from voice to voicelessness which characterises preaspiration is rather different from the onset of voice, where full glottal vibration is achieved very rapidly. These types of differences in voice onset and offset speeds can be observed in the cinefilm of the vocal folds, made by Elizabeth Uldall (1958). There, one can observe the opening vocal folds continuing to vibrate for rather a long period for the prepausal vowel; for the postpausal vowel, only a few glottal "ripples" precede full vocal vibration. This is further discussed in Chapter 2.2.5.

This asymmetry in voice offset and onset posed a few problems. The first was the question of segmentation. Should preaspiration be measured from the point where the vocal folds start abducting, as indicated by the rise in oral airflow? Or should one measure from the end of periodicity in the waveform? A third possibility might be to measure from the point where the amplitude of the audio waveform had reached a low level. This last would be difficult to ascertain consistently. Sometimes there was an identifiable sharp drop in the amplitude of the waveform, between those portions of the BV interval designated as NV and LAV. However, sometimes the waveform amplitude decayed more gradually, and so the cutoff point between these two was a matter of subjective judgment.

The segmentation decision made, was to measure preaspiration from the point where the vocal folds were thought to have begun abducting, on the basis of the sharp rise in oral airflow prior to stop closure. This means that the BV interval was included in the duration of preaspiration. As a matter of interest, the duration of the BV interval was also measured in many of the data sets presented in Chapters 2 and 3, and within BV, an attempt was made to tabulate the durations of the NV and LAV portions.

The inclusion of the BV interval in preaspiration duration, may mean that results here are not directly comparable with those of other authors who may have segmented preaspiration differently. Pétursson (1972), similarly working with recordings of airflow and audio microphone signals, specifies that preaspiration was segmented on the basis of the sudden rise in oral airflow (:63). He does not mention the BV interval ; inspection of the traces included in that paper suggest that in fact his segmentation is not precisely from the point where oral airflow rises but is rather later, and would seem to be a compromise between that point and the end of the BV interval. Pind (1982) made measurements of preaspiration from the audio waveform alone, and it is therefore not surprising that the question of the BV interval is not discussed, as a visual inspection of the acoustic waveform does not signal the point where the vocal folds start opening. Pind states that preaspiration is measured from the point where "the periodic waveform, which signifies the vowel, gives way to a non-periodic waveform, which is the preaspiration" (:77). However, judging by the figure which he includes to illustrate segmentation (:79), he would appear to be segmenting preaspiration from the end of what is here termed NV. Thus, the LAV portion of the BV interval (i.e. the portion where there is low amplitude vibration of the vocal-folds) seems to be included in his measures of preaspiration. These differences in segmentation practice must be borne in mind should one want to compare the results of this study to those presented elsewhere.

The segmentation criteria used here to measure preaspiration, differs from that normally used (and indeed used here) to measure postaspiration. Postaspiration is typically measured as the interval from stop release to onset of voicing (or periodicity in the waveform). This point correlates reasonably closely to the point where the glottis is vibrating with full adduction. An absolutely precise delimitation of postaspiration or of voice onset is not completely unproblematical either (see for example, Fischer-Jørgensen and Hutters, 1981). However, the correspondence between postaspiration and voice onset time is considerably greater than between preaspiration and voice offset time. The different criteria used is measuring pre- and postaspiration presents some difficulties when one wants to compare these two. This problem is further discussed in Chapter 2.4, where such a comparison is attempted.

The BV interval of preaspiration posed a few questions concerning its production and perception. The production data in Chapters 2 and 3 suggest that it is a non-avoidable production artefact, which results from the fact that there is high airflow through the opening and already vibrating glottis. As the vocal tract is open during preaspiration, there is no passive aid to devoicing through a build up in oral pressure with a consequent neutralisation of the transglottal pressure drop.

One must also question the perceptual status of the BV interval. Its inclusion in the preaspiration values presented in this study, may be thought to imply that it is perceived as part of the preaspiration. However, if the BV interval is a non-avoidable aspect of the transition from voice to voicelessness, it is conceivable that it is perceptually cancelled out, in much the same way as the aspiration present in the prepausal vowel is cancelled out. This question is dealt with in greater detail in Chapter 2.2.5, and one aspect of Experiment 1 in Chapter 5 specifically addresses the question of the perceptual relevance of the BV interval.

1.3.3 THE LINGUISTIC MATERIALS RECORDED

The linguistic materials recorded for all measurements involving speech production are tabulated in Table 1.1 A number of data sets were recorded, each for a specific purpose. These data sets are numbered in Table 1.1 to enable back-referencing for results presented in the subsequent chapters.

The main body of data, on which the core of the description of durational features in Chapter 2 is based, was contained in data sets 1, 2 and 3. The supplementary data sets 4 and 5 were recorded to futher elucidate specific areas of discussion in

DATA SET	WHERE PRESENTED	NATURE OF TOKENS: Genuine Words	NATURE OF TOKENS: Controlled Nonsense Paradigms	LANGUAGE/DIALECT	NUMBER OF ITEMS	ENVIRONMENTS: Position: #CV	Position: VCV	Position: VC#	Vowel: Long	Vowel: Short	Consonant: Place of Articulation
1	CHAPTER 2	✓		ICELANDIC (1)	130	✓	✓	✓	✓	✓	All
				SC. GAELIC							
				Skye	112	✓	✓	✓	✓	✓	All
				Lewis (1)	112	✓	✓	✓	✓	✓	All
				IRISH	144	✓	✓	✓	✓	✓	All
2	CHAPTER 2	✓		SC. GAELIC							
				Harris	80		✓	✓	✓	✓	All
				N. Uist	80		✓	✓	✓	✓	All
				Lewis (1)	80		✓	✓	✓	✓	All
3	CHAPTER 2		✓	SC. GAELIC							
				Harris	120		✓	✓	✓	✓	Dental
				Lewis (2)	120		✓	✓	✓	✓	Dental
				IRISH	120		✓	✓	✓	✓	Dental
4	CHAPTER 2		✓	SC. GAELIC							
				N. Uist	24	✓			✓	✓	Bilabial and Dental
				Lewis (2)	32	✓			✓	✓	Bilabial and Dental
5	CHAPTER 2		✓	SC. GAELIC							
				Harris	20		✓		✓		All
				Lewis (2)	20		✓		✓		All
				IRISH	20		✓		✓		All
6	CHAPTER 2		✓	SC. GAELIC Harris	50		✓			✓	Dental
7	CHAPTER 3		✓	SC. GAELIC							
				Harris	88			✓	✓	✓	Dental
				Lewis (2)	88			✓	✓	✓	Dental
				IRISH	80			✓	✓	✓	Dental
8	CHAPTER 3	✓		ICELANDIC (2)	66		✓		✓	✓	Bilabial
9 (a)	CHAPTER 3	✓		IRISH	(a) 40		✓			✓	Dental
(b)					(b) 48		✓			✓	Dental
(b)					(c) 24	✓			✓		Dental
10	CHAPTER 3	✓		ICELANDIC (2)	40		✓			✓	Dental
11	CHAPTER 3	✓		IRISH	81		✓			✓	Dental
12	CHAPTER 5	✓		ICELANDIC (2)	20		✓			✓	Bilabial
13	CHAPTER 5	✓		FRENCH	120	✓	✓	✓		✓	Bilabial and Dental

TABLE 1.1 A summary of the data from which production measurements are presented. Where, for a particular language/dialect, more than one informant was used, they are differentiated by means of the numbers in brackets (e.g. Lewis (2) = the second Lewis informant).

The word lists on which data sets 1, 2 and 13 are based are given in Appendix 5 p.466. The items contained in the other data sets are given in the relevant sections of this study.

Chapter 2. The motivation for these and for the other data sets listed will be discussed below. The data for Harris and North Uist from data set 2 was originally collected by Dr C. Ó Dochartaigh, then of Kings College, Aberdeen University, and permission to use these is gratefuly acknowledged. For the Lewis data of this set the same word list was used. The items on this word list were uttered as citation forms. The items in data set 1 were inserted into the following carrier frames:

Initial postpausal prevocalic

Icelandic	- sagði hann.	" - he said."
Scottish Gaelic	- a th'ann.	"It is -."
Irish	- a dúirt sé.	"He said -."

Medial intervocalic

Icelandic	Hann sagði - við mig.	"He said - to me."
Scottish Gaelic	Thùirt e - rium.	"He said - to me."
Irish	Dúirt sé - liom.	"He said - to me.

Final postvocalic prepausal

Icelandic	Hann sagði -.	"He said -. "
Scottish Gaelic	Thùirt e -.	"He said -. "
Irish	Dúirt sé -.	"He said -. "

The main purpose of the frame is to minimise the likelihood of tempo and pitch changes during the recording. However, one would also expect items in a carrier phrase to be uttered slightly faster than the single citation forms, especially perhaps in medial position. To enable comparison, two sets of data were collected for a Lewis informant, with and without the carrier frame. This informant is labelled Lewis (1) on Table 1.1 to differentiate between her and another informant, Lewis (2), used in subsequent recordings. As expected, results for these did show a small, but consistant shortening in the "framed" items. For that reason, the data for the two recording situations are presented separately in Chapter 2.

The convention of recording items inserted into carrier frames was adopted throughout, with the further exception of data set 6. Where, for a particular purpose, the frames used differed from those given above, this is described fully in the relevant section of the thesis.

Monosyllabic words were used for stops in initial and final positions; for intervocalic stops the words used were disyllabic. In these languages stress falls normally on the first syllable of a disyllabic word. The words used in data sets 1 and 2 contained examples for each place of articulation relevant in a particular language or dialect. In postvocalic environments the vowel length specified is that of the preceding vowel. Insofar as was possible, the quality of this vowel was controlled in the Icelandic and Irish data; with few exceptions for either language, the vowels were the long and short phonemes /a:/ and /a/.In Scottish Gaelic the quality of the vowel was not controlled.

Data set 3 consisted of a paradigm of nonsense words, rather than real words as in data sets 1 and 2. It contained stops in medial and final position after long and short vowels, and both consonantal place of articulation and vowel quality were kept constant. There are two ways in which this data set supplements data sets 1 and 2.

First of all, this set should permit a more accurate characterisastion of temporal features 5 and 6 (i.e. the differences in consonant and in preceding vowel durations which may correlate with the phonological opposition of stop cognates: see sections 1.1.5 and 1.1.6). It was felt that the potentially fine-grained differences might be obscured by data sets 1 and 2, and would be best revealed when vowel quality and consonantal place of articulation were kept constant. Vowel durations are known to vary with vowel quality (Lehiste, 1970:18) and consonantal place of articulation seems to affect consonant closure duration (Lehiste, 1970:27-28).

Furthermore, with fewer variables and consequently a greater number of repetitions of each item, data set 3 was intended to permit statistical testing (and further verification) of the findings of sets 1 and 2 regarding the conditioning effects of positional variation and phonological vowel length on preaspiration duration. Therefore, the statistical details included in Chapter 2 are based on this data set.

Two small further sets of data were recorded to illuminate points in Chapter 2. Data set 4 was a supplementary check on the effects of the length of a following vowel on postaspiration in #CV. Data set 5 was recorded as a check on the effect of place of articulation on preaspiration, where the variable of differing preceding vowel quality was eliminated.

Chapter 3 deals with the effects of stress variation on preaspiration and voicing. All the durational measurements, presented in Chapter 3.1 are based on data set 7.

Sets 6, 8 and 9 included photoelectric glottographic tracings and yield some insight on glottal activity in the production of the stop contrasts of Scottish Gaelic, Icelandic, and Irish respectively. Futhermore, the data recorded in sets 8 and 9 contained stops uttered at differing stress levels. These, it was hoped, would further illuminate the effects of stress level on preaspiration and yield some insight on the glottal control of voiceless consonants in general. They are discussed in Chapter 3.2. For details on what is meant by "differing stress levels", see Chapter 3. For an explanation of the further subdivisions a), b), and c) of data set 9, the reader is also referred to the text of Chapter 3.2.

Data sets 10, 11 and 9(a), included a subglottal pressure signal as a means of checking on some of the aerodynamic consequences of the stress variation discussed in Chapter 3.

Sets 12 and 13 were required in Chapter 5. Set 12 was recorded to obtain particular durational measurements (using the same criteria as in the earlier chapters) on repetitions of the same token as that used for the preparation of the perceptual stimuli of Experiments 1 and 3 of Chapter 5. Set 13 contained some French data and was recorded to illustrate a particular discussion in Chapter 5.

Informants

Production measurements are based on recordings made by the following informants:

Icelandic

S. M., Female, Reykjavík.

P. H., Male, Reykjavík.

These two spoke the linmaeli dialect of Icelandic (see section 1.2.1).

Scottish Gaelic

Harris	M. Mac L., Female, Harris.
North Uist	D. A. Mac D., Male.
Skye	J. Mac I., Male.
Lewis (1)	C. S., Female, Stornaway, Lewis.
Lewis (2)	J. Mac K., Female, The Point Peninsula, Lewis.

These Scottish Gaelic speakers represent two of the dialect areas described by Borgstrøm (see section 1.2.2.3). The first three represent dialect area C1; the two from Lewis represent dialect area B.

The Skye informant grew up on that island but was in fact born in Lewis. He describes himself as having essentially the Skye dialect, but having some North Uist influences. The data will be referred to as Skye data. It is clear from Chapter 2 that this speaker patterns with dialect C1 and is rather different from the Lewis speaker.

Irish

The author was used for recordings of Irish, necessitated by the impossibility of finding other native speakers in the vicinity of phonetics laboratories at the time when this research was being carried out. The recent establishment of a phonetics laboratory at Trinity College, Dublin should allow in the near future a more wide ranging account of voicing and (pre)aspiration for Irish dialects. At present, the author would simply like to note informally that an inspection of a small amount of data obtained from a speaker of a West Kerry dialect (in the South-West of Ireland) would seem to indicate very similar results.

Informant Ages

The difficulty of finding informants for the three languages studied has been noted. Given the lack of choice, it was not possible to select informants with well matched ages. At the time when these recordings were made, the Icelandic, Irish and Lewis Gaelic speakers were in their twenties, while the Skye, Harris and North Uist informants were in the 40-55 age bracket.

CHAPTER 2

TEMPORAL ASPECTS OF OPPOSITIONS INVOLVING PREASPIRATION

2.0. Introduction

2.1. Postaspiration

2.2. Preaspiration

2.3. Voicing: the lenis (unpreaspirating) series

2.4. A comparison of pre- and postaspirating oppositions

2.5. Consonant closure durations

2.6. Vowel durations

2.7. A summary of conclusions

2.0 INTRODUCTION

This chapter looks at the durational aspects of the oppositions involving stop cognates in Icelandic, some Scottish Gaelic dialects and Irish. Each of the features 1 to 6 described in Chapter 1.1, which can be regarded as essentially temporal adjustments, and which have been described as potential production or perception correlates in voicing oppositions in other languages, are examined here to see whether and to what extent they also characterise oppositions involving preaspiration. Discussion of feature 3, VOT and of VOFFT (voice onset and offset time) comes in the sections dealing with post- and preaspiration respectively.

Although these possible temporal features are dealt with seriatim in this chapter, dealing with each feature individually is a matter of organisational necessity and does not betoken a viewpoint (not uncommon in the literature) that these features function as discrete separate cues. In chapter 5.2, a hypothesis will be discussed as to how the various features here (which in themselves might only be used to a small extent) may feed into a cumulative binary decision on the opposition, based on the syllable.

Up to this point the oppositions in question have been referred to as "phonological voicing oppositions" whether or not they involve vocal fold vibration during stop closure. In the following description the series of stops which in these languages exhibit preaspiration (and postaspiration in initial position) will be referred to as the fortis series; the unpreaspirated series will be called lenis. These terms are used simply as convenient phonological terms to avoid the potentially confusing situation where one speaks of voiceless voiced stops, i.e. phonologically voiced stops with no phonetic voicing. The fortis/lenis labels are in no way intended to imply that either stop series is characterised by tense or lax qualities.

The production data presented in this chapter were recorded in Phonetic Laboratories of the Universities of Edinburgh, Oxford, and of University College North Wales, Bangor, as well as in the Royal Hospital for Sick Children, Edinburgh. The experimental configuration is described in Chapter 1.3.

2.1 POSTASPIRATION

2.1.0 Introduction

In initial position, the opposition of stop cognates in Icelandic and Scottish Gaelic has been described as one involving the presence or absence of postaspiration. Thus, as regards this position at any rate, these languages would exemplify "Group 2" of the language types studied by Lisker and Abramson (1964), and described in Chapter 1.1.3, i.e. a contrast of voiceless unaspirated and voiceless aspirated stops. Accordingly, one should expect to find that postaspiration values would fall into the +60ms to +100ms range described as typical by the authors. For the lenis series, VOT values should range from 0ms to +25 ms. Past descriptions of Donegal Irish have described a fully voiced and a postaspirated series (see Chapter 1.2.3.2). However on the basis of the cross-language data presented by Lisker and Abramson (1964), one could reasonably expect that the opposition in #CV might involve <u>either</u> aspiration (as for "Group 2" type languages) <u>or</u> voicing (as in "Group 1" type languages) but not both (see Chapter 1.1.3).

In medial position, given that the medial fortis stops exhibit preaspiration, one should perhaps expect not to find postaspiration. There could be two reasons for such an expectation. Firstly, if there is preaspiration, the linguistic opposition may be sufficiently perceptually cued, thus rendering postaspiration functionally redundant. A different, production based rationale underlies the claim by Löfqvist (1980) that preaspiration will not co-occur with postaspiration. The rationale underlying this claim would seem to be that the glottal opening/closing cycle is a single ballistic gesture which takes a roughly constant amount of time. If a stop is to be preaspirated, peak glottal opening will occur early during stop closure. The vocal folds will then immediately commence adduction. By the time the stop is released, the vocal folds should be more or less in the configuration for voicing.

2.1.1 Initial Postpausal Position

Figure 2.1 gives average aspiration durations (or average positive VOT values) for initial fortis stops in both short (SV) and long vowel (LV) environments for Icelandic, Scottish Gaelic (the Skye and Lewis dialects) and Irish. These are the data from set 1 in Table 1.1, and average VOT values for the lenis series are also shown. In order to facilitate comparison, the lenis values have been superimposed on the fortis values and are represented by the shorter shaded portion within each bar. This means that the main unshaded portion of the bar represents the difference in duration between the fortis and lenis averages. Standard deviation values are also shown as the lines that cut through the average values, with each line being two standard deviations long.

The data here conform reasonably well to the ranges predicted in the study by Lisker and Abramson (1964). Values for the fortis series do generally fall into the +60ms to +100 ms range; only in

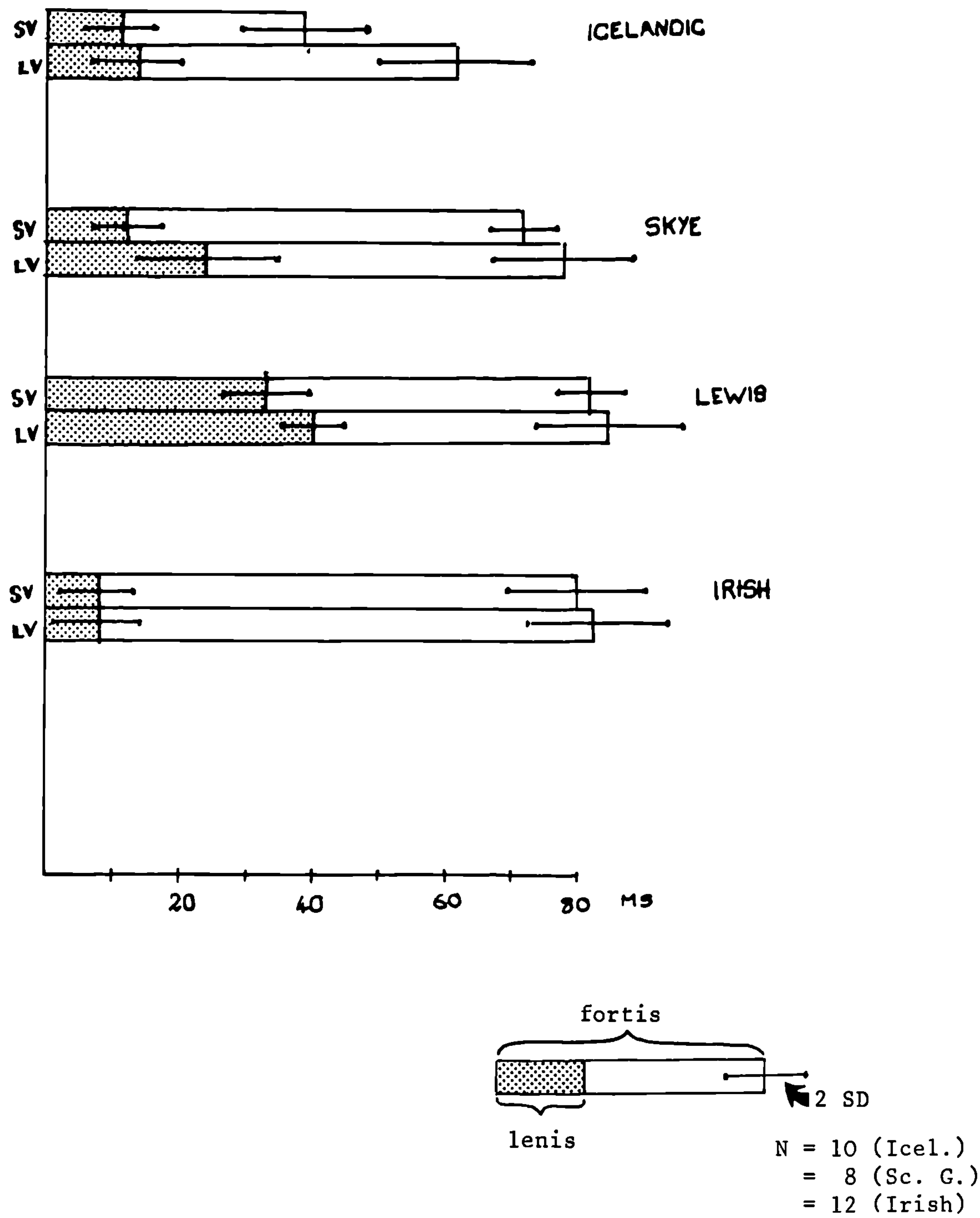


Figure 2.1 Postaspiration values for stops in #CV. Lenis values are superimposed on fortis as shown

the Icelandic data in the short vowel environment do values lie outside of this range and seem strikingly short. Values for the lenis series generally fall within the Oms to +25 ms range; the exception here is in Lewis Gaelic where the VOT values are somewhat higher. Icelandic and Lewis Gaelic thus offer the least good separation of fortis and lenis categories. However, even in Icelandic, in the short vowel environment which has the least separation, the two series do remain distinct in VOT terms.

As expected, the opposition for Irish in this position does not involve both voicing and postaspiration, but rather the latter. Indeed, Irish probably best exemplifies the Lisker and Abramson VOT ranges for "Group 2" type languages, and of the languages looked at, has the clearest separation of fortis and lenis categories.

Figure 2.1 would seem to indicate a tendency for slightly longer postaspiration in all these languages when a long vowel follows. In the Icelandic data the differences in fact are very striking. The finding of longer postaspiration with long vowels has also been reported by Johnson and Nolan (1981) for German, and by Weismer (1979) for American English. The values in Figure 2.1 consisted of averages across the range of consonants in each language. Furthermore, the vowel qualities varied. Both the place of articulation of the consonant and the quality of a following vowel have been shown to cause differences in aspiration durations, albeit only slight ones (see Lehiste, 1970:22). In order to check further the effect that vowel

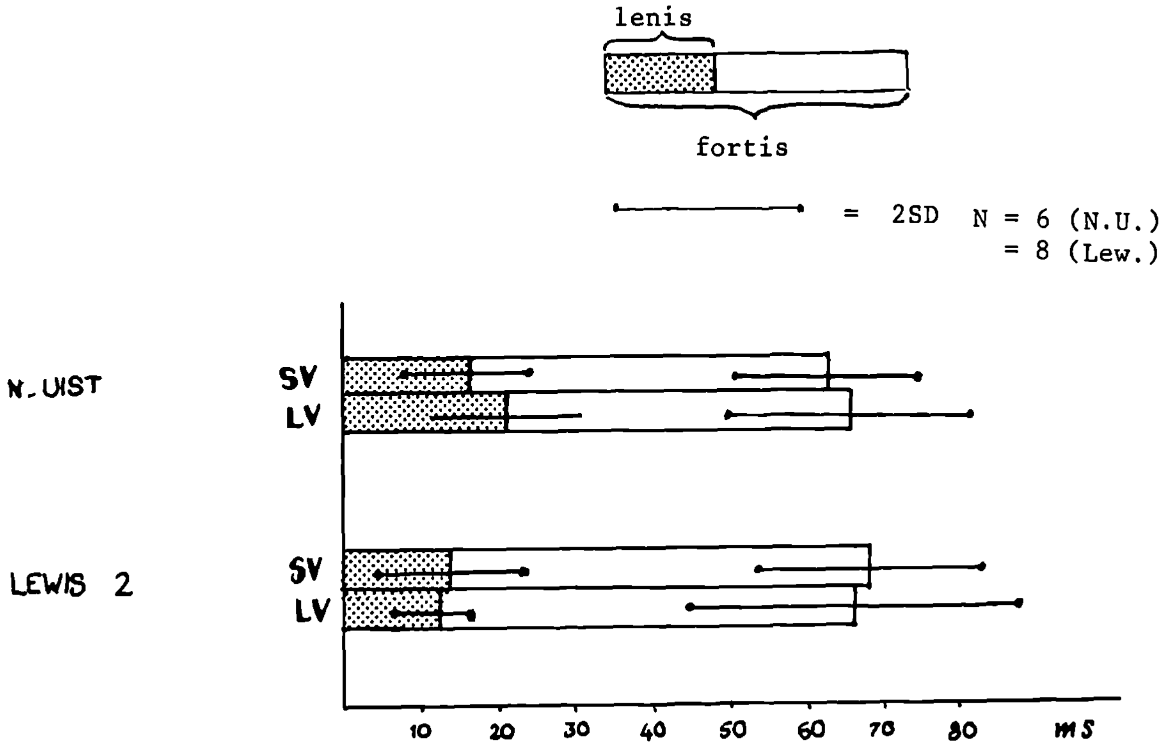


Figure 2.2 Postaspiration durations with long and short vowels for the additional data set 4. Lenis values have been superimposed on the fortis

length has on aspiration duration, an additional data set was recorded for two Scottish Gaelic informants, from Lewis and North Uist. This was data set 4 in Table 1.1 and it consisted of a paradigm of nonsense words where only the long and short /a/ phonemes were used, preceded by bilabial or dental stops.[1] The results, presented in Figure 2.2 in the same way as for Figure 2.1, are inconclusive. The tendency for longer vowels to be associated with a slight increase in VOT average is still there for the North Uist speaker, but the Lewis speaker shows the reverse tendency. One must therefore conclude, that although such an effect may well manifest itself, it need not always be present.

Average aspiration values are shorter overall in Figure 2.2 than in Figure 2.1. This may be due to two factors. It is possible that speakers used a quicker rate of speech in these recordings. Furthermore, one should expect shorter VOT averages given the fact that data set 4 was limited to labials and dentals. VOT values are known to be generally greater as the place of articulation shifts back in the mouth (see Lehiste, 1970:22), and the absence of palatal and velar segments would lessen the overall average in data set 3 as compared to the earlier data set.

------

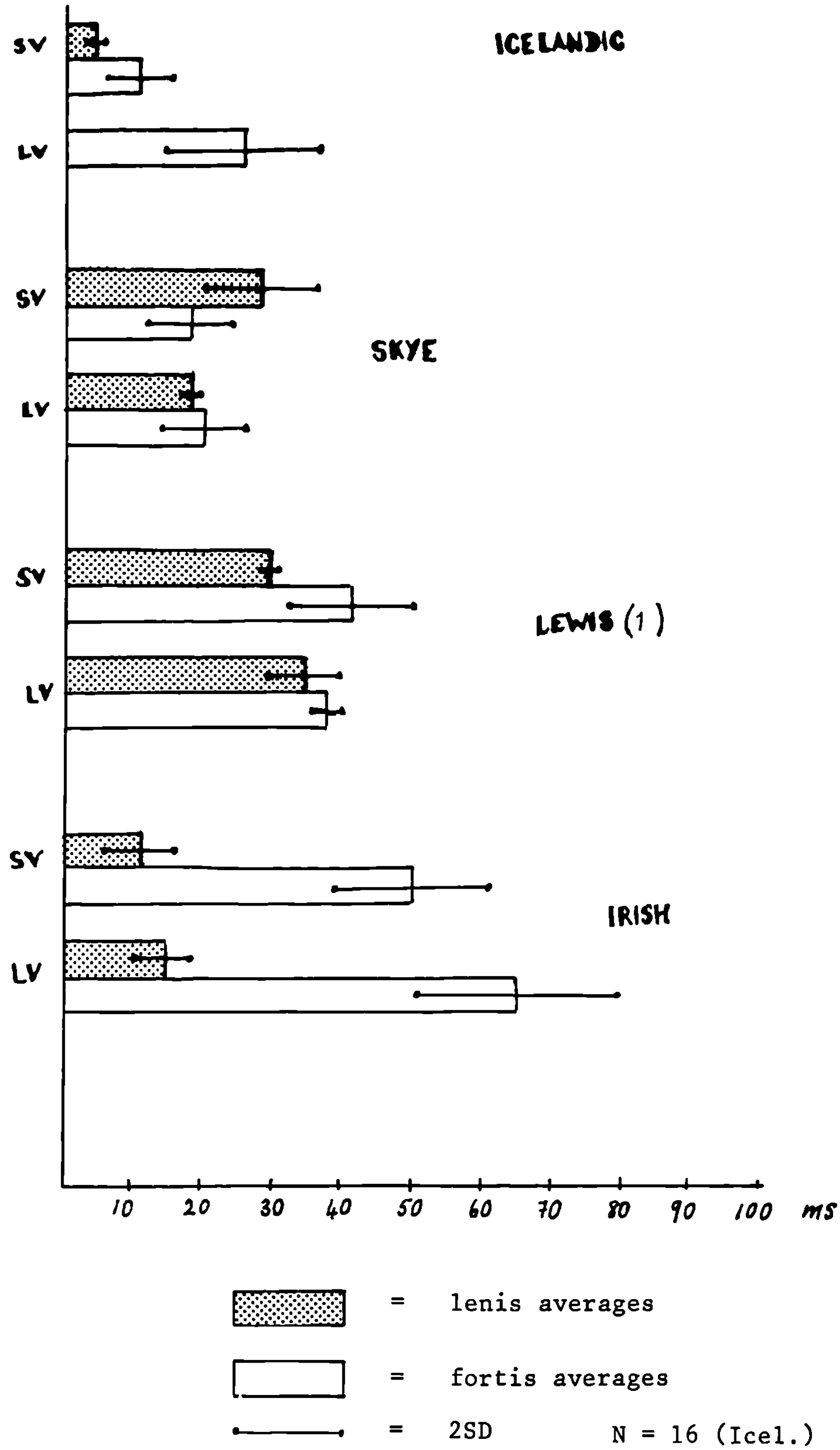
[1] These nonsense words were of the form /Ca(:)n/, where C stands for bilabial and dental fortis and lenis stops.

2.1.2 Medial intervocalic position

Figure 2.3 presents the values for medial position (for data set 1 of Table 1.1. The format is similar to that of Figure 2.1, except that here lenis values are not shown superimposed on the fortis, due to the fact that they are not necessarily shorter. Aspiration is generally much shorter in this environment, which is not very surprising, as VOT is known to be considerably shorter and less useful in differentiating stop categories in medial than in initial position (see Chapter 1.1.3). The actual values of postaspiration in Irish and Lewis Gaelic are roughly typical of the range shown by the "Group 2" type language in Lisker and Abramson's (1964) study.

As can be observed from the average values and standard deviations in Figure 2.3 Irish is the only language where there is a separation of the stop categories on the basis of postaspiration in VCV. This may correlate with the very good fortis/lenis separation observed for initial position.

For the other languages, the lack of a clear fortis/lenis separation must mean that postaspiration is contributing minimally or not at all to the linguistic opposition, even in the Lewis dialect. In Icelandic, after long vowels, there is no contrast of stops. After short vowels, the contrast involves not only preaspiration, but also gemination of the non preaspirated stops.



N = 16 (Icel.)
= 10 (Sc. G.)
= 12 (Irish)

Figure 2.3 Postaspiration values for stops in VCV

In the introduction to this section, two possible reasons were suggested as to why contrasts involving preaspiration might not exhibit postaspiration. The first was one of perceptual redundancy: conceivably the contrast would simply not require the additional cueing feature of postaspiration, when preaspiration is present. The second referred to a claim by Löfqvist (1980), suggesting that pre- and postaspiration could not co-occur for production reasons.

The first line of reasoning would gain some support from the data. As will be seen in the next section, Irish exhibits the least preaspiration. It is therefore the language where a postaspiration difference would appear to be least perceptually redundant, and this could be one type of possible explanation of the fact that it is the only one of these languages where postaspiration is contributing to the linguistic opposition.

Löfqvist's hypothesis is not supported by the data here. It is obviously not impossible for a stop to have both pre- and postaspiration; this is evidenced by the Lewis Gaelic and Irish data.

One could however suggest a weaker, and perhaps less interesting, version of Löfqvist's hypothesis. Anticipating again the results of the next section, Lewis Gaelic and Irish, which exhibit the shortest preaspiration, also show the longest postaspiration. Icelandic and Skye Gaelic have long preaspiration and very little postaspiration. This may indeed reflect a tendency for the glottal opening/closing cycle to take a roughly constant amount of time. A weak version of the hypothesis might suggest that the duration of postaspiration (for a preaspirated stop) will be approximately inversely correlated with the duration of the preaspiration.

To sum up, postaspiration does differentiate between the stop categories in these languages in #CV. In VCV, where the stops have preaspiration (see next section) it is possible to find both pre- and postaspiration co-occurring. However it would appear to contribute to the linguistic opposition only in the case of Irish which has the shortest preaspiration durations.

2.2 PREASPIRATION

2.2.0 Introduction

In this section the durational characteristics of preaspiration are described. Taking the broader perspective first of all, the cross language data are looked at in section 2.2.1, based on data set 1. The descriptive base is then broadened, in section 2.2.2, with the additional data from set 2 on the Scottish Gaelic dialects from areas C1 and B (see Chapter 1.2.2.3). The interest is not only on the grosser differences/similarities between the different languages and dialects, but also within languages, or some of the finer-grained conditioning effects from positional variation, preceding vowel length and consonantal place of articulation (sections 2.2.4 and 2.2.3).

As regards the effect of vowel length, it has been suggested by Pind (1982), in a study of Icelandic, that preaspiration duration should correlate positively with that of the vowel. Preaspiration does not occur with phonologically long vowels in Icelandic; Pind's observation is based on the fact that in Icelandic, when speaking rate or the number of syllables in the word are varied, there is a reasonably close correlation between the duration of preaspiration and that of the vowel. In a language such as Scottish Gaelic, where preaspiration occurs in both long and short vowel environments, it is of interest to establish whether such a positive correlation is to be found when speaking rate and phonetic environment are otherwise kept constant. One would not necessarily expect this to be the case: Borgstrøm (1940 and 1941) mentions that preaspiration can sometimes be longer and more distinct with short vowels.

Preaspiration has traditionally been regarded as the mirror image of postaspiration. However, as was pointed out in Chapter 1.3.2 in the discussion on segmentation, preaspiration differs from postaspiration in having a slow transition from voice to voicelessness, and this was termed the breathy voiced transition. What appears to be happening is that the vocal folds continue vibrating for some time after they have begun to separate (see Figure 1.6). Voicing continues, initially at a relatively high amplitude, and then at a very low amplitude. In the discussion below, the following mnemonics will be used to refer to the various component parts of preaspiration, illustrated in Figure 1.6: BV for the breathy voiced transition itself; within the breathy voiced transition, NV for the part which has relatively high amplitude voicing, and LAV for the part with low amplitude voicing; H stands for the truly voiceless aspiration.

The initial decision regarding the measurement of preaspiration was to measure from the point where the oral airflow trace rose sharply, indicating, it would appear, the beginning of vocal fold abduction. The breathy voiced transition was thus included. A subsequent experiment reported in Chapter 5.1 appears to add perceptual weight to this initial decision and seems to indicate that the breathy voiced transition is perceived as preaspiration. For interest's sake, in Figures 2.4 and 2.5, which present the durational data on preaspiration, the duration of BV (and of its component parts NV and LAV) is indicated.

2.2.1 Preaspiration across languages

In Figure 2.4, the durations of preaspiration are presented for the cross-language data, of set 1 in Table 1.1. These are the data elicited in sentence frames for Icelandic, Skye (area C1) and Lewis Gaelic (dialect areas C1 and B respectively), and for Irish. The vertical line marks oral closure and is given the time value zero.

Final prepausal position

Final prepausal position seems to be the environment where the longest preaspiration values are found. The longest preaspiration of all occurs in Icelandic but values in Skye are also very long. The standard deviation is 30ms and 26ms for these respectively. Therefore the difference in averages is probably not very important as there is considerable overlap of values. Lewis preaspiration is much shorter than that in Skye. In fact, it seems closer to the Irish values; the standard deviation of 25ms for the Lewis average, and of 14ms for the Irish, means that values overlap also here.

Medial intervocalic position

Durations are generally much shorter here than in VC#. This difference is most noticeable in Icelandic. Irish values are not

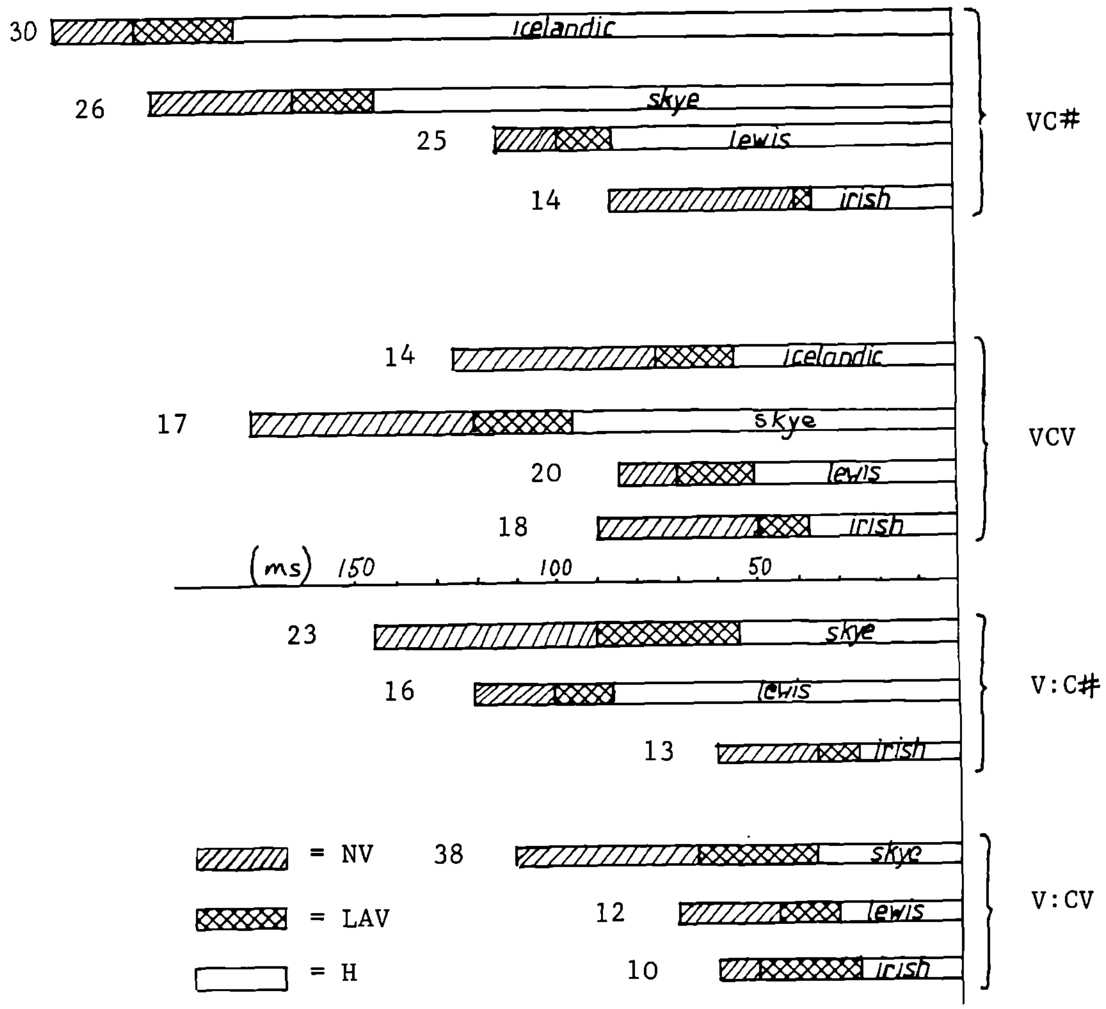


Figure 2.4 Preaspiration durations for Icelandic, Skye and Lewis, Gaelic and Irish

SD is shown to the left of each bar

N = 14 (Icel.VC#)
= 16 (Icel.VCV)
= 10 (Sc. G.)
= 12 (Irish)

in fact lower here, and the similarity between these and the Lewis values is even more striking.

Vowel length conditioning

Preaspiration does not occur with long vowels in Icelandic. Comparing VCV with V:CV in Scottish Gaelic and Irish, preaspiration durations are clearly shorter following the long vowels. In final position this observation still holds for Irish and Skye Gaelic, but not for Lewis (but see next subsection).

2.2.2 Preaspiration in the Scottish Gaelic dialects: some additional data

To broaden the descriptive base somewhat, Figure 2.5 presents more data on the Scottish Gaelic dialects, this time comparing Harris, North Uist (which like Skye belong to area C 1) and Lewis (area B). It will be recalled that this set of data, numbered 2 in Table 1.1 was elicited in citation form, and is therefore presented separately from the data described in the preceding subsection, elicited in sentence frames.

Average durations of Lewis preaspiration are generally shorter than in the other dialects. However, as can be seen from the standard deviations, only in VCV is there no overlap of values.

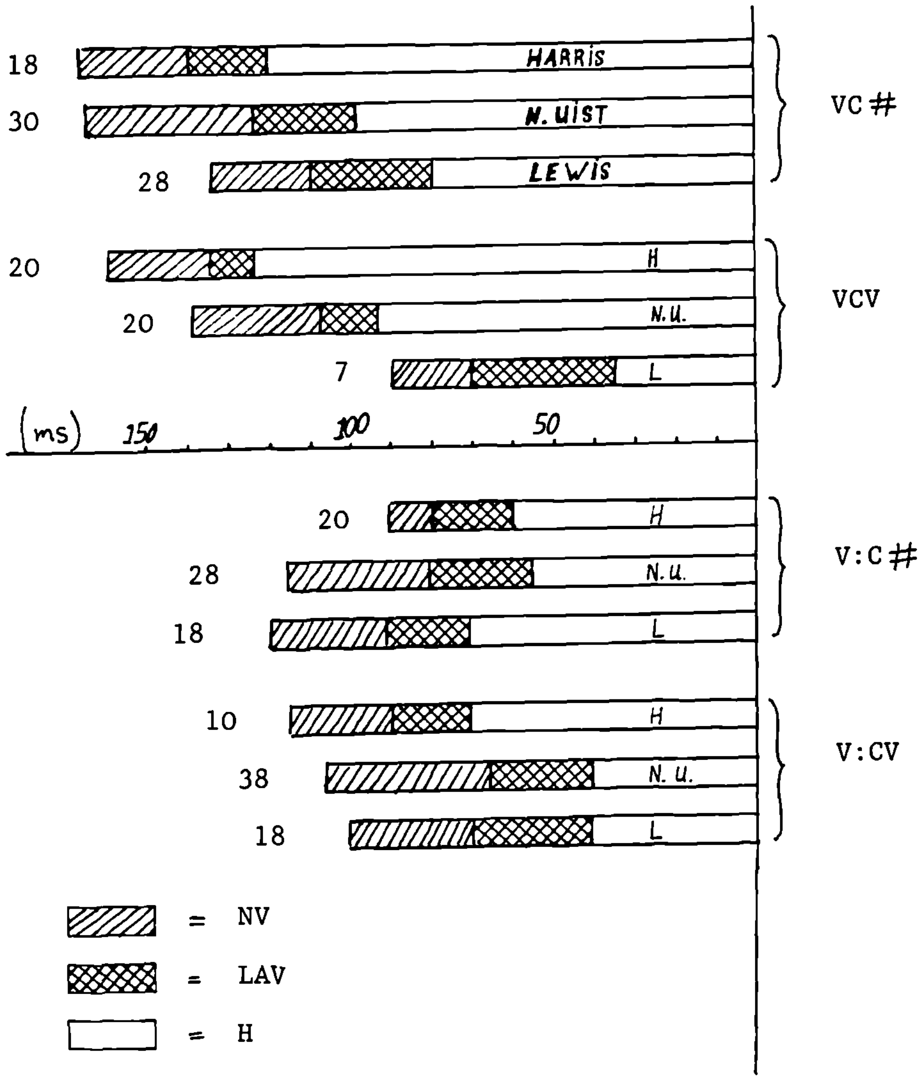


Figure 2.5 Preaspiration durations in the Scottish Gaelic Dialects
SD is shown to the left of each bar
N = 10

These data also exhibit the same type of positional variation as was observed in Figure 2.4, i.e., a tendency towards shorter preaspiration medially than finally. Looking at all the data in Figures 2.4 and 2.5, this tendency is exhibited by all but the Harris and Irish results.

Vowel length conditioning of preaspiration duration is also clear from Figure 2.5. Again, the Lewis data fails to conform consistently to this trend. It was mentioned in Chapter 1.3, that this particular Lewis informant did not maintain a consistent durational difference between her long and short vowels; her "long" vowels were considerably shorter than for the other Scottish Gaelic speakers, or indeed for the second Lewis informant used. The lack of a consistent length distinction between the vowels for this informant may explain why these data do not exhibit, consistently, the vowel length conditioning of perspiration observed for all the other Scottish Gaelic speakers and for the Irish informant.

To sum up on preaspiration in the Scottish Gaelic dialects, it would seem generally true that it is of lesser duration in comparable environments for the Lewis dialect than for either of the other three dialects. Although the difference between the Lewis values and those of Skye were indeed very striking, the difference between Lewis and the other speakers from the Cl dialect area was less so.

Looking across languages, it is interesting to remember that although, for example, Skye, Lewis and Irish exhibit at the phonetic/physical level differing degrees (or durations) of preaspiration, past descriptions of these dialects would have led one to expect them to be rather more different (see Chapter 1.2). For example, the opposition of the Gaelic and Icelandic stops have been described in terms of preaspiration: in Donegal Irish it has been described as involving voicing and postaspiration. Yet the voice offset pattern in Irish fortis stops is often not very different from that of Lewis Gaelic. It is therefore quite possible that other languages hitherto described simply as having a contrast of voiced versus voiceless (and possibly postaspirated) stops, may in fact have similar amounts of preaspiration.

This gives rise to an interesting perceptual question: how long does preaspiration have to be in order to be perceptible as such? This point will alluded to again in Chapter 4 dealing with the origins of preaspiration, and in Chapter 5 which explicitly addresses the question of preaspiration perception.

2.2.3 Place of articulation effects on preaspiration duration

Consonantal place of articulation is known to affect postaspiration duration. Longer duration of VOT for velars than for labials or alveolars was pointed out by Lisker and Abramson (1964). Peterson and Lehiste (1960) cited in Lehiste (1970:22) give the average values of 58ms, 69ms, 78ms and 72ms for bilabial, alveolar, palatal and velar stops respectively. These differences can possibly be explained in terms of articulator mobility and its consequences for the aerodynamic conditions which affect voice onset. With slow articulators, as movement away from the oral stricture is more gradual, it takes longer for oral pressure to fall. In other words, it takes longer for the transglottal pressure drop to reach a point where voicing can begin.

In preaspirated stops, the aerodynamic factor is not relevant. However, one might reasonably assume preaspiration duration to be affected by stop place of articulation. Vowel durations have been shown to be affected by the place of articulation of a following consonant (see Lehiste, 1970:20). It would seem that the variation in vowel duration can be attributed to the mobility of the active articulator involved in the consonantal gesture and to the distance it has to travel from vowel to consonantal target. For the preaspirated stops, if one assumes that the command for oral closure is given at a fairly constant time after preaspiration onset, one could hypothesize that this could lead to inequalities in preaspiration duration. And if this were the case, one should expect slightly longer preaspiration durations with stops for which the tongue body (back or front) is the active articulator than for stops articulated with the comparatively more mobile lips or tongue tip. Roach (1978) has reported slower oral closing times for velar than for alveolar or dental stops.

Data set 5 was recorded for the Harris, Lewis (2) and the Irish informants to see whether a tendency towards longer preaspiration is in fact found with tongue body articulations. Scottish Gaelic and Irish are particularly useful languages for this purpose, as they have phonological oppositions between five distinct places of articulation. In this data set a paradigm of nonsense words was used, where each place of articulation occurred after the long /a:/ vowel.[1] (In data sets 1 and 2, the lack of control on the quality of the preceding vowel, particularly in Scottish Gaelic, makes it impossible to deduce place of articulation effects with any reliability.)

In addition to measuring the duration of preaspiration in these data, a further measure was made which should correlate with the speed of oral closure for the different articulators. As suggested by Roach (1978), the time interval from the point (prior to oral closure) where oral airflow starts to drop to the moment where oral airflow can be considered to have ceased (oral closure) should give some indication of articulatory closing speeds. In preaspirated stops, oral airflow prior to stop closure is very high, and therefore the interval mentioned is particularly easy to ascertain.

Although for convenience the measured interval will be here referred to as the articulator "closing time", it need not, and in fact probably does not, correspond to the full oral closing time. Presumably airflow will only begin to drop when oral

---

[1] These nonsense words were of the form /pa(:)Cə/. C represents bilabial, dental, palato-alveolar, palatal and velar fortis stops.

closure has proceeded to a point where oral stricture exceeds glottal stricture. Nevertheless, the measured time interval should give some indication of articulatory closing times.

An estimate of articulator closing times is of interest for two related reasons. The first is to see whether differences in preaspiration durations match differences in oral closing speeds, and might thereby be accounted for. The second reason has already been alluded to in Chapter 1.2.4, where it was suggested that a tendency towards preaffrication would be more likely to develop in those preaspirated stops whose active articulators are sluggish, i.e. velars, palatals and possibly palato-alveolars.

Figure 2.6 shows preaspiration durations and articulator closing times for the three speakers as a function of place of articulation. These results are generally consistent with expectations. Looking first of all at preaspiration durations, velars and palatals do seem to have higher values than labials and dentals. The palato-alveolar stop is generally closer to labial and dental values than to velar and palatal values.

Looking now at the match between preaspiration durations and articulator closing times, there does seem to be a fairly good correspondence in the Harris and Irish data. The least good correspondence is found for the Lewis speaker, especially where the closing times for the palato-alveolar and velar stops are not reflected in the comparative durations of preaspiration.

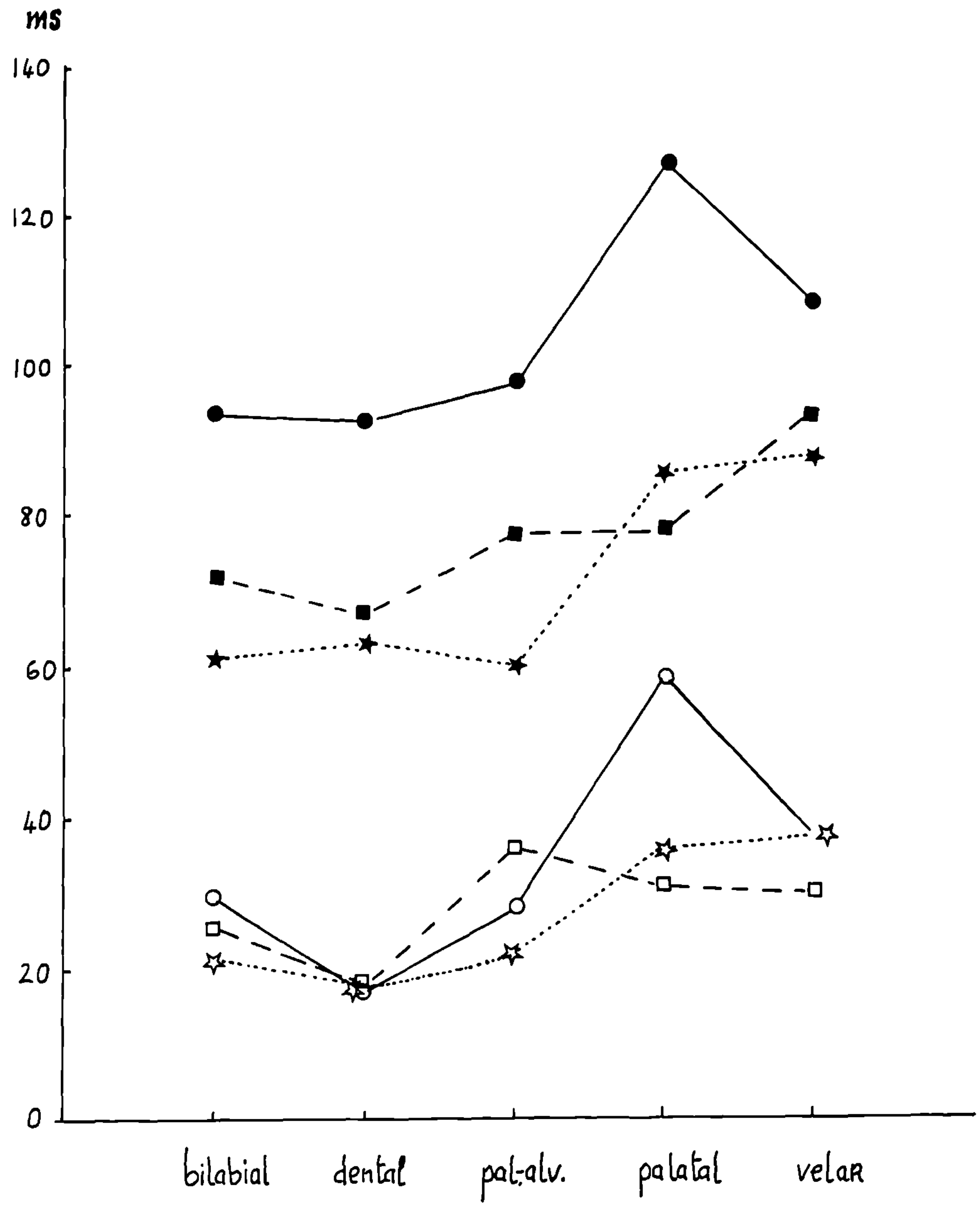


Figure 2.6 Preaspiration durations and articulator closing times as a function of stop place of articulation N = 5

Preasp. dur.		Artic. clos. times
●———●	Harris	○———○
■– – – –■	Lewis	□– – – –□
★·········★	Irish	☆·········☆

Excepting the closing times for the palato-alveolar stop of Lewis, velar and palatal stops do have the slowest closing times and longest preaspiration durations. Comparing these two however, there is no one pattern. Velars have slightly longer durations for the Irish and Lewis speakers; for the Harris speaker, the palatals are considerably longer than the velars. For every speaker, the dentals had the shortest closing times of all; in fact, values for the three speakers are almost identical.

To sum up, therefore, these data do offer some support for the suggestion that the longest preaspiration durations and slowest oral closing times would be found with the velar and palatal places of an articulation. The preaspiration duration differences do generally seem to reflect differences in oral closing times. And the fact that velars and palatals tend to have the slowest oral closing times may go some distance towards explaining the fact that preaffrication has developed with these places of articulation in most Scottish Gaelic dialects.

2.2.4. Positional variation and vowel length conditioning of preaspiration duration

In sections 2.2.1, and 2.2.2, it was generally noted that the duration of preaspiration was conditioned by both the position (VC# versus VCV) and the preceding vowel length. Data set 3 of Table 1.1, recorded for the same Irish and Harris informants and for a different Lewis informant, permitted a further check on positional and vowel length conditioning effects on preaspiration, in a paradigm where all the variables of differing vowel qualities and consonantal places of articulation were eliminated. Figure 2.7 presents the average values of preaspiration durations for each environment. The data in this figure are grouped according to language to facilitate observations regarding positional and vowel length conditioning for each speaker.

Positional variation

In Figure 2.7, the general trend of positional variation noted earlier was found to be consistently present for each speaker. Preaspiration duration was shorter in every case for medial intervocalic than for final stops.

This effect of positional variation on preaspiration duration was tested using the ANOVA t-test,[1] and the t-statistics obtained from these tests are contained in Table 2.1. (For construction and exposition of the t-test, see Snedecor and Cochran 1971:93.) The significance of the differences between preaspiration values in final and medial positions, was tested separately for the short and the long vowels in each of the three languages.

------

[1] The analysis-of-variance tests used throughout this study are the classical statistical tests for repeated unbiased events.

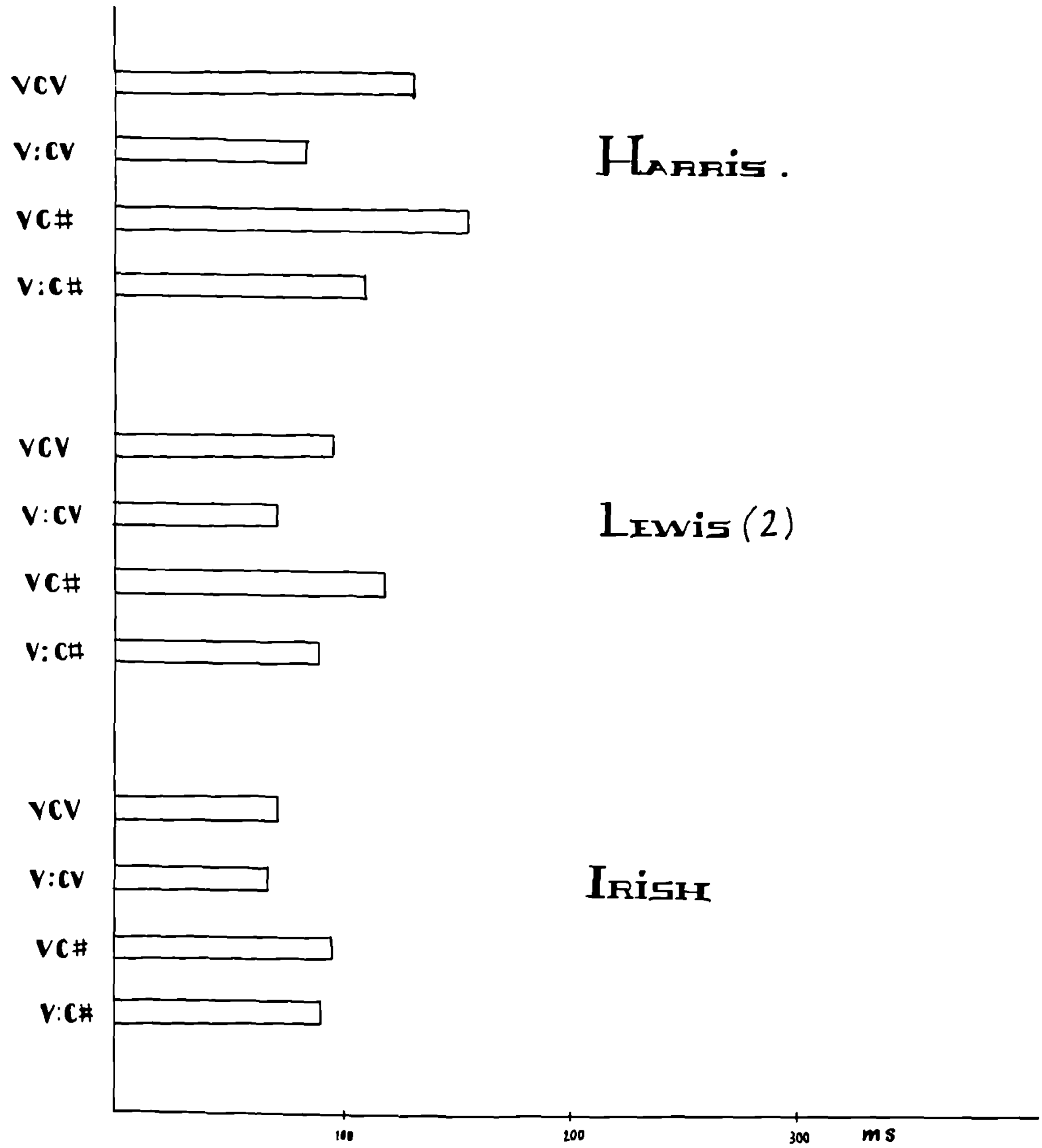


Figure 2.7 Average values of preaspiration durations in data set 3 N = 15

Table 2.1 The effect of positional variation on preaspiration duration: t-statistics

	Harris	Lewis	Irish
Final versus Medial			
Short Vowels	11.63	1.97	5.54
Long Vowels	4.33	4 18	3.83

Critical values for the t-test with 14 degrees of freedom are, approximately, 1.345 (.10 level), 1.761 (.05 level), 2.145 (.025 level), 2.624 (.01 level) and 2.977 (.005 level).

As can be seen from the table, with the exception of the Lewis short-vowel environment, all the differences are statistically significant at all conventional levels of significance. For the Lewis short vowel environment the difference is significant at the .05 level but not at higher levels.

Vowel length conditioning

It is also clear from Figure 2.7 that the effects of vowel length conditioning, generally noted in the preceding sections, hold also for these data. The extent of the difference is particularly striking for the Harris speaker, whose preaspiration values are the longest in any case. The effect is also to be observed for the Lewis speaker. As this second Lewis informant did have a clearcut long/short vowel distinction, this finding supports the suggestion made earlier, that the lack of consistent vowel length conditioning for the first informant, is probably a reflection of the inconsistent long/short vowel distinction.

Irish shows only a very slight effect of vowel length conditioning.

The significance of the effect of phonological vowel length on the duration of preaspiration in Harris, Lewis and Irish was tested, for medial and final position separately, using the ANOVA t-test. The t-statistics obtained are summarised in Table 2.2.

Table 2.2. The effect of phonological vowel length on preaspiration duration: t-statistics

Short versus long Vowel	Harris	Lewis	Irish
Medial	14.48	8.73	1.43
Final	16.36	4.64	0.82

The critical values for t-statistics with significance levels in parenthesis, are 1.345 (.10), 1.761 (.05), 2.145 (.025), 2.624 (.01) and 2.977 (.005).

Both t-statistics, for medial and final position, are highly significant for Harris. In the case of Lewis, vowel length conditioning of preaspirated stops is highly significant also. The statistical significance of the vowel length effect is weakest for Irish. It is only significant at the .10 level in medial position, but is not statistically significant at any acceptable level in final position.

This conforms with the general observations on the data presented in the preceding sections. A strong vowel conditioning effect was observed for the languages/dialects with longest preaspiration. Indeed, the difference in the long/short vowel environments is very pronounced in these cases. In languages/dialects where preaspiration is shorter in any case, the effect of phonological vowel length is less noticeable. Effectively, what this amounts to is that there seems to be a constraint against long preaspiration with long vowels.

These results run counter to the proposal mentioned earlier by Pind (1982) that preaspiration duration would correlate positively with vowel duration. The correlation observed by Pind (for Icelandic, where preaspiration is found only after short vowels) was across shortening/lengthening environments, i.e. for words with different numbers of syllables and uttered at different speaking rates. It appears to be the case that in shortening environments, the degree of reduction in preaspiration duration is rather similar to that found in the vowel. Similar findings to Pind's are also reported for Scottish Gaelic and Irish in Chapter 3.1 below, where the consequences of stress variation are looked at. However, it is clear from the data presented above that preaspiration duration need not be a fixed ratio across different vowel lengths.

2.2.5 The breathy voiced transition

Looking at the data presented in Figures 2.5 and 2.6, it is clear that the breathy voiced (BV) period of preaspiration does not vary greatly and that most of the variation in the total preaspiration duration is attributable to differences in the truly voiceless (H) portion. Unlike H, the BV portion does not differ greatly across language, or as a function of position or vowel length environment. Average BV durations for any speaker or environment in data sets 1 and 2 range from 30ms to 90ms. In contrast, average durations of H range from 26ms to 176ms. The Skye speaker has slightly longer BV than the others generally exhibit. This correlates with a tendency for this speaker to have what appears from the microphone signal to be a breathy voiced onset also, though of considerably shorter duration than the breathy voiced offset. This may indicate a tendency towards a more breathy voiced quality and a slacker vocal fold setting for this speaker.

Taking a broader perspective on the question of voicelessness production, one might take the view that there are basically two ways of achieving voicelessness. The first is by an opening, slackening gesture of the vocal folds. The other de-voicing mechanism is a tensing and closing gesture of the vocal folds, i.e. glottalisation (and obviously available only to stops). Voiceless stops in languages are of one or other kind, and it may be that tendencies towards the use of one or other strategy may correlate with other features of voice quality in a given language or dialect and may reflect different articulatory settings of the vocal folds. For example, languages which use glottalisation as a means of achieving stop voicelessness may be more prone to a creaky voice quality and may have an overall more tense vocal fold setting. This could be true of many dialects of English, which have glottalised stops. On the other hand, languages which favour the slackening/opening gesture, may tend towards a breathier voice-quality and may have an overall more lax setting of the vocal folds. (Some phoneticians have made informal observations that Hiberno-English does sound breathier than many dialects of British English. Such observations are highly speculative and could bear further investigation. This topic, however, lies beyond the scope of the present study.)

Returning to the differences in the transition between voice onset and offset in the data here, one might suggest that these are production artefacts and not under voluntary control. In the cine film of the vocal folds made by Elizabeth Uldall (1958) one can observe these types of differences in voice onset and offset of the post- and prepausal vowel respectively. At voice onset full glottal vibration is achieved very rapidly. One or two vibrations of the vocal folds can be observed before full vocal fold adduction: the process is no doubt rapidly achieved due to the Bernouilli effect. At voice offset the process is much more gradual, and the vibrations of the vocal folds continue for quite some time.

The difference between voice onset and offset, one would therefore conclude, results from mechanical/aerodynamic factors and is non-avoidable. It is also one of degree: voice onset is

1 One might further mention here two possible explanations of the <u>nolla-hallon</u> effect which are discussed by Lindblom (1980). The first is that the perceived asymmetry results from the listener's knowledge of the structure of his language. Thus for the Swedish listener, the absence of word-final or syllable-final /h/, and furthermore, the absence of a word *allon in the lexicon give rise to the perceived initial glottal fricative of <u>nolla</u> played backwards.

As Lindblom points out, this explanation loses some of its force when one considers that the name <u>Anna</u> played backwards is perceived as <u>Hanna</u> and not <u>Anna</u>. This is in spite of the fact that both are names which should be in the listener's lexicon.

The other possible explanation suggested by Lindblom for the <u>nolla-hallon</u> effect is that there may be asymmetries of temporal masking due to the universal properties of the human speech perception mechanism. The perceptibility of glottal friction in initial as opposed to final position might be construed as evidence to suggest that forward masking is more pronounced than backward masking.

A perceptual experiment by Holmberg and Gibson (1979) aimed at testing the second type of explanation, failed however to demonstrate a significant difference in forward and backward masking thresholds.

only relatively instantaneous. As demonstrated by Fischer-Jørgensen and Hutters (1981) and as is also clear from Elizabeth Uldall's (1958) cine film, an absolute and precise characterization of the moment of voice onset time can also be problematical. (On this topic, see Darwin & Pearson, 1982.)

If, as suggested, the BV portion of preaspiration is a production artefact, this may have implications for perception. Roger Lass has suggested (personal communication) that this transition may be entirely cancelled out by our perception. This could be true of all transitions from voiced to voiceless segments, or of transitions from voice segment to silence as in V#. Such a suggestion would gain support from a psychoacoustic experiment reported by Lindblom (1978). In this experiment it was found that when the Swedish word nolla "zero" was played backwards, listeners perceived hallon "raspberry". One interpretation of this finding would be that the postvocalic [h] at the end of nolla, which we can assume moves through breathy-voice to voicelessness, is perceptually cancelled out when it occurs in postvocalic prepausal position. This could be because in this position it would be non-avoidable. In initial prevocalic postpausal position it is avoidable and usually contrasted with a form which does not contain it, and will therefore not be perceptually cancelled out.[1] It would not be surprising to find that the breathy voiced portion of preaspiration is similarly cancelled out and therefore irrelevant to our perception of the preaspirated stop. An attempt to establish the perceptual relevance to preaspiration of the breathy voiced interval forms the basis of one aspect of the first perception experiment in Chapter 5.

The perceptual status of BV may be crucial to the perception of preaspiration for another reason. It has been mentioned that although BV durations do not vary greatly, the durations of H are sometimes very short indeed and vary as a function of the particular language, dialect, or phonetic environment. Chapter 3 will indicate further environments which have very short H durations. This raises the question of the perceptibility of preaspiration in such cases, especially if the breathy-voiced interval is perceptually irrelevant.

One final point might be made here regarding the BV interval of preaspiration. It has been mentioned above that the stop contrast in Irish has been previously described as one of voicing/postaspiration, and that a degree of preaspiration similar to that found in Irish may also characterise other languages hitherto described as having a voicing/postaspiration contrast. A small amount of preaspiration may not be as rare as is commonly thought to be the case, and although not identified as such could be important in cueing the contrast. At the very least, one could expect a breathy voiced transition to a following consonant not to be too unusual.

If one may at this point anticipate the results of the perception experiments of Chapter 5, it appears that a very short duration of preaspiration, and indeed even the breathy voiced transition alone, may be perceptually very important. Therefore, it may well be that the voice offset patterns in other languages might prove a fruitful area for further investigation. Other pointers in this direction come from an experiment reported by O' Kane (1978) which suggests that the offset of the vowel before voiceless stops may be perceptually very important. In his experiment, the perception of CV syllables was investigated, where the vowel was cut back from its offset in 20ms steps. The stimuli were constructed from /kɔp/ and /kɔb/ type utterances, and compared the perception of the "original" CV sections, with "hybrid" ones where the vowel of /kɔp/ was replaced by that of /kɔb/ and vice versa.

Although in fact O' Kane argues that <u>overall</u> the perception of the hybrid series is not significantly different from the "original" ones of similar duration, it is quite clear from his figures and tables that the last 20ms of the vowel offset matters greatly to the perception of a following voiceless consonant. For stimuli of the same duration, the last portion of the vowel offset seems to be responsible for an average difference of 32% in listeners' responses. In five out of the six series of stimuli used, it determines whether voiced or voiceless judgements predominate; these observations have been deduced from Tables 1 and 2, in O' Kane (1978:314).

Although from O'Kane's study one can not say what it is about the vowel offset which effects the shift in listeners' responses, one possibility must be that the vowel offset is in fact a breathy voiced transition such as is described here.

2.2.6 Some conclusions on preaspiration

To summarise the results on preaspiration, one of the most striking characteristics of preaspiration would seem to be the breathy-voiced transition. It is, insofar as one can deduce, a non-avoidable mechanical/aerodynamic consequence of high airflow through the vibrating and elastic vocal folds.

Preaspiration duration exhibits positional variation; durations for final prepausal position are nearly always longer than in medial intervocalic position.

Phonological vowel length also conditions preaspiration, i.e. duration is shorter following long vowels. The difference between preaspiration durations in long and short vowel environments is most pronounced in those dialects which have long preaspiration in any case, such as Harris Gaelic. In Irish, where preaspiration durations are very short, vowel length conditioning is small. It appears as though there may be some constraint on long preaspiration with long vowels.

Consonantal place of articulation also affects preaspiration duration. It is longest with velars and palatals. The differences observed for consonantal place of articulation would seem to reflect the mobility and closing times of the individual articulators. It is also suggested that the more sluggish articulators will be the most likely to give rise to preaffrication tendencies.

2.3 VOICING :THE LENIS (UNPREASPIRATING) SERIES

2.3.0 Introduction

Descriptions of the lenis (or unpreaspirated) members of the oppositions in these languages/dialects would lead one to expect varying durations of voicing in the consonants. To recapitulate briefly on past phonetic descriptions: Icelandic, and the Scottish Gaelic dialects other than Lewis have been described as having voiceless lenis stops; Lewis Gaelic has been described as having an opposition involving frequent partial voicing of the lenis, as well as weak preaspiration of the fortis series. Irish lenis stops have been described as fully voiced.

In a discussion of Icelandic, Thráinsson (1978) predicted that preaspiration will only be found in languages which have no clear voice/voiceless distinction. If one can interpret this prediction as meaning that languages will not have both preaspiration and voicing proper, then it appears that the prediction may have been made from a too narrow linguistic viewpoint, as past descriptions alone would lead us to expect Lewis Gaelic at least to exhibit both phonetic features.

Historically, the lenis stops in each of the languages derive from what would appear to have been voiced geminates. Some of the constraints on stop voicing which may in time lead to devoicing have been briefly touched upon in Chapter 1.1.1. This topic will be discussed in greater detail in Chapter 4.2, and in Chapter 4.1 an account is proposed for the process of change which led to the modern reflexes of the historical oppositions in these languages.

2.3.1 Voicing across languages

It was thought useful to facilitate immediate comparison of the voicing in lenis stops with the preaspiration of the fortis cognates. Therefore, in Figure 2.8, based on data set 1, information on the voicing of lenis stops is presented alongside average durations of preaspiration in the fortis stops in the same environments. In this figure average durations for the lenis stops are indicated to the right of the vertical line zero; black corrugations show the period for which voicing extends into the stop. To the left of the vertical line zero are presented the average preaspiration values already shown in Figure 2.4. Across languages, a solid line joins the points where voicing ends in the lenis stops, and another joins the beginning of preaspiration in the fortis stops, to draw attention to possible correlations between these two. In a similar fashion, a dotted line joins the points across languages where the BV interval of preaspiration comes to an end. This is done in order to facilitate comparison of voice offset times (or the end of periodicity) in the waveform of both stop series.

The most striking thing perhaps in Figure 2.8, is how little voicing there is of the lenis stops in any of these languages. This is surprising only for Irish where past descriptions might have led us to expect fully voiced lenis stops.

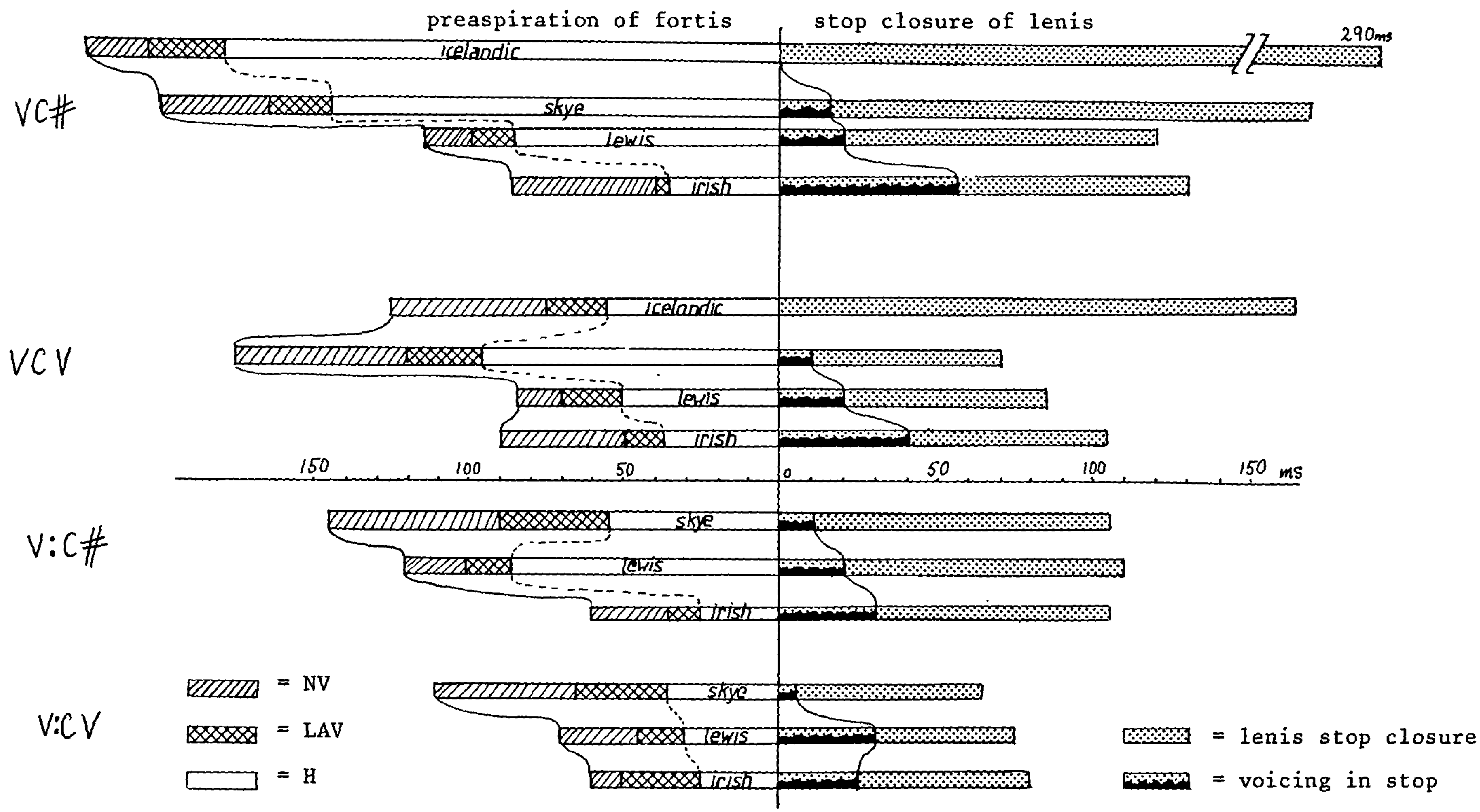


Figure 2.8 Voicing of lenis stops, shown in conjunction with preaspiration of the fortis N = 16(Icel.VC); 14 (Icel.VCV); 10(Sc.G.); 12(Irish)

Looking at the solid lines to the left and right of the diagram, which join across languages the points where preaspiration begins in the fortis series or voicing ends in the lenis, there is clearly a strong negative correlation between preaspiration durations in one stop series and the voicing durations of the other. Thus, the order of magnitude of voicing (Irish > Lewis > Skye > Icelandic) generally correlates inversely with the order of preaspiration durations.

Therefore, with the exception of Icelandic where there is no voicing of the lenis, both voicing proper and preaspiration could seem to play some role in oppositions typically described as plus or minus preaspiration. And, of course, the converse is true, as in Irish, where preaspiration appears to play a role in an opposition typically described as plus or minus voicing.

In Figure 2.8, the lines joining the VOFFT points (or the end of periodicity) for both stop series are reasonably parallel. This means that there is good separation of fortis/lenis categories along the VOFFT axis, regardless of the actual duration of preaspiration. In each language, the stop oppositions in medial and final positions are well characterised in terms of a VOFFT contrast. This observation holds equally for the additional data on Scottish Gaelic, presented in the next subsection (Figure 2.9). The problem of whether the perceptual correlate of VOFFT in the fortis stops might be the end of periodicity (dotted line) or the beginning of preaspiration (solid line on the left) is a rather separate issue, which does not alter the fact that the preaspirating opposition seems to function just like a voicing opposition.

2.3.2 Additional data on voicing in the Scottish Gaelic dialects

Figure 2.9 shows the additional data on Scottish Gaelic (data set 2 in Table 1.1) in a fashion similar to Figure 2.8.

The overall inverse correlation found across languages, of preaspiration duration in the fortis stop with voicing in the lenis, is generally borne out in these additional Scottish Gaelic data.

Lewis has more voicing than either Harris or North Uist; the difference is not as great as between the Lewis and Skye dialects, as, of all four, Skye exhibited least voicing. The greater presence of voicing in the Lewis stops is, of course, not at all surprising in view of, say, Borgstrøm's descriptions of these dialects (1940 and 1941). The only stops for which Borgstrøm speaks of voicing at all are in fact the lenis stops of Lewis. Viewed another way, it is perhaps more surprising that, although the Lewis speaker exhibits only slightly more voicing than, say, the North Uist speaker, yet in the other Outer Hebridean dialects, there has been no mention of stop voicing. The data here could prompt the type of perceptual question already asked concerning preaspiration. As values for the different dialects/languages appear to be distributed along a

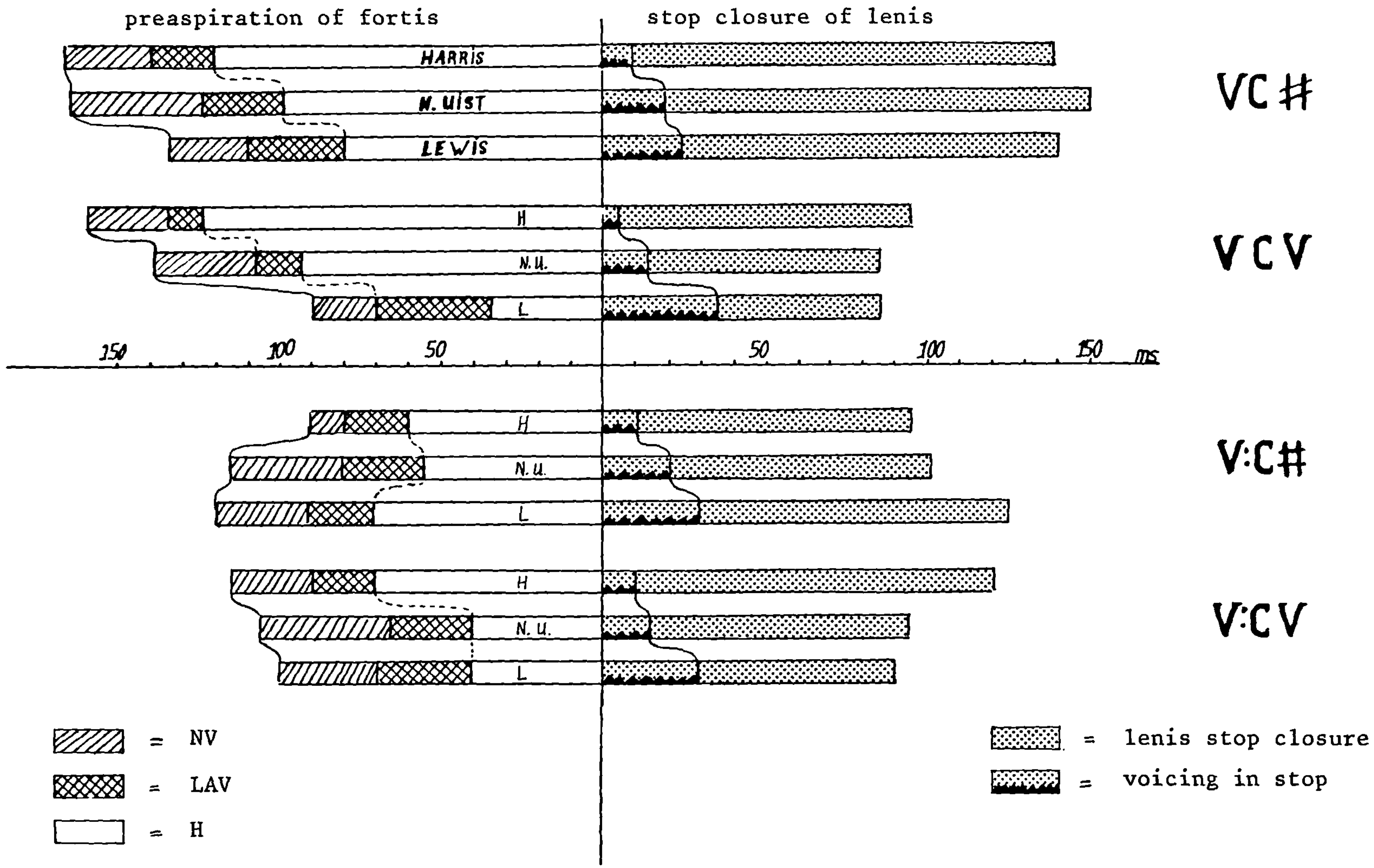


Figure 2.9 Voicing of lenis stops in the Scottish Gaelic dialects, shown in conjunction with preaspiration of the fortis N = 10

continuum, one might ask, at what point along such a continuum does a stop get perceived as voiced. However, as will be clear from some glottographic recordings discussed below in section 2.3.4, there are some fundamental differences between the voicing present in, say, Irish and Harris Gaelic. These differences may go some way towards explaining the differences in past descriptions of the lenis stops in dialects such as Harris and Lewis.

2.3.3 <u>Possible conditioning factors in voicing duration</u>

Positional variation: final versus medial

As has been briefly mentioned in Chapter 1 and will again be discussed in more detail in Chapter 4, not all word positions favour voicing equally. In the literature on voicing oppositions, medial position seems to be an optimal environment for voicing to occur, whereas the final prepausal position is the opposite. This is evidenced by the fact that voicing lenition (a change from voiceless to voiced) is most likely to occur in VCV, whereas in VC#, devoicing is the more likely development. Furthermore, in some languages (like Korean and German) stops are not voiced at all in VC# (or in #CV) but are in VCV.

It is surprising, therefore, that expectations for longer voicing in medial stops are not borne out in the data. An inspection of Figures 2.8 and 2.9 shows that differences in voicing duration are very small; such differences as exist show an opposite trend in general.

Length of preceding vowel

In one way it would seem odd to expect the duration of voicing in a consonant to be conditioned by the length of the preceding vowel. However, one might remember here the rather large conditioning effect of vowel length on preaspiration duration, described in the preceding section of this chapter. And as noted above in this section, preaspiration duration correlates generally inversely with voicing duration of the lenis, across languages for any single positional variant. Therefore, it might seem reasonable to expect that, as preaspiration duration is considerably shorter following long vowels, the duration of voicing in the lenis stop might be longer.

The only case in all the data which shows any durational difference of note is the Irish data, where voicing duration in the lenis consonant seems in fact to be shorter following long vowels. This of course coincides with the fact that the actual consonant closure durations are also shorter following long vowels in Irish. If one calculates the absolute duration of voicing as a percentage of consonant closure, a difference nevertheless remains:

Voicing as a percentage of total closure duration

VC#	43%
VCV	40%
V:C#	26%
V:CV	34%

This difference for Irish seems to be consistent and was further borne out in the voicing durations of the lenis stops of the additional data set 3.

2.3.4 Electroglottographic light on voicing of the lenis stops

Some electroglottographic recordings for Harris Gaelic and Irish, illustrate an important difference in the lenis stops of the two languages. The average values for voicing in Figures 2.8 and 2.9 measured from the microphone signal, seemed to indicate that the voicing values in Harris, North Uist, Lewis and Irish represent simply slightly differing degrees of the one feature. The electroglottographic recordings however, indicate that there is a difference in kind between the voicing present in Irish and Harris Gaelic at any rate. Figure 2.10 illustrates a medial intervocalic lenis dental stop in the two languages (the Harris words were elicited in citation form, the Irish in sentence frames, so that the word carried nuclear stress). As can be seen from the glottographic trace (Gx) in either recording, the lenis stop of Harris has glottal abduction whereas that of Irish does not seem to. Thus the mechanism underlying devoicing in these stops would appear to be radically different for the two languages. The voicing which the larynx microphone picked up in the lenis stops of Harris occurs while the glottis is opening. It is therefore akin to the breathy voiced transition noted in preaspiration, although considerably more rapid, presumably because of the different aerodynamic conditions pertaining to oral closure (i.e. a rapid buildup in oral pressure, leading to

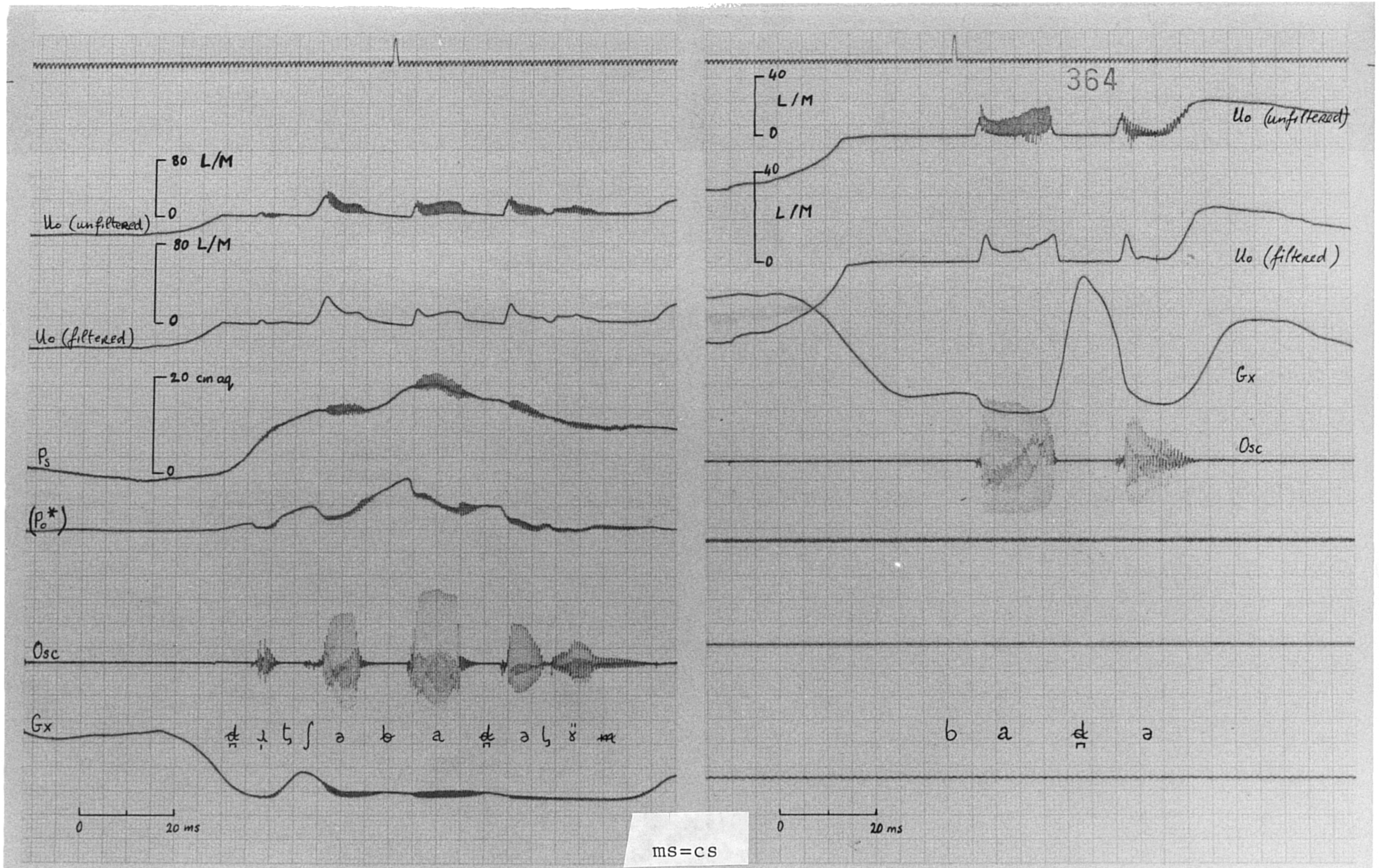


Figure 2.10

Mingogram of the word [bad̪ə] in Harris Gaelic (right) and Irish (left). In Irish the word is in the frame: "Dúirt sé -- liom." Note the glottal abduction in the medial lenis stop of Harris Gaelic as compared to that of Irish (indicated by the Gx trace).

Uo = oral airflow
Gx = photoelectric glottogram
Ps = subglottal pressure
(Po*)= (oral pressure transducer: not correctly positioned)

(Po*)= (oral pressure transducer: not correctly positioned)

neutralisation of the transglottal pressure drop). Westbury (1979) has observed for voiceless stops in American English that vocal fold vibration persists for a few cycles into stop closure. Similar findings are illustrated by the computer implemented model of the breath-stream dynamics of stop voicing by Westbury and Keating (1980). The visible presence on the acoustic record of a few periodic striations during the closure of voiceless stops has been discussed also by Lisker and Abramson (1964), who concluded that they were below the level of perceptibility. It seems, therefore, that the lenis stops of Harris (and almost certainly also those of the other Cl dialects, Skye and North Uist) are rightly considered as voiceless stops, in keeping with past descriptions.

In Irish, on the other hand, as the vocal folds do not appear to open, devoicing is likely to be due to a purely "passive" mechanism, i.e., attributable only to pressure neutralization. Of the three languages for which glottographic traces were obtained (Irish, Icelandic and Scottish Gaelic) Irish was the only one not to show glottal abduction for the Lenis stop in VCV. Figure 2.11 shows for this environment the peak amplitude of glottal opening (measured in arbitary units) in relation to average stop closure. These measurements come from data sets 6, 8 and 9(a), and involved for Harris tokens uttered in citation form, whereas in Icelandic and Irish tokens were uttered in a sentence frame and carried nuclear stress. (Full details of these data for Icelandic and Irish are given in Chapter 3.2.) The Harris data set (6) contained simply repetitions of the words /baʰtə/ and /badə/.)

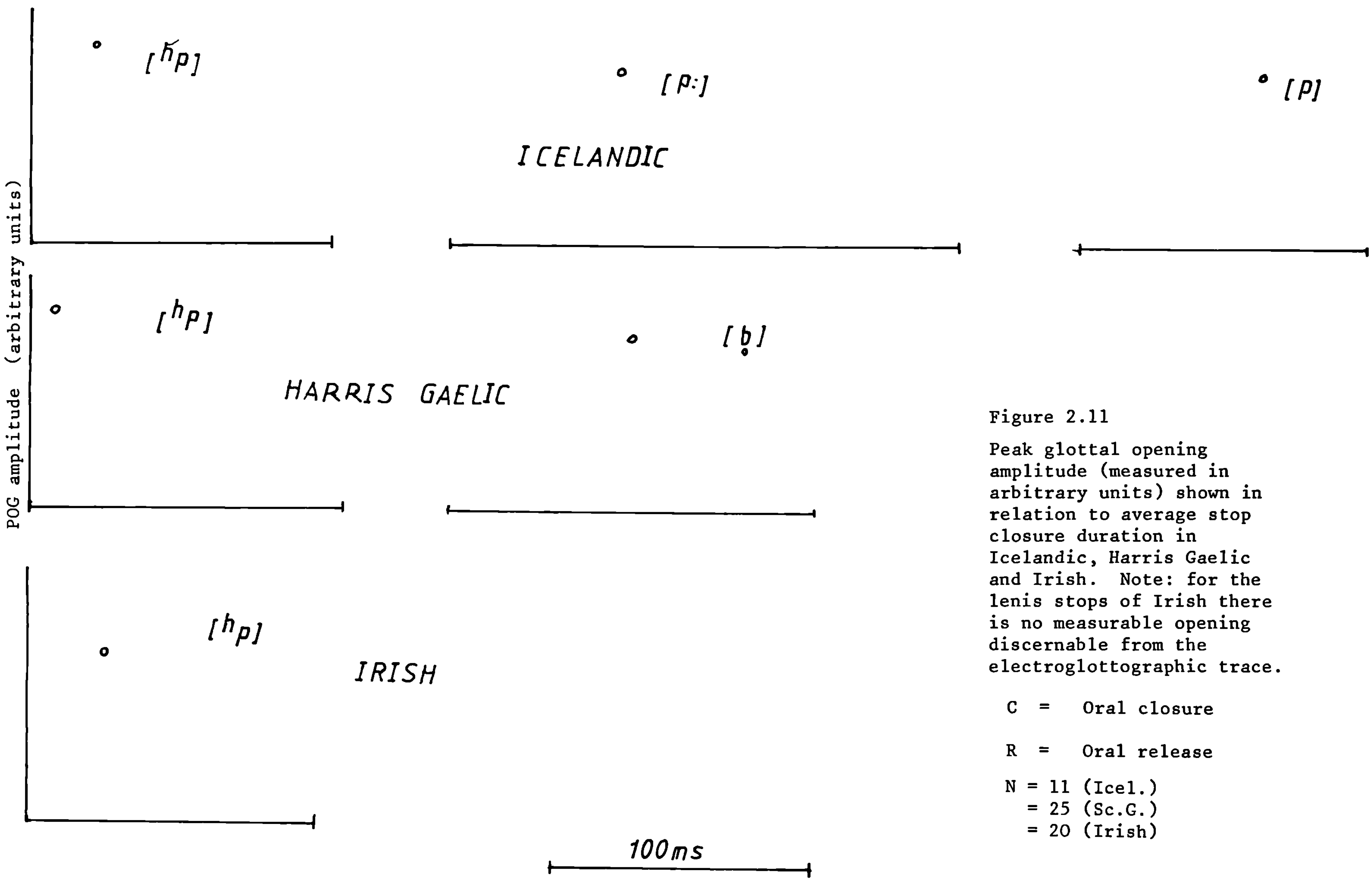


Figure 2.11

Peak glottal opening amplitude (measured in arbitrary units) shown in relation to average stop closure duration in Icelandic, Harris Gaelic and Irish. Note: for the lenis stops of Irish there is no measurable opening discernable from the electroglottographic trace.

C = Oral closure

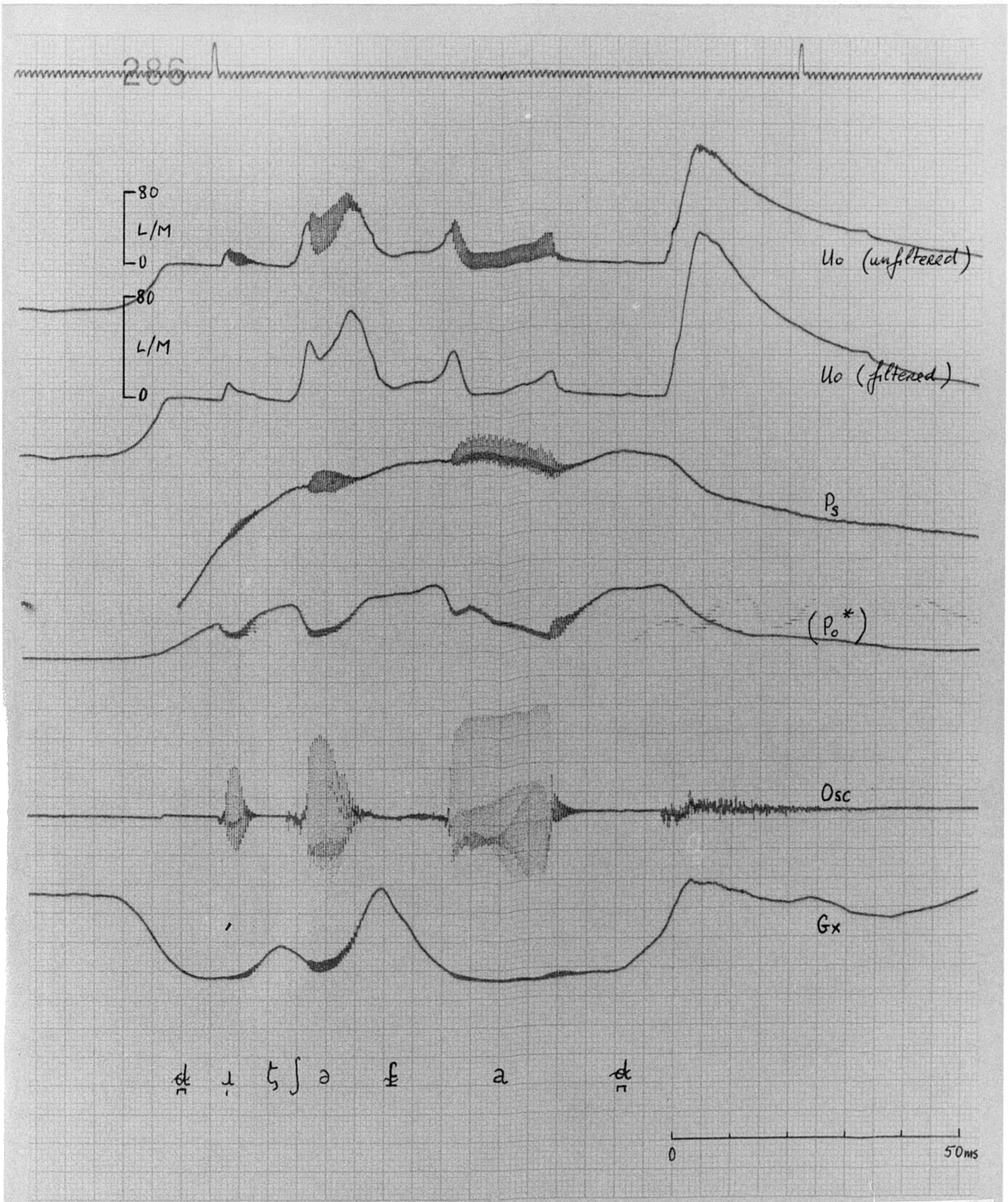
R = Oral release

N = 11 (Icel.)
= 25 (Sc.G.)
= 20 (Irish)

It is clear from Figure 2.11 that there is glottal abduction in each stop series in Icelandic and Harris Gaelic. The difference between stop series is reflected in the timing of peak glottal opening, and does not involve abduction versus adduction of the vocal folds. In Irish, there was no measurable adduction for the lenis stops, hence their omission from Figure 2.11.

As concerns the lenis stops of Irish however, it should be pointed out that a configuration of adducted vocal folds does not fully characterise all positional variants. As can be seen from Figure 2.12 which shows a recording of a lenis stop in VC#, glottal abduction does occur, beginning some time before the release of the stop. In this figure (as in Figures 2.10 and 2.14) there is also a lenis stop in #CV, and it is clear that glottal adduction occurs during rather than before stop closure. Note however (in Figure 2.10) that when the word-initial stop [b̴] is medialised in a frame, there is no glottal abduction.

Although not pertinent to this discussion on voicing, it is worth noting here that the fortis stops of Irish show a greater degree of articulatory invariance across word position. The recording in Figure 2.13 illustrates the fortis stop [t̴̪] in utterance initial position. Here, athough the glottis is in an abducted position prior to the utterance, it first narrows to a fairly adducted position for the stop articulation, and then proceeds with an opening/closing cycle. (This particular token was uttered with emphatic stress, but the same is true for utterances with normal nuclear stress.) It is rather curious that the

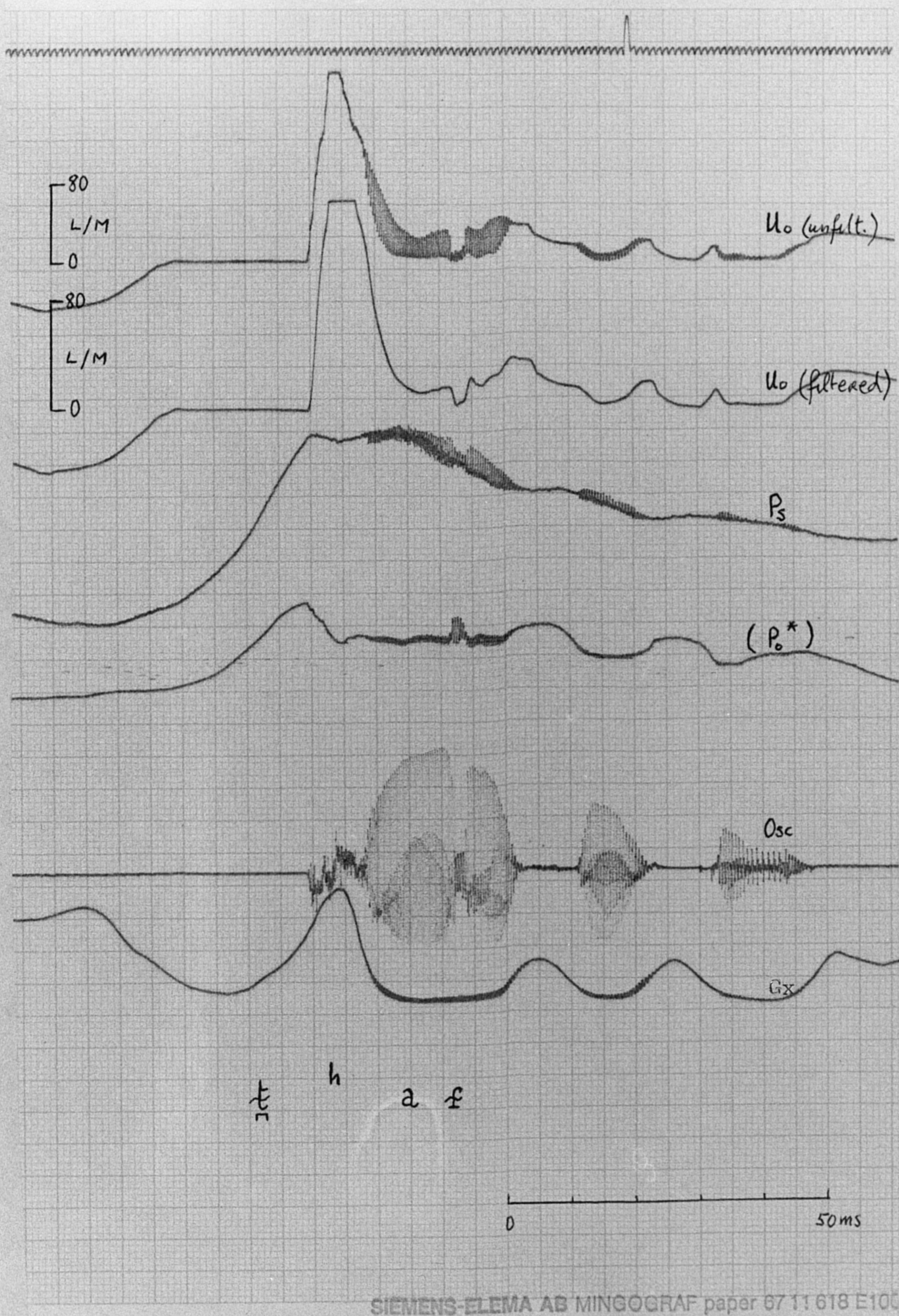


ms = cs

Figure 2.12

Mingogram of the Irish word [ɫad] spoken with emphatic stress in the carrier frame: "Dúirt sé -- ."

Uo	=	oral airflow
Ps	=	subglottal pressure
Osc	=	audio oscillogram
Gx	=	photoelectric glottogram
(Po*)	=	(oral pressure transducer: not correctly positioned)



ms=cs

Figure 2.13

Mingogram of the Irish word [t̪ʰaf] spoken with emphatic stress in the carrier frame: "-- a' focal."

Uo = oral airflow
Ps = subglottal pressure
Osc = audio oscillogram
Gx = photoelectric glottogram
(Po*) = (oral pressure transducer: not correctly positioned)

laryngeal articulation does not take advantage, as it were, of the already open state of the vocal folds.

The fortis stop in VC# exhibits similar behaviour, as can be ascertained from Figure 2.14 (the utterance in question here carries normal nuclear stress). It is again curious to note that when the glottis has opened for the stop, it does not remain fully abducted for expiration as one might expect, but partially completes the closing phase of the opening/closing cycle.

These findings are similar to observations made by Löfqvist (1980) and seem to corroborate his suggestion that the typical glottal gesture for a voiceless consonant is a relatively fixed ballistic opening/closing cycle.

2.3.5 The historical perspective

Across languages and dialects there seems to be an inverse relationship between preaspiration and voicing, i.e., languages and dialects with longer preaspiration tend to have shorter voicing, and vice versa. One might recall here the prediction by Thráinsson (1978) that preaspiration will only be found in languages with no clear voice/voiceless distinction. He appears to be making phonetic predictions from a phonological standpoint, and thus obscuring the fact that, at the phonetic level, both preaspiration and voicing may be present. And both may potentially serve as perceptual cues to the opposition, operating in inverse relationship to each other. Nevertheless, in essence

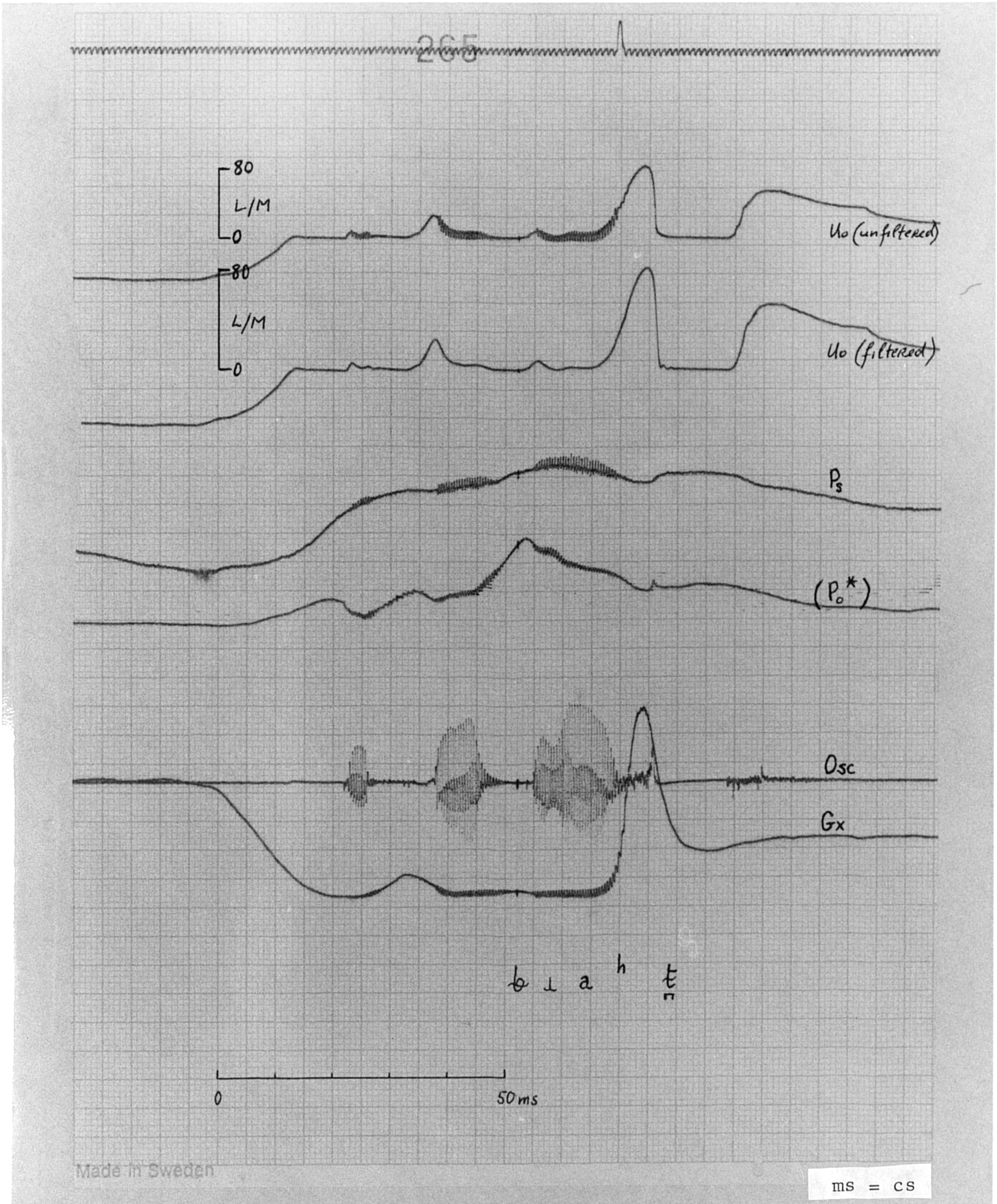


Figure 2.14

Mingogram of the Irish word [ƀɹaʰt̪] in the carrier frame:
"Dúirt sé -- ."

Uo = oral airflow
Ps = subglottal pressure
Osc = audio oscillogram
Gx = photoelectric glottogram
(Po*) = (oral pressure transducer: not correctly positioned)

Thráinsson is right in that there is obviously a close correlation between the loss of voicing proper in the opposition and the development of preaspiration.

To sum up, one might say that preaspiration functions as a voicing opposition, but one which has moved leftwards into the preceding vowel. Historically, it would appear that this is what happened, or is happening, in these languages. In all the cases described here, the oppositions involving preaspirated and non-preaspirated stops are thought to have evolved from long voiceless and voiced stops. Possible steps in the evolution of these changes are proposed in Chapter 4.1; the more general question of the phonetic motivation for sound changes involving voicing is the topic of Chapter 4.2.

2.3.6 Conclusions on voicing

The actual duration of voicing in the unpreaspirated series is usually rather short. In Irish, the language with the most voicing, average durations are still less than half of the consonant closure duration, and less than the duration of the preaspiration for the fortis stop series of Irish. As was found with preaspiràtion durations, Lewis has durations of voicing which are intermediate between those of Irish and of the Cl dialects of Scottish Gaelic. These latter dialects have very little voicing. Icelandic has none.
Voicing durations did not show much conditioning due to position

or to the length of a preceding vowel. There was a slight (surprising perhaps) tendency for voicing to be shorter in medial than in final position. The length of a preceding vowel influenced the duration of voicing only for the Irish stops, where values seem to be shorter following long vowels. This effect was noticeably absent for the Scottish Gaelic informants, except for the Skye speaker who showed a very slight similar trend.

On the face of it, when simply measured from the audio oscillogram, Icelandic, Skye, Harris, North Uist, Lewis Gaelic and Irish appear to exhibit increasing degrees of the same phenomenon on a single continuum. However, electroglottographic recordings indicate that the mechanism underlying the devoicing may be rather different between some of these languages and dialects. The small amount of voicing observed for Harris is no more than the "edge vibrations" of an opening glottis, so that effectively one is dealing with voiceless stops. In Irish the devoicing would appear to be probably the result of passive aerodynamic forces, so that here one is dealing with voiced stops which contain a voice break. Edge vibrations in voiceless stops have been described also by Lisker and Abramson (1964), who concluded that they were of no perceptual importance.

2.4 A COMPARISON OF PRE- AND POSTASPIRATION

Preaspiration can be regarded as being basically similar to postaspiration, i.e. both could be considered as forms taken by a phonological voicing opposition where the timing of vocal fold vibration is not synchronous with supraglottal articulation. As such, it is of some interest to compare the characteristics of pre- and postaspiration.

One striking difference between the two has been discussed in some detail above, namely the comparatively slow transition between voice to voicelessness of preaspiration, which has been termed the breathy voiced transition. It has also been suggested above that the breathy voiced transition is most likely not under voluntary control and represents rather a production (mechanical/aerodynamic) artefact. Perceptual Experiment 1, reported in Chapter 5.1, suggests that the breathy-voiced transition is perceived as preaspiration. This means that, whereas postaspiration duration can be regarded as being more or less synonyomous with VOT duration, a characterisation of preaspiration as Voice Offset Time (VOFFT) is less accurate or desirable, as it may fall substantially short of the perceived duration of preaspiration.

In comparing pre- and postaspiration, one is therefore confronted with a problem. Should one compare postaspiration durations (which are in fact VOT measures) with the truly voiceless portion only of preaspiration (this would be, strictly speaking, a voice offset time (VOFFT) measure)? This would in one way ensure a single measuring criterion, but would underestimate the perceived duration of preaspiration. Alternatively, one could simply compare preaspiration durations (including the breathy voiced transition) with postaspiration durations, assuming that this approximates more closely to their perceived durations.

The latter solution seemed the more reasonable, and was the one chosen for the discussion in section 2.4.1, where in a general way, pre- and postaspiration are compared and discussed along with some of the salient characteristics of oppositions where one or the other feature is used. However, in the subsequent section, which compares fortis/lenis category separation in a "preaspirating" opposition with the category separation in a "postaspirating" opposition, it was thought best to present this in terms of separation by VOFFT versus separation by VOT. The reason for this is as follows:

It will be recalled from section 2.3, that there is vocal fold abduction in the lenis stops of these languages (excepting Irish and perhaps, Lewis Gaelic). Thus VOFFT for these stops (like the fortis) occurs some time after the vocal folds have begun to separate. But the onset of glottal abduction is not ascertainable for the lenis as for the fortis, as one does not have the cue of the sharp rise in oral airflow. It would therefore make little sense to estimate category separation in terms of glottal abduction in the fortis, but in terms of voice offset in the lenis. A measure of the difference in Voice Offset Times for both stop series seemed the more sensible method. Perception considerations point somewhat in the same direction. As discussed by Lisker and Abramson (1964) the "edge vibrations" of the opening glottis during voiceless stop closure do not seem to be perceptible. Therefore, although VOFFT of the fortis stop is apparently later than the perceived onset of preaspiration, this, to some extent, should be compensated for, as VOFFT in the lenis stop is also later than the perceived onset of voicelessness.

2.4.1 The characteristics of preaspiration and postaspiration and of the oppositions in which they occur

Durations

Preaspiration is potentially of much longer duration than postaspiration. Looking back to the preaspiration values of Figure 2.4 and the postaspiration values in Figure 2.1, if we compare them in VC# and #CV(:) respectively (where the longest values of either are to be found), it is striking how much longer the preaspiration values are. The longest average preaspiration duration observed in this study was 222ms. for Icelandic; compare to the longest average postaspiration value of 84ms. in Lewis Gaelic. The fact that the breathy voiced transition (BV) is being considered as part of preaspiration contributes to the difference, but, even if one omitted the BV duration from the reckoning, the general observation would still be true.

Range of pre/postaspiration values

Still restricting discussion to the same environments, it is rather striking how wide the range of preaspiration durations is across languages. Average values can range from 58ms, for Irish, to 222ms for Icelandic. This is very different from postaspiration values which are much more uniform across languages; the cross language study of Lisker and Abramson (1964) describes a range of 60ms to 100ms for postaspirated stops. In Figure 2.1 average postaspirated values as low as 40ms are observed for Icelandic stops in #CV; even so, the range is comparatively a much more compact one.

Characteristics of the pre-/postaspirating oppositions:

In the Lisker and Abramson study, the following characteristics were observed for stop oppositions in initial postpausal position (see discussion in Chapter 1.1.3).

(a) VOT values exhibited a tri modal distribution, clustering into three fairly neat categories;
   - voiced, with a median value of -100ms VOT
   - voiceless unaspirated, with a median value of + 10ms VOT
   - voiceless aspirated, with a median value of +75ms VOT.

(b) Languages with a two-way distinction did not use the extremes of the possible range.

(c) As can be inferred from a) and b), languages with a two-way distinction tend to have either a contrast of voiced versus voiceless (unaspirated) or of voiceless unaspirated versus voiceless aspirated. Languages do not usually seem to contrast an aspirated stop with a voiced (or partially voiced) one.

Looking at the "preaspirating" oppositions, as illustrated in Figures 2.8 and 2.9 (and still restricting discussion for the moment to the VC# environment) it is clear that:

(a) There is no analogous neat clustering of values into fairly discrete categories. Preaspiration values (and if one prefers, VOFFT values) vary rather continuously over the possible range.

(b) As is the case with "postaspirating" oppositions, extremes of the range are not exploited in "preaspirating" oppositions either. Although preaspiration values are frequently much longer than postaspiration values in #CV, the duration of voicing is never very long, especially when the preaspiration values are. The duration of voicing, when there is any, is never as long as that normally observed for voiced stops in #CV (see above).

(c) As has been noted earlier in this chapter, the "preaspirating" opposition can, and does, contrast a preaspirated and a (partially) voiced stop. In this respect it differs from "postaspiration" oppositions, where, in #VC at any rate, two-category languages usually seem to use either voicing or postaspiration, but not both.

Conditioning of pre-/postaspiration durations

Positional variation:

The longest pre- and postaspiration durations are found in final prepausal and initial postpausal positions respectively. Medially, values are shorter in both cases.

Vowel length conditioning:

Both pre- and postaspiration showed some effect from the phonological vowel length, and in the case of the former the effect is rather dramatic. Average postaspiration values tend to be very slightly longer preceding long vowels. Preaspirated stops do not occur after long vowels in Icelandic. In the Scottish Gaelic dialects and Irish, where they do, preaspiration values tend to be shorter. The relatively short values of preaspiration with long vowels suggests that there may be some type of contraint (e.g. a production constraint) on long preaspiration following a long vowel; the shortening in this environment is much more dramatic in the dialects which have long preaspiration durations and less in evidence in Irish or Lewis Gaelic, where preaspiration durations are shorter in any case.

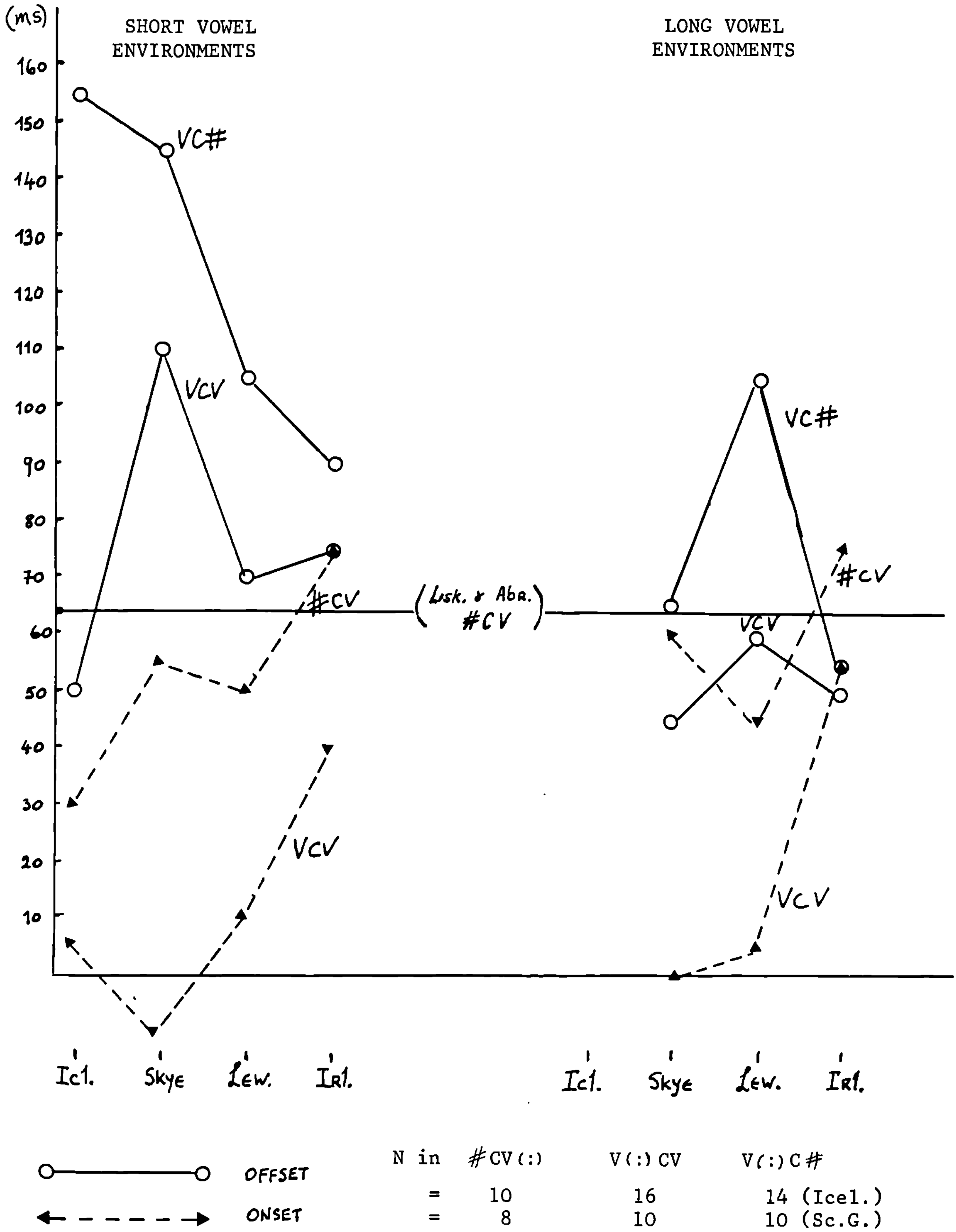
2.4.2 The separation of fortis/lenis categories in "preaspirating" and "postaspirating" oppositions: VOT versus VOFFT.

For the reasons explained above (2.4.0) the fortis/lenis category separation is best described in terms of the separation at VOFFT versus that at VOT. Hence, for the "preaspirating" oppositions, one is now comparing, on a VOFFT continuum, the offset of voice in the lenis with the offset of voice (or breathy-voice) in the fortis.

The average values for the separation of fortis/lenis categories at voice offset as opposed to onset are represented graphically in Figure 2.15. Because of the extensive conditioning effect of the vowel length on preaspiration duration, the results with long and short vowels are shown separately in this figure. The solid horizontal line at 65ms indicates the separation in VOT between aspirated and unaspirated stops in #CV which has been deduced from the cross-language data by Lisker and Abramson (1964). Note that postaspiration values for #VC in the languages studied here fall generally below this line, showing that the VOT separation is (sometimes considerably) less good. In VCV, VOT does not serve to differentiate stop categories of Icelandic or Scottish Gaelic (see also Figure 2.3 which presents the averages and standard deviations for this environment.)

<u>Short vowel environments</u>

Values for the short vowel environments are indicated to the left of the figure. It is immediately obvious that VOFFT affords better separation of categories than VOT.



N in	#CV(:)	V(:)CV	V(:)C#
=	10	16	14 (Icel.)
=	8	10	10 (Sc.G.)
=	12	12	12 (Ir.)

Figure 2.15 Average separation (of fortis/lenis) at voice offset and onset

VC# and #CV

If we compare VC# and #CV, the environments which show longest pre- and postaspiration respectively, we find that separation is considerably greater at VOFFT. This is still true even if we compare separation at VC# to the horizontal line at 65ms, which represents typical separation across languages for VOT in #CV.

In Irish the separation for VOT and VOFFT are much closer and in fact not very different, although separation at VOFFT is still he greater of the two.

VCV

Comparing VOT and VOFFT for VCV one finds similarly a better separation for VOFFT. This still holds if we compare VOFFT in VCV to the more typical cross-language VOT separation represented by the horizontal dotted line. In comparing VOT and VOFFT in VCV however, one must bear in mind that VOFFT belongs in the stressed syllable for these three languages, and that VOT does not. The importance of stress in aspiration is already well attested for VOT (see for example Keating et al., 1983); its importance for preaspiration is the subject matter of Chapter 3.

Long vowel environments

Separation values of #CV and VC# are much more similar in long vowel environments. This seems to be due to the fact that preaspiration values are never very long with long vowels. The apparently contradictory Lewis data has already been discussed above in sections 2.2.1 and 2.2.2, and should probably be discounted, as this particular speaker (the Lewis 1 informant) had rather short durations for the phonologically long vowels.

In VCV, VOFFT separation is again greater than VOT separation, except in the case of Irish, where values are almost the same. The comment in the preceding paragraph regarding the role of stress, would be equally relevant here.

2.4.3 Conclusions

To recap briefly, the main differences between preaspiration and postaspiration would appear to be the following:

- Preaspiration is characterised by a comparatively slow transition from voicing to voiceslessness, termed the BV interval here.

- The duration of preaspiration can be, at its longest, considerably greater than postaspiration. This observation would still be true if one excluded the BV interval from the preaspiration measure, and has been commented upon by other researchers such as Pétursson (1972).

- Overall, the range of observed preaspiration durations is greater than that reported for postaspiration durations.

- Preaspiration values across languages do not group into the discrete categories observed for postaspiration by Lisker and Abramson (1964). Rather, preaspiration values exhibit more continuous variation, a fact which could have implications for preaspiration perception.

- Preaspiration shows considerable vowel length conditioning, and it looks as if there may be a constraint on long preaspiration following a long vowel. Vowel length conditioning of postaspiration duration is generally very slight and not invariably present.

- There is generally better category separation of fortis/lenis stop categories on the basis of VOFFT than VOT. Given the extensive vowel length conditioning of preaspiration duration, this observation is especially relevant to the short vowel environments, and less true for long vowel environments.

2.5 CONSONANTAL CLOSURE DURATION

2.5.0 Introduction

Consonantal closure duration is another feature which could be expected to play a part in the opposition of stop cognates. As was discussed in Chapter 1.1.5, past studies in other languages have shown a tendency for longer stop duration with the fortis series. Studies of this feature in production and perception would lead us to expect it to operate more in intervocalic than in final position. However, many of these studies were based on dialects of English where final stops are not always released, and where, consequently, stop closure duration is only intermittently available to our perception. In languages and dialects where stops are always released (as in all the data for the three languages presented here) if stop closure duration were to operate as a perceptual cue, one might expect it to be as important also in final position.

2.5.1 Expectations for closure duration differences in oppositions involving preaspiration

One might expect closure duration differences to be less important in a language where the fortis stops are preaspirated. With preaspiration operating in postvocalic positions, the contrast might be sufficiently distinct for this feature not to be called upon. If this is the case, one should expect that the language, dialect or even the environment with the least preaspiration should most exhibit this tendency.

There are also other considerations which might lead us to expect, not the longer fortis stop described in other languages, but the reverse. As will be outlined in Chapter 4.1, the present opposition in the languages studied here of a preaspirated and an unpreaspirated stop series derives historically from what would appear to have been an opposition of voiceless and voiced geminates respectively. In the same chapter, it is hypothesised that the loss of voicing in the geminates triggered the development of preaspiration. Furthermore, shortening of the geminate when it occurred (it did not happen to the original "voiced" geminate of Icelandic) is hypothesised to have started with the voiceless (and gradually preaspirating) series. The reason suggested for this is that the additional preaspiration would result in a very long segment, so that a shortening in consonantal closure duration might be a reasonable expectation.

If these hypothesised derivations are roughly correct, it might lead one to expect durational differences among the consonants not related directly to the phonological voicing opposition as such, but rather to the historical length of these stops. For example, if the preaspirated series shortened first, might one not expect vestigial traces of length in the unpreaspirated series?

Of course, in purely synchronic terms, a comparatively long lenis stop might be expected to compensate for the extra length in the syllable with preaspiration.

2.5.2 Results

As has been explained in Chapter 1.3, the data recorded in data sets 1 and 2 were not ideally suited to the task of ascertaining the possibily fine-grained differences in the durations of fortis/lenis stops and in their preceding vowels. For example, the fact that the quality of the preceding vowel was not controlled (especially in the Scottish Gaelic set) could result in apparent but spurious vowel duration differences, given that intrinsic vowel duration is known to vary with vowel quality (see Lehiste, 1970:18). For this reason it was felt that, although the measurements of vowel and consonant durations obtained from data sets 1 and 2 might be useful in indicating general tendencies, the additional controlled recording of data set 3 was required in order to establish with confidence the nature and extent of the differences.

In data set 3, a single place of articulation (dental) was involved, and the quality of the preceding vowel was always long or short /a/.[1] This data set was recorded for the Irish, Harris, and for the second of the Lewis informants. In Icelandic, the quantity rule (see Chapter 1.2.1) makes the question of intrinsic, fine grained differences rather redundant; the preaspirated single stop, which only occurs after short vowels, contrasts with an unpreaspirated geminate stop.

Figure 2.16 illustrates durations for fortis and lenis stops in all the languages included in data sets 1 and 2. Bearing in mind

------

[1] These nonsense words were of the form /ba(:)C(ə)/, where C represents fortis and lenis dental stops.

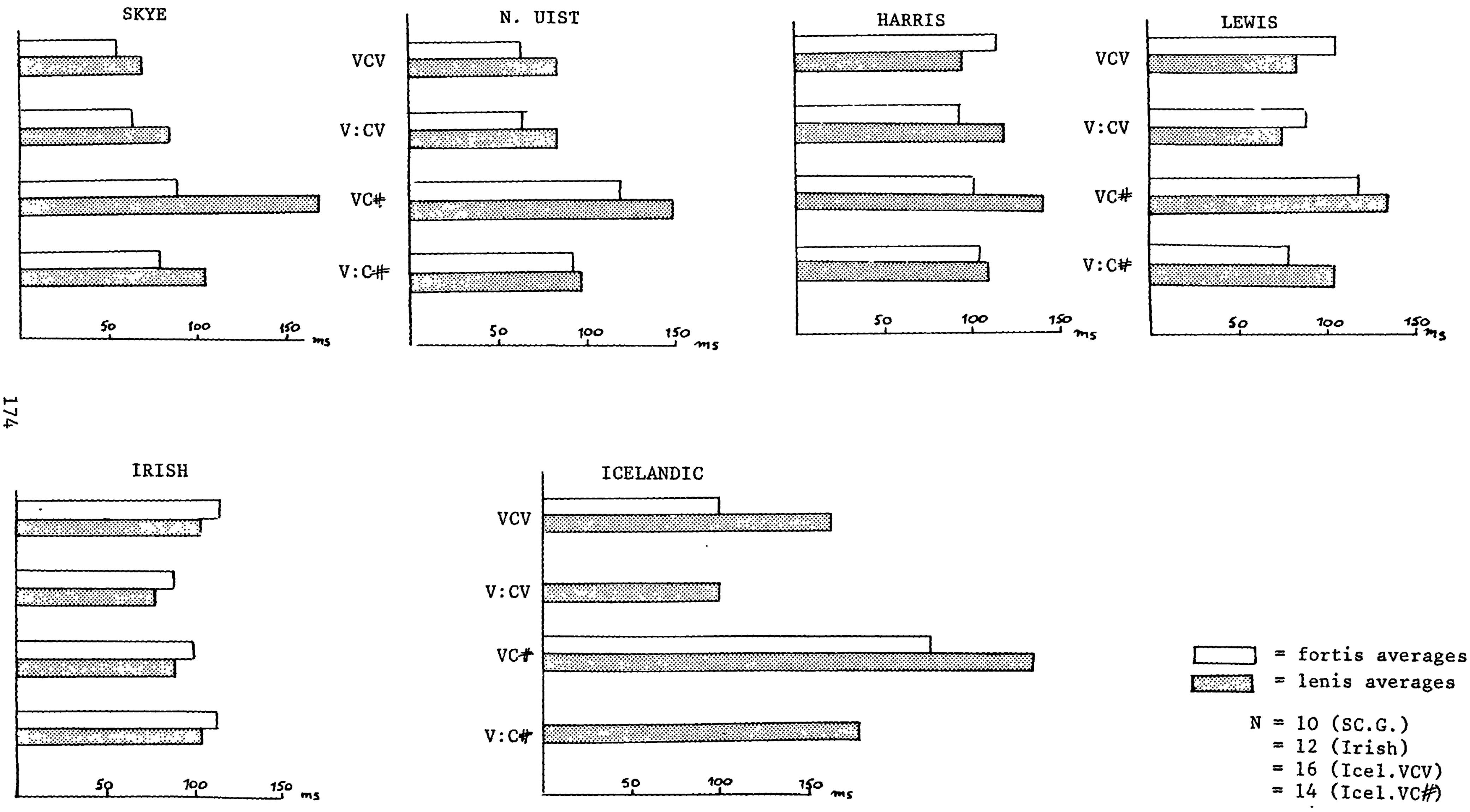


Figure 2.16 Stop closure durations (data sets 1 and 2)

the possible reservations regarding these measurements, the following tendencies seem to emerge.

Irish is the only one of these languages where fortis stops appear to be generally longer than the lenis. In this respect it shows the more general pattern described for voicing oppositions for other languages such as English.

Icelandic and the Scottish Gaelic dialects exhibit rather the reverse tendency. In Icelandic, the longer lenis than fortis stop is not surprising, as the lenis here is a geminate. In fact, a more curious thing is the length of the unpreaspirated stop in VC#, as it is typically described as a single stop.

Within Scottish Gaelic, looking first of all at dialect area Cl (represented by Skye, North Uist and Harris), lenis stops are generally longer than the fortis. This is less consistently true for the Harris informant than for the other two. For all three, it would appear that VC# is the environment where the difference is greatest; indeed it is strikingly large for the Skye speaker. For area B, i.e. for the Lewis informant, things are not absolutely clearcut. The general tendency of longer lenis than fortis stops seems to hold for final position. In medial position there appears to be a reverse tendency of longer fortis than lenis stops.

The results of data set 3 are presented in Figure 2.17 in a fashion similar to Figure 2.16. The significance of the differences between the fortis and lenis stop durations was tested on the basis of a t-test and the results of this test are presented in Table 2.3.

Table 2.3 <u>Closure duration differences in the fortis and lenis Stops: t-statistics.</u>

Environment	Irish	Lewis	Harris
VCV	+5.67	+2.16	-5.38
V:CV	+7.67	+1.01	-5.05
VC#	-0.28	-5.81	-13.89
V:C#	+1.34	-3.04	-5.21

The critical values for the t-statistics with significance levels in parentheses, are 1.345 (.10), 1.761 (.05), 2.145 (.025), 2.624 (.01) and 2.977 (.005).

<u>Note</u>: A negative t-statistic indicates that the mean for the lenis stops is greater than the mean of the fortis stops. A positive t-statistic signifies the opposite. It is the absolute value of the t-statistic which indicates its statistical significance.

Data set 3 in fact generally confirms the tendencies observed in The earlier data sets.

<u>Irish</u>

Irish does pattern in the more usual way for voicing oppositions, with longer fortis than lenis stops. As can be seen from Table 2.3, the difference is highly significant at all levels of significance in medial position. For final stops, the difference

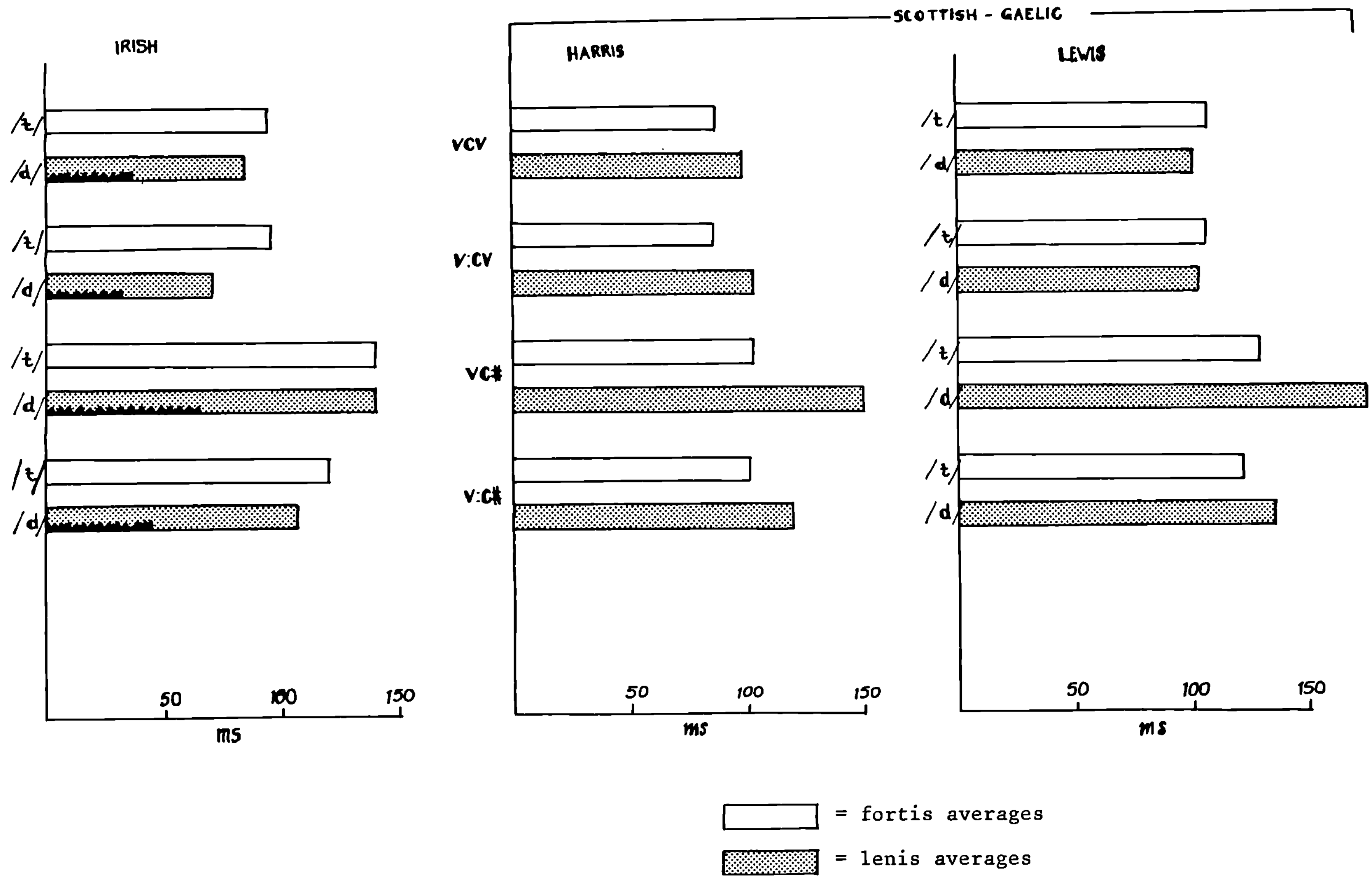


Figure 2.17 Stop closure durations (data set 3) N = 15

is not statistically significant with short vowels and is only weakly significant with long vowels. The greater importance of the stop durational differences in medial than in final position is also consistent with the pattern of other languages such as English. The fact than final stops in Irish are invariably released, does not seem to increase the importance of this feature in final position, a possibility that was suggested earlier.

Scottish Gaelic

Area C1: Harris

The Harris speaker here bears out the reverse tendency noted above for the C1 dialects, of longer lenis than fortis stops. The differences are statistically highly significant, at all levels and in all environments.

Area B: Lewis

Again, the trends noted in the earlier data are confirmed. In Lewis there is not a single trend, but rather two, depending on word position. Final stops exhibit a pattern like that of Harris, with longer lenis than fortis stops. The differences here are highly significant at all levels. In medial position the differences are very slight and in the opposite direction. Although the differences are slight, in VCV they would appear to be statistically significant at the .025 level. In V:CV, differences are not significant.

For both Scottish Gaelic dialects, the greatest fortis/lenis difference occurs in VC#. This fact also accords with the earlier data sets.

2.5.4 Interpretation of observed differences in consonant duration

The greater duration of fortis than lenis stops has been shown for other languages to be a perceptually important cue to the phonological opposition (see Chapter 1.5). It was hypothesized in section 2.5.1 that one should expect for perceptual reasons to find the greatest use of this feature in a language, dialect or environment which had least preaspiration. The results provide a measure of support for such a hypothesis. Irish is the language with least preaspiration in this study, and the only one to show longer fortis than lenis stops. Furthermore, within Irish, the environments with least preaspiration (medial intervocalic) would appear to make most use of this feature.

The Scottish Gaelic dialects had longer lenis than fortis stops in final position for both dialects, and also in medial position for Harris. The greatest difference for both was in VC#. In perceptual terms, this might appear to be surprising as this is the environment which shows the longest duration of preaspiration for the fortis series. Further cueing of the phonological contrast therefore, by means of durational differences in vowel or consonant is least necessary here. For this reason, it would seem reasonable to suggest that the tendency towards longer lenis stop duration in the Scottish Gaelic dialects is not perceptually motivated.

The possibility of finding longer lenis than fortis stops in these languages was also discussed in section 2.5.1, for reasons other than the perceptual cueing of the phonological opposition. Two possible, and of course related, causations were presented for this. First, it was suggested that the lenis stops might continue to exhibit traces of historical gemination. Second, in synchronic terms, any tendency in the language to equalize the length of syllables (with and without preaspiration) could result in longer lenis stop durations.

Looking at the stop durations in Figure 2.17, it would seem far fetched to argue that the lenis ones exhibit traces of gemination. Although the fortis/lenis differences are consistent and would appear to be generally statistically significant, the extent of these differences is usually very small. The only sizeable difference is found in VC#, where it is 45ms for both speakers: in all other environments the difference is under 20ms. Reverting to Figure 2.16, if one compares the durations of the Scottish Gaelic lenis stops with the geminates of Icelandic in the same environments, one is struck rather by the ungeminate nature of the Scottish Gaelic stops.

The second type of causation for longer lenis than fortis stop durations seems the more plausible, i.e. that the difference may reflect a synchronic tendency to compensate the durational inequality of syllables with and without preaspiration. The fact that final position, which displays the greatest consonant duration differences, is also the environment which has the longest preaspiration durations, lends some support to this line of explanation.

2.5.3 Conclusions

To sum up briefly the main findings regarding the use of this feature, it would appear that Irish behaves differently from the Scottish Gaelic dialects. Irish exhibits the type of differences found more generally for voicing oppositions, i.e. the fortis stop tends to be longer than the lenis, especially in medial position.

In the Scottish Gaelic dialects rather the reverse tendency is found, i.e. lenis stops tend to be longer. This is true of every positional variant for Harris, but only for final stops in Lewis Gaelic. For both, the greatest difference is found where preaspiration values are longest. It was argued therefore that the observed durational differences may not so much be perceptually motivated, as reflect a compensatory tendency in the language, to equalize the duration of syllables with and without preaspiration.

2.6 VOWEL DURATIONS

There seems to be a universal tendency for vowels to have longer duration before lenis (or phonologically voiced) than before fortis segments, particularly in final position. Mention has been made in Chapter 1.1.5 to hypotheses by Javkin (1979) and by Scully (1974) to the effect that this tendency may be the result of heightening a perceived difference in vowel duration. It was further suggested that the tendency towards vowel duration differences, whatever its initial motivation, may function to reinforce an unstable voicing opposition in a particular environment. In other words it may operate as a perceptually equivalent rescue strategy in a language where final devoicing of the lenis stop is leading towards neutralisation for that position. (See Chapter 4.2 for a discussion on the tendencies in stops towards sonorisation and de-sonorisation and the possible phonetic motivation for such tendencies). It is further pointed out by Javkin that there are cases where voicing proper has been lost, but the contrast maintained by means of the vowel duration difference.

2.6.1 Expectation of vowel duration differences in these data

Should one expect vowel duration differences to operate in oppositions involving preaspiration?

A reason why perhaps one should expect not to find a vowel duration difference might be that it simply is not necessary, as was argued in the preceding section dealing with stop duration differences. If a language develops (or has) preaspiration, the opposition may be sufficiently distinct, and the additional perceptual boosting through vowel duration difference may not be required. In Chapter 4.1.4 it is proposed that preaspiration developed in response to the loss of voicing proper in the geminate, as a means of mainaining a threatened opposition. Therefore, in historical terms, if a language adopted this particular means of boosting the opposition, the alternative and more commonly favoured strategy of vowel lengthening might not be necessary. If this line of reasoning has any basis, one should expect vowel duration differentiation (as consonant duration differentiation) to be more likely in a language, dialect, or position where there is least preaspiration.

Of course, there are reasons for which one might indeed expect that "preaspirating" oppositions would exhibit longer vowel duration before the lenis. If preaspiration is regarded as simply an earlier glottal opening, could it not be expected that a shorter vowel duration might be the sacrificial cost of the preaspirated stop? In this case, one might expect the vowel preceding the lenis stop to be of roughly equivalent duration to the sum of vowel and preaspiration durations in the other series.

Even if the development of preaspiration did not eat into the duration of the preceding vowel, should one not expect a compensatory lengthening of the vowel before the lenis? As was argued in the discussion on consonant durations, such a tendency might operate to equalize the durations of syllables with and without preaspiration. It is worth noting in this context the finding by Peterson and Lehiste (1960) cited in Lehiste (1970:23) that vowels are shorter following aspirated stops (i.e. postaspiration) than unaspirated (and longer if the duration of the aspiration is added to the vowel duration).

To sum up, if there is any tendency to compensate for the preaspiration duration by increasing the duration of vowels before the lenis series, then one would expect vowel duration differences to be maximally present in environments where preaspiration is longest. If there is a strong trend towards maintaining an equal syllable length, then one might expect the vowel preceding the lenis stop to be of roughly equivalent duration to the sum of vowel and preaspiration duration of the other series.

On the other hand, if there are vowel duration differences whose function it is to boost the opposition perceptually, one would expect the differences to be maximal where preaspiration is shortest.

Methodological points

In comparing vowel durations one encounters again the problem discussed in earlier sections when describing preaspiration: where does the vowel end and preaspiration begin? Should the breathy voiced portion belong to the vowel, i.e. the portion where the vocal-folds are opening but still vibrating and where voicing and aspiration are both present?

Insofar as deductions can be made from the first perceptual experiment described in Chapter 5, it would appear that the breathy voiced interval is perceived as preaspiration. Calculations made on the basis of this experiment (and discussed in section 5.1.1.4) suggest that the breathy voiced transition is perceptually roughly equivalent to the same duration of voiceless aspiration in cueing the preaspirated stop. (One should note, however, that truly voiceless aspiration is not acceptable to all subjects, and probably less natural-sounding). This would suggest that the breathy voiced transition belongs perceptually to preaspiration, and should not be apportioned to the vowel. The results presented here are based on that assumption.

2.6.2 Results

Figure 2.18 presents the durations of vowels preceding fortis and lenis stops from the cross-language data in sets 1 and 2. Given the reservations expressed earlier about the suitability of some of these data for ascertaining such possibly fine-grained vowel duration differences, these results are used simply to get some impression of general tendencies: for more precise and quantified measures, the results from the controlled paradigms of data set 3 will be presented below.

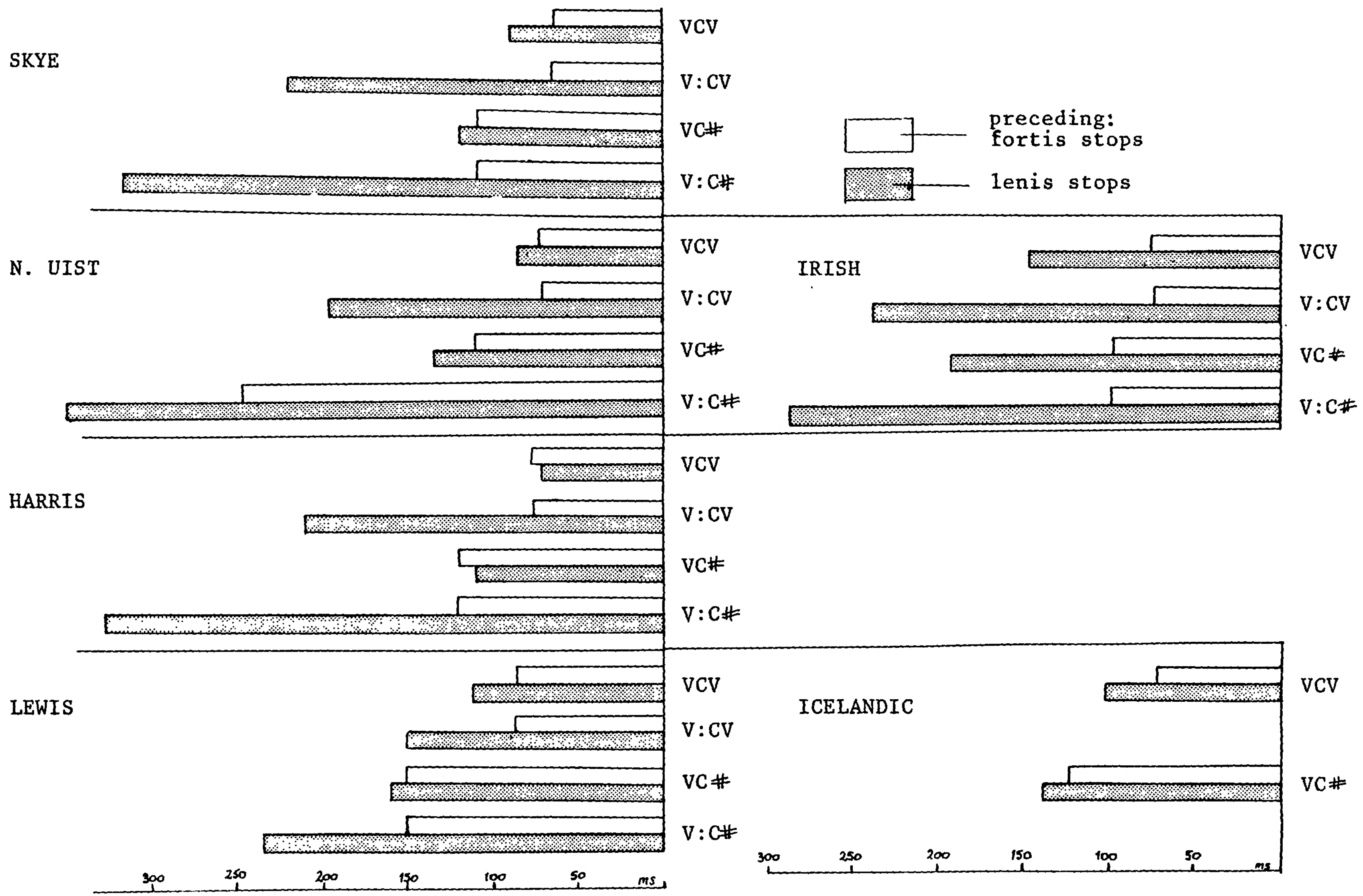


Figure 2.18 Vowel durations preceding lenis/fortis stops (data sets 1 and 2)
N values are as in Figure 2.16

From Figure 2.18, it would appear that all of these languages illustrate the "universal" tendency towards longer vowels before lenis than before fortis stops. The extent of the difference is very striking for Irish in every environment. In Scottish Gaelic, it would appear that phonological vowel length may affect the extent to which this feature will play a role. In short vowel environments the differences are generally very slight, and for the Harris data, run in the opposite direction. Differences are greater in long vowel environments generally, and especially in final position.

The results for data set 3, recorded for the Harris, Lewis (2) and Irish informants are presented in Figure 2.19. (The duration of preaspiration for the fortis stops is also indicated in this figure, as it is relevant to some of the points discussed here.) The tendencies which emerge here for vowel duration differences generally conform to those observed in Figure 2.18.

Irish

For Irish, the difference in vowel durations is again found to be particularly large in every environment. Furthermore, it is quite striking that the duration of the vowel before the lenis stop is very close to the sum of vowel and preaspiration durations for the other series. To describe preaspiration in Irish therefore as an "earlier glottal opening" would seem reasonably apt. Thus in Irish, syllables with a preaspirated

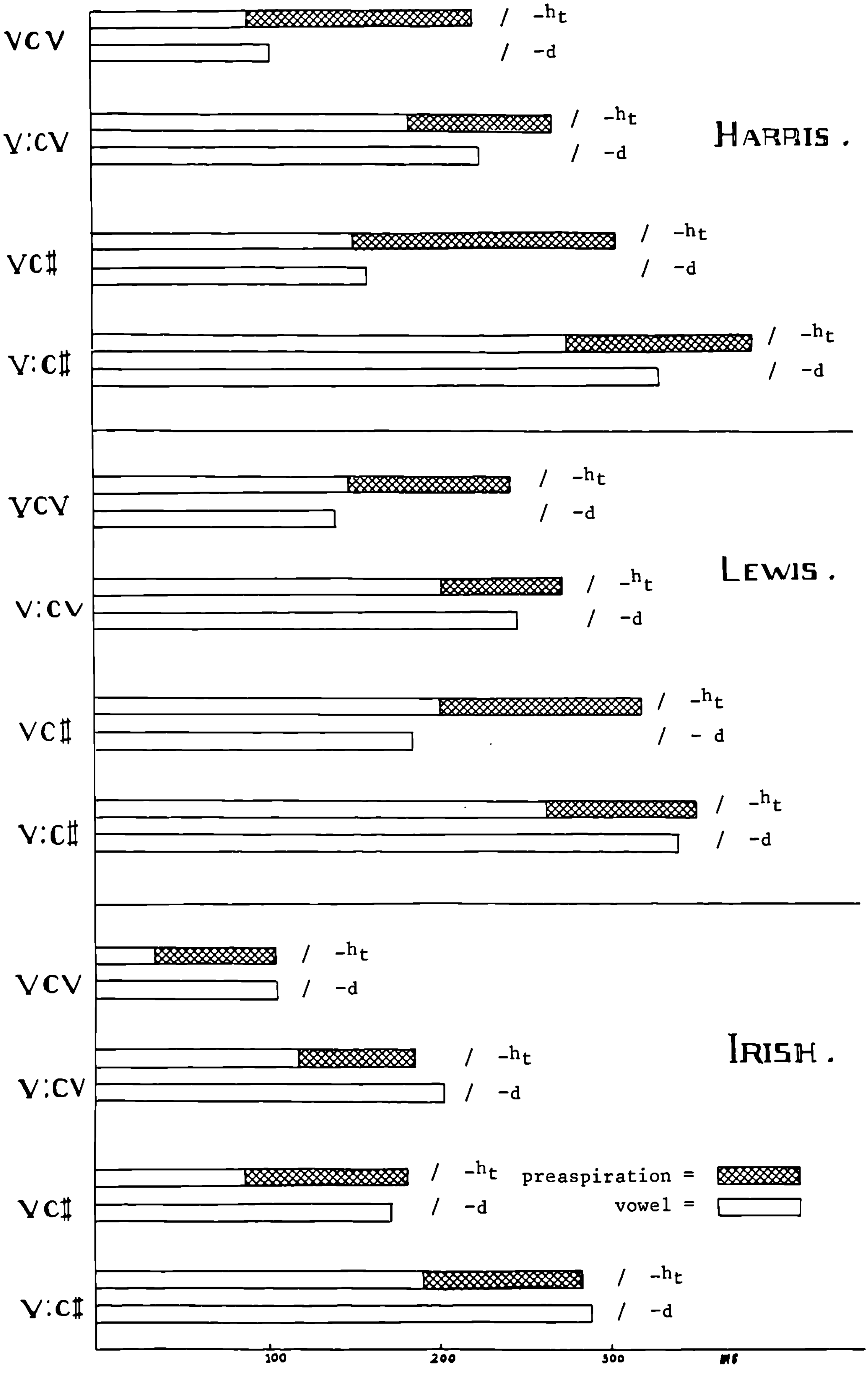


Figure 2.19 Vowel durations preceding fortis /t/ and lenis /d/ stops (data set 3) N = 15

stop or with an unpreaspirated stop will be of roughly equal duration.

Scottish Gaelic

The differences in vowel durations are substantially less in the Scottish Gaelic dialects than in Irish. And as seemed to be the case in the earlier sets of data presented, the phonological vowel length appears to be relevant to the use of this feature. In short vowel environments, differences are very small, and for the Lewis speaker are in fact in the reverse direction from the general trend.

Unlike Irish, there does not seem to be any strong tendency to equalise syllable length; in both the Harris and the Lewis data, the duration of the vowel preceding the lenis stop is considerably shorter than the sum of vowel and preaspiration in the fortis series. Preaspiration can clearly not be described as an "earlier glottal opening" for these dialects.

The significance of all the observed durational differences in vowels before lenis and fortis stop was tested on the basis of a t-test. The results are presented in Table 2.4.

Table 2.4 Differences in vowel duration preceding fortis and lenis stops: t-statistics

Environment	Harris	Lewis	Irish
VCV	+4.19	-1.82	+26.36
V:CV	+8.14	+6.70	+12.82
VC#	+2.40	-2.90	+18.98
V:C#	+12.21	+8.86	+17.14

The critical values for the t-statistic, with significance levels in parentheses, are approximately 1.345 (.10), 1.761 (.05), 2.145 (.025), 2.624 (.01) and 2.977 (.005).

Note: A negative t-statistic indicates that the mean vowel duration before the lenis stop is shorter than before the fortis stop. A positive t-statistic shows the opposite. It is the absolute value of the t-statistic which indicates its statistical significance.

From this table it is clear that all the observed differences in vowel duration are statistically significant, indeed highly so in all but the Lewis data in VCV. This is not surprising for Irish, given the extent of the difference in the average values. It is, however, surprising in the case of the short vowel environments for the Scottish Gaelic dialects, where the observed average differences were quite small (see Figure 2.19).

The effects of vowel length on the use of vowel-duration differences

It has already been noted above in discussing Figures 2.18 and 2.19 that the phonological length of the vowel may be relevant to the use of this feature in Scottish Gaelic. With long vowels the difference in duration is always at its greatest; with short vowels, the difference is either very small or negative. Once again, t-tests were carried out to test the effect of phonological vowel length on the extent to which durational differences will be found before fortis and lenis stops. The results are reported in Table 2.5.

Table 2.5 <u>The effects of phonological vowel length on the extent to which durational differences are found before fortis and lenis stops: t-statistics.</u>

Vowel durational differences in	Harris	Lewis	Irish
V:CV versus VCV	+6.21	+6.02	+2.79
V:CV versus VC#	+9.27	+7.66	+1.63

The critical values for the t-statistic, with significance level in parenthesis are, approximately, 1.345 (.10), 1.761 (.05), 2.145 (.025), 2.624 (.01) and 2.977 (.005).

All of these t-statistics support the hypothesis that the durational differences are statistically significant, and with the exception of Irish in final position, they are all highly significant. It appears therefore that the "vowel duration" feature is much more in evidence in long vowel environments for these languages.

It is rather interesting to note the strong effect of phonological vowel length on the use of vowel duration differences, in the Scottish Gaelic dialects especially. As will perhaps be recalled from Section 2.2.4, phonological vowel length also affects the duration of preaspiration in these dialects (again the effect is less strong and not fully present for Irish, which has considerably shorter preaspiration in any case).

Taken together, these observations would seem to indicate that in the Scottish Gaelic dialects, there is most use of the vowel-duration differences in those environments where there is least preaspiration.

A correlation of preaspiration duration with vowel duration differences was carried out for Harris and Lewis Gaelic. This was done for medial and final stops separately, combining, in each case, the data on long and short vowels. The results are reported in Table 2.6. The first column of numbers contains the simple correlation coefficients between the corresponding pairs of variables. However, the appropriate test statistic to test the statistical significance (from zero) of the correlation coefficient would require a large number of observations in order to be reliable. For this reason, an alternative indirect, but inherently more reliable, method of testing the statistical significance of the correlation coefficients was undertaken.

Analysis of variance regression techniques were applied to each pair of variables. The particular method used was Ordinary Least Squares, and this is described in Wonnacott and Wonnacott (1972). The regression coefficients (column 2, Table 2.6) are analogous to the correlation coefficients and can be interpreted in a similar manner, but they are not identical. A t-test of the statistical significance of these regression coefficients is reliable for the number of observations in the data set, and these can be used to infer the statistical significance of the correlation coefficients.

Table 2.6 <u>The correlation of vowel duration differences (before fortis and lenis stops) with preaspiration duration, in medial and in final positions.</u>

	Simple Correlation Coefficient	Regression Coefficient	t-statistic
Correlation of vowel duration difference and preaspiration duration in			
Harris			
medial position	-0.583	-0.662	3.79
final position	-0.810	-0.736	7.30
Lewis			
medial position	-0.575	-0.411	3.58
final position	-0.563	-0.214	3.47

The critical values for the t-test with 30 degrees of freedom, with significance level in parenthesis are, approximately, 2.457 (.01), 2.042 (.025), and 1.697 (.05).

Note: The negative sign indicates a negative correlation.

It is clear from Table 2.6 that there is a highly significant, negative correlation between preaspiration duration and the vowel duration differences preceding fortis and lenis stops. Note that the statistical significance is inferred from the t-statistics in Column 3, and that this is quite distinct from the magnitude of the correlation coefficients themselves. It would therefore seem to be the case that the vowel duration difference is maximal when there is least preaspiration, and vice versa.

2.6.3 Conclusions

As discussed in the introduction to the section, two possible functions could motivate a longer vowel duration before lenis stops. In the first instance the difference in vowel duration could be a compensatory effect to reduce the durational disparity in syllables with and without preaspiration. Alternatively, the function of the vowel duration difference could be to boost the opposition perceptually. If the first function is the more important, then one would expect vowel duration differences to be maximally present where preaspiration is longest. On the other hand, if the difference is perceptually motivated, one would expect maximal differences where preaspiration is shortest.

The results reported here suggest that the vowel duration differences are perceptually important. First of all, Irish, the least preaspirating of these languages, has the most extensive and most consistent (across environment) use of this feature. One might also recall that Irish also had greatest use of some of the other features, such as voicing of the lenis, or postaspiration of the fortis (in VCV).

In the Scottish Gaelic dialects there is greatest use of this feature in the long vowel environments where there is least preaspiration. Here the use of the feature is likely to be perceptually motivated, rather than by a need to compensate the duration of syllables with and without preaspiration. If it were a question of a compensatory effect, one should expect substantial vowel duration differences in those environments where preaspiration is longest, e.g. with short vowels. This effectively also means that syllables with and without preaspiration can have rather disparate durations in Scottish Gaelic: there is clearly no very strong tendency to equalise their durations.

2.7 SUMMARY OF CONCLUSIONS ON THE USE OF DURATIONAL FEATURES IN OPPOSITIONS INVOLVING PREASPIRATION

Some of the main findings regarding the temporal features in these oppositions can be summarized with reference to Figure 2.20, compiled from the data sets 1, 2 and 3. In this figure the use of each feature is tabulated for the three positional variants investigated (represented as three vertical lines). Features relevant to the short vowel environments are tabulated to the left of a particular line, and those relevant to the long vowel environments are tabulated to the right. This is done separately for Icelandic, Harris Gaelic, Lewis Gaelic and Irish. The feature numbers are consistent with those given in Chapter 1.10:

1) voicing
2) postaspiration
4) preaspiration
5) stop closure duration differences
6) differences in duration of preceding vowel

(VOT labelled feature 3 in Chapter 1.1.0. Durational values for this feature are covered by features 1 and 2 above.)

The vertical height at which the number representing a particular feature has been placed indicates its temporal contribution to the distinction. Thus, to take the example of the Harris values in Figure 2.20, for initial position the only differentiating feature between the lenis and fortis series is the presence or absence of postaspiration - indicated by the numeral "2". It has

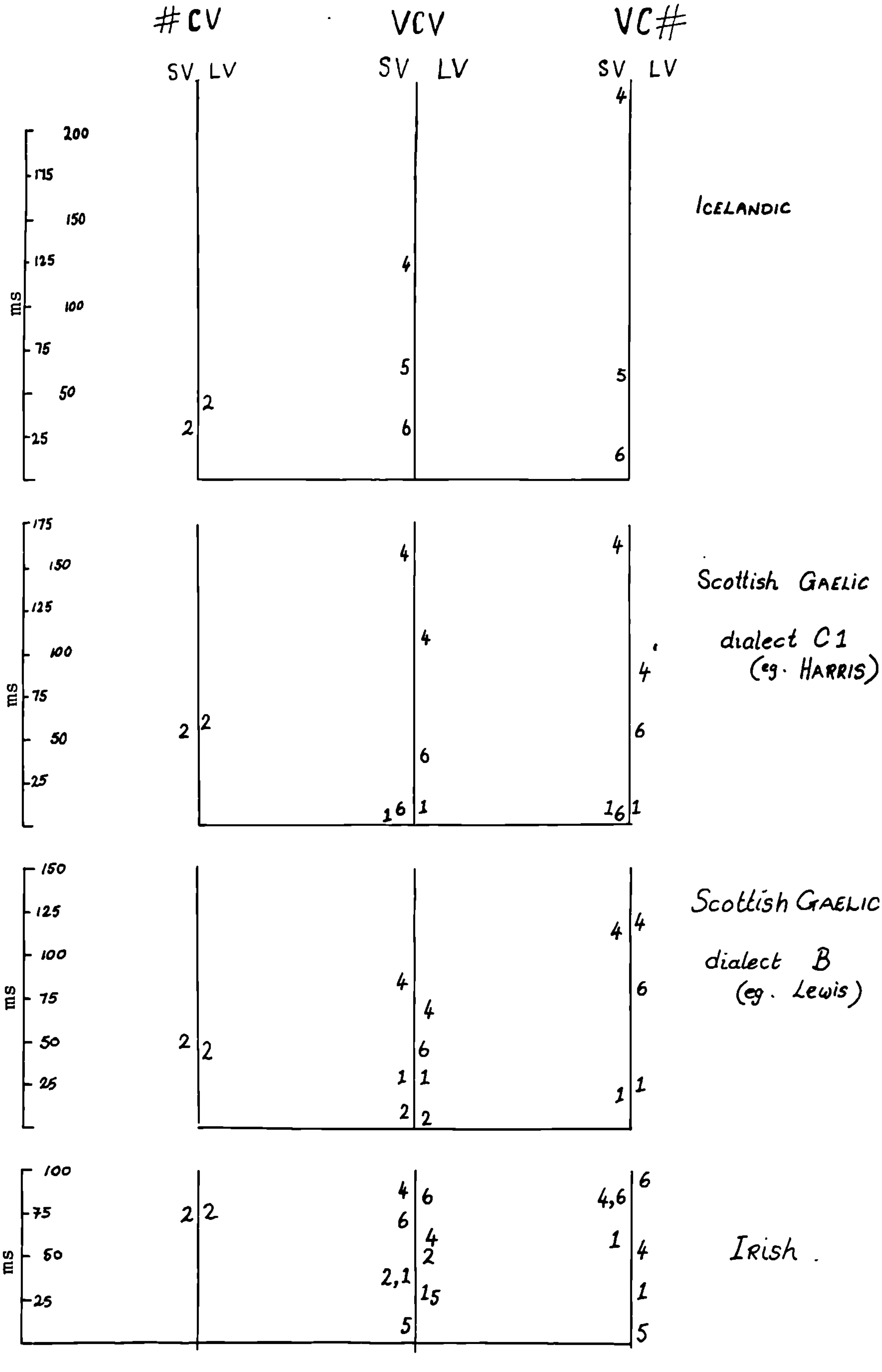


Figure 2.20 The temporal contribution of features 1 - 6 in the stop oppositions:

1 = voicing
2 = postaspiration
4 = preaspiration
5. Difference in stop closure duration
6. Difference in preceding vowel duration

an average duration of 55ms before short vowels and of 60ms before the long. In medial position after long vowels, the numerals "1" and "4" represent absolute values of voicing (in the lenis stop) and of preaspiration (of the fortis) respectively. Their average absolute values can be read off from the scale on the left hand side. The numeral "6", at a value of 35ms here, represents the average difference in vowel duration before the two series of stops.

It is immediately clear that there is a gradation from Icelandic to Harris Gaelic (dialect C1) to Lewis Gaelic (dialect B) to Irish. In that order the extent of use of preaspiration decreases (feature "4"), and the extent of use of other features increases. Irish would seem to be particularly rich in the use of these features: all of features 1, 2, 4, 5 and 6 seem to be involved to some extent in the opposition. The most important in durational terms for postvocalic positions would seem to be features 4 and 6.

The apparent multiplicity of features, especially in a language like Irish, must prompt questions regarding their perceptual relevance. If these are all perceptually relevant as cues to the opposition, this raises the question as to how numerous cues can be perceptually integrated to yield a binary linguistic percept. This question is again raised in Chapter 5, where a hypothesis is put forward which attempts to explain the type of integration that may be involved.

To sum up briefly some of the main conclusions of this chapter:

- Preaspiration can be very long. However, its duration is highly variable and seems to be determined by factors such as position and vowel length environment.

- Preaspiration can be seen as made up of two portions; the breathy voiced transition (BV) and the truly voiceless portion (H). Insofar as one can ascertain from the data, the BV portion is an unavoidable aerodynamic/mechanical effect of the transition from voice --> voicelessness.

- The data prompt questions regarding the perceptual relevance of the BV portion of preaspiration, particularly as the H portion is often very short. The breathy voiced transition could be simply cancelled out by our perception.

- Generally speaking, the shorter the duration of preaspiration for a particular language, dialect, or environment, the more use there is of the other durational features.

- The lenis stops in these languages do not exhibit a great deal of voicing. In Icelandic there seems to be none, in Irish the stop is half-voiced (in medial and final positions). The Scottish Gaelic dialects fall between these two. Across these language, there seems to be an inverse correlation between the degree of voicing in the lenis stop, and preaspiration of the fortis. In the languages studied, these oppositions seem to derive in all cases from an older opposition of voiced and voiceless geminates. Thus it appears that there is an intimate link between the loss of voicing proper and the development of preaspiration. This topic is broached again and developed in Chapter 4.1 which deals with the historical evolution of preaspiration.

- Glottographic results indicate that the voicing present for the lenis stops of Irish differs in kind from that observed in Harris Gaelic, in that the vocal folds appear to remain adducted, at least in medial position. For the lenis stops of Harris Gaelic (and of Icelandic) there is clear glottal abduction. One would tend to conclude therefore that the devoicing observed in intervocalic position for Irish lenis stops is due to passive mechanisms, i.e. aerodynamic factors.

CHAPTER 3

THE EFFECTS OF DIFFERING STRESS LEVELS ON CONTRASTS WHICH INVOLVE PREASPIRATED STOPS

3.0 INTRODUCTION

This chapter attempts to broaden the scope of the last, by looking at some of the ways in which "preaspirating" oppositions are affected when the stress level changes for the syllable in which it occurs.

The first subsection of this chapter, 3.1, concentrates on the temporal consequences of variation in stress level, and in particular on the consequences for the duration of preaspiration of the fortis stop and voicing of the lenis. The data presented in this section are data set 7, as tabulated in Table 1.1. In this data set, stressed and relatively unstressed environments were compared for Harris and Lewis Gaelic and for Irish. By "stressed" is meant that the syllable in question carries the main sentence (nuclear) stress; by "relatively unstressed" is meant that the same tokens occur in the immediately prenuclear position. Further details on the data recorded are given in section 3.1.1.

In the second section of this chapter, 3.2, some electroglottographic data are presented for stops of Icelandic and Irish. These recordings included samples which compared tokens with and without nuclear stress as just described; for Irish, there were also utterances where normal nuclear stress was contrasted with emphatic stress. More precise details on the nature of the data are given in section 3.2.1. For ease of reference in the following text, "relatively unstressed" will simply be called unstressed; tokens with normal nuclear stress will be referred to as stressed (or normally stressed, to differentiate them from emphatically stressed tokens). The results presented refer to data sets 8 and 9 in Table 1.1. Information on subglottal pressure, which is also referred to in this section, was obtained from data sets 10 and 11 as well as from data set 9a) which included a Ps signal. The focus of interest in this section concerns the more theoretical question of how glottal control of aspiration and voicelessness is effected, given the temporal and aerodynamic changes that occur with stress variation.

There were a number of reasons for the inclusion of some data where the stress level was varied. The first was simply a matter of descriptive adequacy. Aerodynamic factors are known to be crucial in the production of voicing and aspiration. As aerodynamic conditions may vary with the stress level within and between utterances, one might expect considerable variability at the phonetic level in the realisations of phonological voicing oppositions. Instrumental work, for obvious reasons, tends often to favour well-differentiated tokens carrying main sentence stress (and most frequently in word initial position). All the data in Chapter 2 involved words with main sentence stress, whether uttered within frames or as citation forms. This is typical laboratory procedure and does give useful information on the realisation of a contrast in its optimal, i.e. maximally differentiated, form. One inherent danger with this approach is that the results are often overgeneralized and one might forget that in running natural speech many, if not most, of the tokens will not be thus optimally produced nor will they necessarily carry main sentence stress.

Another reason for the interest in the description of relatively unstressed forms, concerns the possible link between such forms and lenition, or more specifically, sonorisation. In the following chapter a hypothesis is discussed to the effect that relatively unstressed and rapidly uttered speech tokens may provide a triggering environment for lenition. One can expect synchronic and diachronic variation to be related. If realisations of voicing and aspiration vary with stress variation, the observable synchronic alternations may provide some insight into the process of the diachronic changes which occur in voicing oppositions.

A further interest of the cross-stress data has been mentioned briefly above. It was hoped that the electroglottographic recordings might provide some insight into the question of how aspiration (and voicelessness) is glottally controlled, and into two rather different control models proposed by Kim (1970) and Löfqvist (1980). These are elaborated upon in section 3.2.

3.1 TEMPORAL CONSEQUENCES OF VARIATION IN STRESS LEVEL FOR PREASPRIATING OPPOSITIONS

3.1.0 Introduction

Of particular interest in this section was the question of how the durations of preaspiration (of the fortis) and voicing (of the lenis) might be affected by changes in the stress level of the syllable in which a particular segment is uttered. In the case of voicing proper, if the vocal folds are adducted during the lenis stop (as appears to be the case of Irish), it is not self-evident how its duration should be affected by stress level. On the one hand, it would seem reasonable to expect that a higher stress level would facilitate voicing continuation and lead to longer voicing duration. Vocal fold vibration ceases when the transglottal pressure drop falls below a critical level, approximately 2 cm Aq (Catford, 1977:29). One can expect a higher subglottal pressure in a stressed than in an unstressed syllable (Ladefoged, 1967:20; for more discussion on this expectation, see below). One could perhaps therefore hypothesize that for the voiced stop in the unstressed syllable, the transglottal pressure drop will fall below the critical level more quickly. This suggestion is being put forward as a rather weak hypothesis. Against it, one could conceivably argue that, as oral pressure (Po) will also build up at a more gradual rate at lower stress levels, neutralization of the transglottal pressure drop might not in fact be hastened. Furthermore, viewed from a perceptual angle, even if vocal fold vibration ceases earlier in the unstressed condition, if the consonant's closure duration is also shortened, the stop may still yield an equally "voiced" percept. As regards preaspiration, one should probably expect shorter durations in the untressed syllable. The duration of postaspiration is known to be affected by stress, with average values typically longer in stressed environments (see for example Keating et al., 1983) If there is shortening in the unstressed syllable, the question which springs to mind concerns how the relative proportions of the BV (breathy voiced) and H (truly voiceless) portions of preaspiration might be affected.

It was suggested in Chapter 2 that the breathy-voiced portion of preaspiration is a non-avoidable aerodynamic/mechanical artefact, and not under voluntary control. If this is the case, one must consider how its duration might be affected by a lower Ps and a lower rate of air flow through the glottis. If one assumes that the glottal gesture remains constant across stress changes, then one should probably expect vocal fold vibration to cease more quickly in the unstressed syllable. At the very least, one should probably expect a reduction in the duration of NV, i.e. the portion of BV for which relatively high amplitude voicing persists.

If, on the other hand, the BV interval is under voluntary control, then one should probably expect that any shortening of preaspiration duration would be reflected equally in the durations of the BV and of the H portions.

3.1.1 Some further details on data and instrumentation

The data presented in this section (data set 7 in Table 1.1) involved recordings made of Harris and Lewis Gaelic and of Irish. They consisted of the following nonsense syllables:

/b a ^{h} t/

/bad/

/ba:^{h}t/

/ba:d/

These were inserted into the following two frames, and read so that frame 1 alternated with frame 2.

1. Sc. Gaelic: "Thà '-- ann". Irish: Tá '-- ann".
   gloss: "There's a -- there.
2. Sc. Gaelic: "Thà -- 'àlainn ann". Irish:"Tá --'álainn ann".
   gloss: "There's a lovely -- there".

The purpose of these frames was to ensure that the words would carry nuclear stress in frame 1, but be in relatively unstressed prenuclear position in frame 2.

Instrumentation and Segmentation

These recordings were carried out in the Royal Hospital for Sick Children, Edinburgh with the assistance of Dr. J. Anthony. The experimental configuration included a laryngograph as a means of obtaining information on voicing, rather than a microphone inside the airflow mask or a larynx microphone as was used in the other establishments (see description of equipment in Chapter 1.3). An external microphone was included in this configuration, but as there was a high level of background noise, this was not used for segmentation.

The use of the laryngograph as an indicator of voicing had certain consequences for the measuring of the breathy voiced (BV) interval of preaspiration. Figure 3.1 shows a typical recording made with this experimental configuration, and will serve to illustrate this discussion. As in Chapter 2, preaspiration was measured from the point where the oral airflow trace rose sharply. The laryngograph trace did not show, as did the earlier microphone traces (see for example Figure 1.6), a continuation of relatively high amplitude voicing for some time (here termed NV) followed by an interval of low amplitude voicing (LAV). Rather, the laryngographic trace tended to cut out more or less entirely at a given point designated "X" in Figure 3.1). This point was taken to represent the end of the NV period (time point B in Figure 1.6). The end of LAV (time point C in Figure 1.6) was ascertained from the quasi-disappearance of the "voicing" ripple on the unfiltered oral airflow trace, in conjunction with the (noisy and therefore less useful) external microphone labelled as "Y" in Figure 3.1. Therefore, the segmentation criteria for the NV and LAV portions of preaspiration differ somewhat from those used in Chapter 2. A comparison of data here with similar utterances for the same speaker in Chapter 2 showed that the BV interval, and especially the LAV portion, was longer when measured in this fashion. However, the focus of interest in this chapter is on changes which occur across stress level; as the

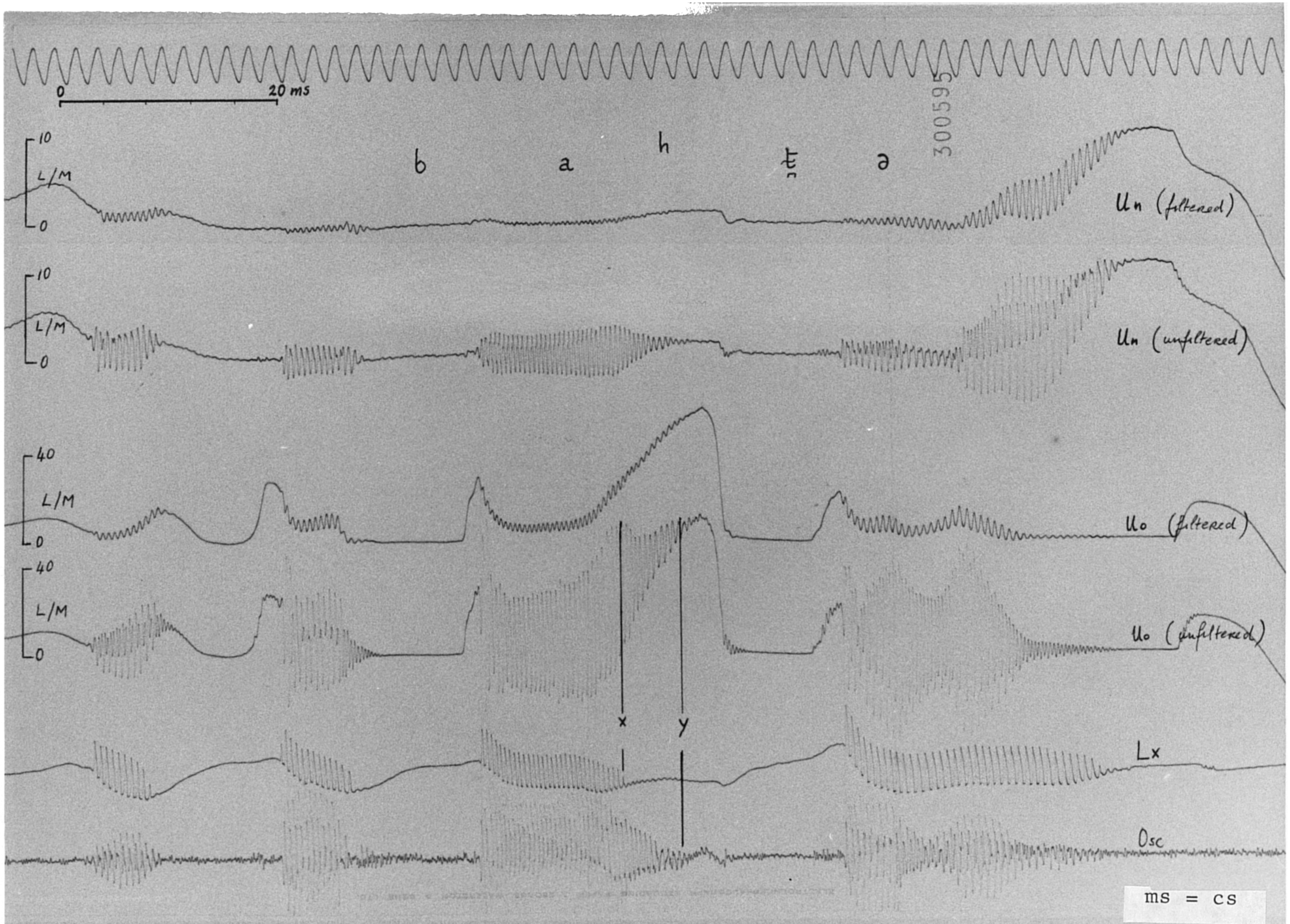


Figure 3.1

Mingogram of the word [bà^{h}tə], spoken by a Harris Gaelic subject in the carrier frame: "Thùirt e -- rium." Segmentation points x and y are discussed in text.

Un = nasal airflow
Uo = oral airflow
Lx = laryngogram
Osc = audio oscillogram (from external microphone)

Lx = laryngogram
Osc = audio oscillogram (from external microphone)

measuring criterion is internally consistent, the slight differences with Chapter 2 should not effect the comparisons of interest here.

Voicing proper during the stop was only measured for Irish, this being the language where devoicing is most likely to be "passive" (i.e. aerodynamically induced) rather than the result of active vocal fold abduction. As was seen in Chapter 2.3.3, non-pausal lenis stops appear to have an adducted vocal-fold configuration. The duration of voicing was also ascertained from the laryngograph signal.

3.1.2 Results

Figure 3.2 presents the average durations of vowel, preaspiration and stop closure for the words containing fortis (preaspirated) stops. In this figure, values for the unstressed condition are presented immediately under the stressed value to facilitate comparison. The percentage figures alongside the unstressed values indicate what they represent as a percentage of the stressed ones. Figure 3.3 shows in a similar fashion values for vowel and stop closure durations in the words containing lenis stops. For the lenis stops of Irish, the duration for which vocal fold vibration continues is indicated by black corrugations.

VOWEL AND FORTIS STOP

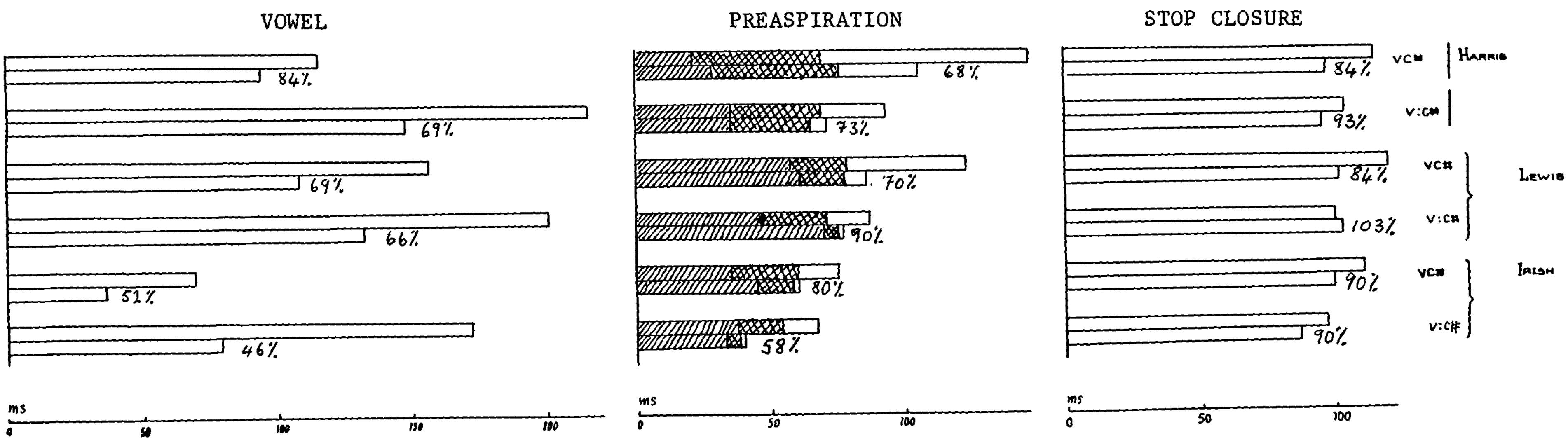


Figure 3.2 Average durations in words with fortis stops. Unstressed values are placed immediately beneath stressed values; percentage values indicate (unstressed ÷ stressed) x 100

N for stressed tokens = 12(Sc.G.)
= 10(Irish)
for unstressed tokens = 10(Sc.G.& Ir.)

For preaspiration durations (hatched) =NV; (cross-hatched) =LAV (blank) =H

Relative reduction in stop, vowel and preaspiration durations

In Figure 3.2, looking at the amount of reduction for the vowel, preaspiration and stop closure, it is clear that the most resistent to shortening is stop closure. Similar greater shortening of the vowel than of stop closure is also evident for the vowel and lenis stop sequences, as can be seen in Figure 3.3. Taking both lenis and fortis stops into account, the closure durations for the unstressed show only a slight reduction - to about 92% of the stressed forms. For the vowels, and for preaspiration durations, the durational consequences of destressing are more substantial - the overall average reduction in vowel durations (in Figures 3.2 and 3.3) is 69%; preaspiration values reduce to 73%.

Vowels show the greatest amount of reduction in the unstressed condition. Long vowels reduce more than do short vowels. Even if one considers the reduction, not in absolute terms, but as a percentage of the duration of the stressed long and short vowels, there is still a noticeable difference with long vowels shortening to 62% when unstressed, as compared to 76% for short vowels. The length distinction for vowels is therefore less well maintained in unstressed environments.

The most striking case of long vowels shortening more than the short, is in Irish, and particularly with the lenis stops. In this dialect of Irish, there is quite a difference in the qualities of the long /a:/ and short /a/ phonemes; phonetically

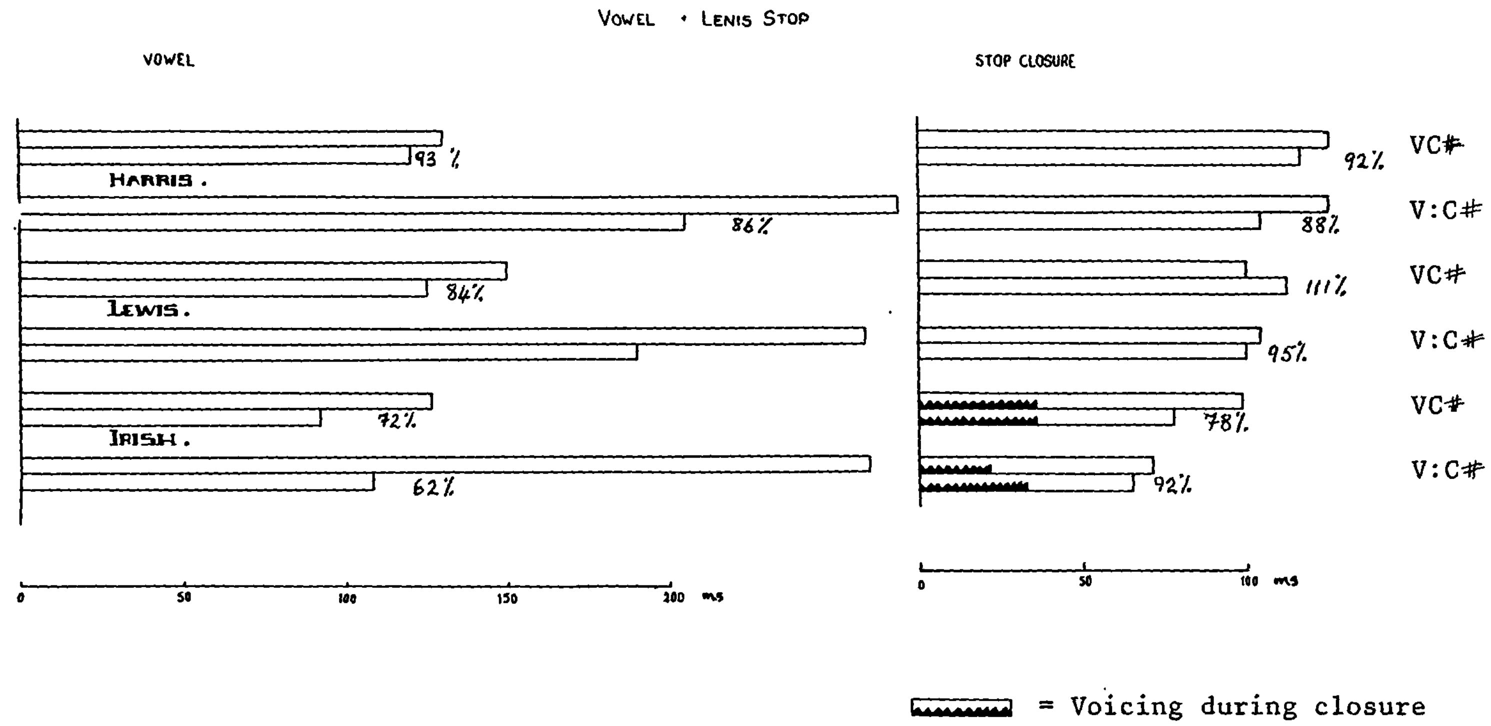


Figure 3.3 Average durations in words with lenis stops expressed in a similar fashion to Figure 3.2

N for stressed tokens = 12(Sc.G.); 10(Ir.)

for unstressed tokens = 10(Sc.G.& Ir.)

they are [æ̆:] and [a]. For the Scottish Gaelic dialects looked at here, the qualities of the long and short phonemes are very similar. It may be, that the quality difference in the Irish case allows more scope for reduction in the durational *difference*.

Comparing Figure 3.2 and 3.3, it would appear that there is a greater reduction in the vowels before fortis (here preaspirated) stops than before the lenis. The only exception to this is in Irish in the environment of long vowels. This would have the consequence that the use of a vowel duration difference as a cue to the fortis/lenis opposition may be heightened in the unstressed environment.

Preaspiration

The shortening of preaspiration durations in unstressed position is considerable also, but slightly less than that of the vowel. In Figure 3.2 there is the following breakdown of the component parts of preaspirtion, measured from the data in the way described above. The truly voiceless portion is unshaded (H) and the breathy voiced portion is shaded (BV). Within the BV portion, the duration of the relatively high amplitude voicing (NV) is shown by slashes [////], and the low amplitude voicing (LAV) is shown by cross-hatching [xxxx].

It is clear from this figure that the reduction in preaspiration duration is due almost entirely to a shortening of the voiceless (H) portion. The duration of the breathy voiced transition (BV) remains relatively constant. Looking again at the unstressed durations as a percentage of the stressed ones, one gets the following:

	Environment	PREASPIRATION BV	H
Harris	V -	105%	40%
	V:-	94%	25%
Lewis	V -	101%	16%
	V: -	105%	10%
Irish	V -	102%	8%
	V: -	74%	3%

In most cases the duration of the BV transition is not in fact shorter and can even be slightly longer for the unstressed condition. The voiceless H portion on the other hand is always substantially reduced and is at times almost altogether missing. It is also clear that the duration for which relatively high amplitude voicing continues (NV) is much the same, and certainly not decreased in the unstressed environment.

It was also clear in Chapter 2 that when preaspiration is shortest (for example in Irish, or more generally in Scottish Gaelic when preceded by a long vowel), it involves a shorter duration of H much more than of the BV portion. The potential for shortening of H as compared to BV does seem to reinforce the suggestion made in Chapter 2 that BV is an unavoidable aerodynamic/mechanical effect of the voiced --> voiceless transition.

It was suggested in section 3.1.0 that even if the BV portion of preaspiration constitutes an aerodynamic/mechanical artefact of the devoicing gesture, one might expect it to have a longer duration in stressed than unstressed syllables. This is because subglottal pressure can be expected to be higher at a higher stress level (for more on this see 3.2.3). However, the assumption underlying this suggestion was that the glottal opening gesture is constant across stress conditions. As will be seen in the second half of this chapter, such an assumption may not be warranted.

Voicing of lenis stops

Looking at the duration of voicing in the Irish stressed/unstressed stops in Figure 3.3, one finds that it is the same or slightly longer in the unstressed condition. The length of the preceding vowel may play some role: voicing would appear to continue slightly longer in the unstressed syllables which have a long vowel. In the environment of short vowels, voicing duration is unaltered.

In the unstressed condition, as stop closure durations are shorter and the durations for which voicing continues are the same or longer, the voiced part of the stop is proportionally greater, and may be perceptually more important. If the duration of voicing is presented as a percentage of the stop closure for each condition one gets the following:

Environment		Voicing duration as a % of closure duration
V -	+ stress	36%
	- stress	47%
V: -	+ stress	38%
	- stress	51%

The fact that the duration of voicing in the Irish stops is not shorter in the unstressed condition (and is therefore proportionally longer), may offer some support for the suggestion that the observed voice breaks of Irish may be attributable to "passive" aerodynamic factors. If the devoicing were "active" (i.e. brought about by voluntary muscular adjustment) one should probably expect the duration of voicing to remain a fairly constant percentage of the stop closure duration.

3.1.3 Summary of the temporal consequences of destressing

Syllables in unstressed environments are of overall shorter duration than when in stressed environments. There is considerably more shortening of the durations of the vowel and of preaspiration than of stop closure.

The most dramatic consequence of destressing is the very great shortening of the voiceless portion of preaspiration. In the unstressed environment there is usually very little of truly voiceless preaspiration left. This fits in with the pattern noted in Chapter 2: in dialects or environments where the duration of preaspiration is comparatively short, this seems mostly to be reflected in the duration of its voiceless portion (at the expense of H as it were). The duration of the BV portion is very little affected and the duration of the sub-part with high amplitude voicing tends to be much the same or even fractionally longer when the stress level is relatively lower. It would seem that the breathy voiced transition is the least compressible section of the word. This fact would tend to support the viewpoint that it is a non-avoidable consequence of the elastic vibrating mass of the vocal folds taking a necessary amount of time to move from voicing to voicelessness, given that the vocal tract is open and there is nothing to impede the transglottal flow.

The fact that the truly voiceless portion of preaspiration (H) is subject to shortening and that the breathy voiced component (BV) is not, raises a question (already asked in Chapter 2) regarding the perceptual relevance of the two components. If BV is no more than a mechanical product, a non-avoidable transition from voice to voicelessness, one must consider the possibility that our perception may cancel it out, in a way similar to which it cancels out the period of what must be breathy voice at the end of prepausal vowels. But if this is the case, questions arise regarding the perceptibility of the preaspirated stop in those dialects or phonetic environments where there is very little voiceless aspiration present.

These questions form the starting point of the first perceptual experiment carried out in Chapter 5. The results of that experiment would seem to indicate that the voiceless (H) portion of preaspiration can be dispensed with entirely and a preaspirated stop will still be unambiguously identified.

In nearly every case, the unstressed vowel before the lenis stop showed less temporal reduction than did the unstressed vowel before the fortis (preaspirated) stop. This may mean that vowel duration differences may play a more important role in maintaining the phonological contrast in unstressed positions. Furthermore, for Irish at any rate, the duration of voicing in the lenis stop is as long or longer in the unstressed position. As stop closure duration is reduced, the perceptual importance of voicing may be heightened here.

It may therefore be the case that a reduction in the perceptibility of preaspiration in relatively unstressed environments, is compensated for to some degree by increased use of other features such as the vowel duration difference, or voicing in the lenis stop.

3.2 STRESS AND THE CONTROL OF VOICELESS AND ASPIRATED CONSONANTS: SOME GLOTTOGRAPHIC DATA

3.2.0 Introduction

This section presents glottographic data on voiceless and preaspirated stops in Icelandic and Irish in differing stress conditions. These data were recorded in the Phonetics Laboratory, Oxford University with the assistance of Dr. Ameen Al-Bamerni. The focus of interest here concerns the question of how glottal control of aspiration (and voicelessness) is effected. There are two current approaches to this problem, which make different but potentially complementary claims:

> On the basis of an X-ray study of Korean stops, Kim (1970) has hypothesized that the presence, absence and duration of aspiration are directly related to the degree of glottal opening during stop closure. More specifically, the degree of glottal opening at oral release should determine aspiration duration. Catford (1977), working from Kim's data, gives an approximate graph showing the relationship between glottal aperture during stop closure and aspiration duration (shown as voicing lag). This is shown here as Figure 3.4.

More recently, Löfqvist et al. (1981) have questioned whether speakers are in fact controlling the degree of glottal opening as a means of determining the duration of aspiration. They suggest that "voluntary control of the size of glottal opening is rather

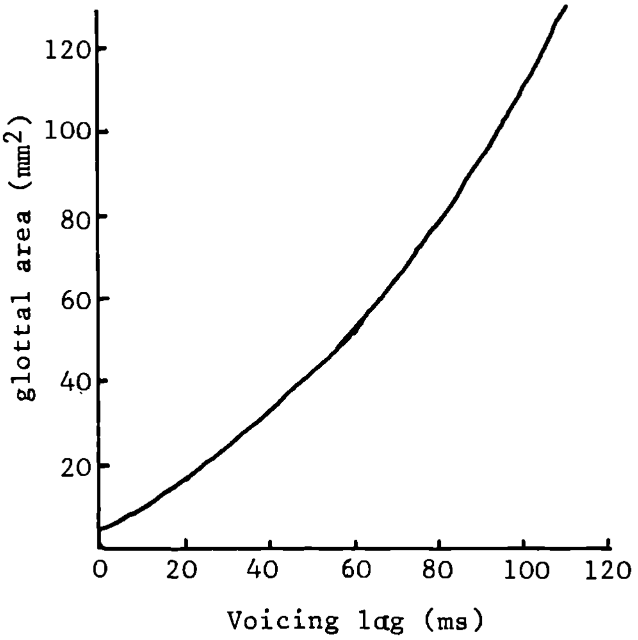


Figure 3.4 Relation of voicing lag to glottal area (from Catford 1977)

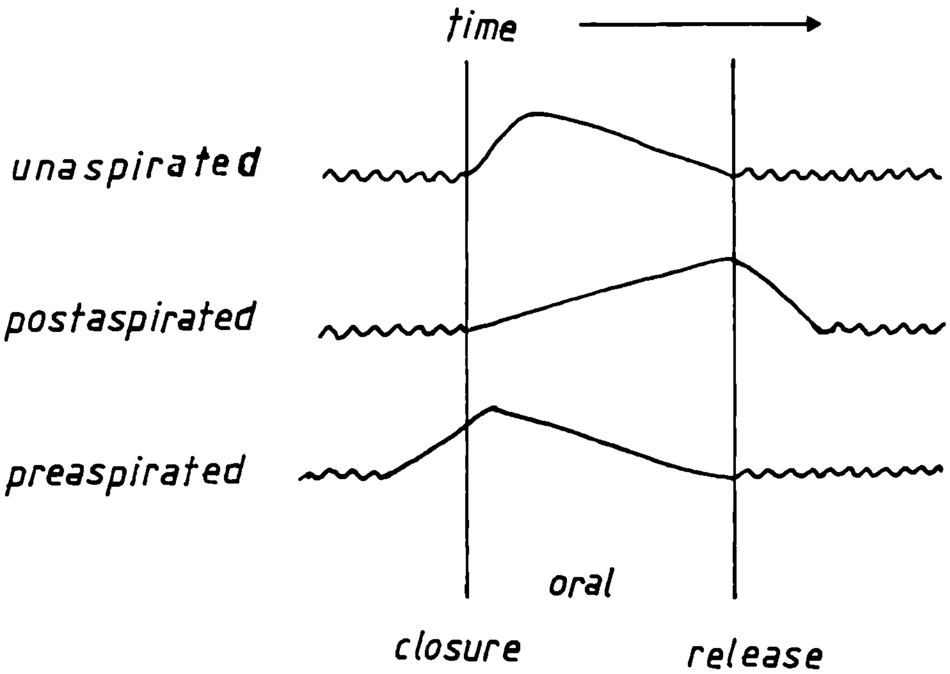


Figure 3.5 Timing relationships between laryngeal opening/closing and oral gesture closing/release

poor and that subjects are unable to make very fine graded adjustments along this dimension". (:265) Löfqvist (1980) further suggests that the glottal gesture is a relatively fixed ballistic opening/closing cycle; once peak glottal opening has been attained, the closing gesture tends to start immediately rather than maintain a static open position. Löfqvist of course does not deny that differences in glottal opening, especially at stop release may correlate with aspiration duration. However he hypothesises that such differences may simply result from the different timing relationships that pertain between the laryngeal opening and closing gesture and the oral closing and opening gesture in stop production:

> ... "timing appears to be the basic way in which the articulatory system solves the problem of controlling glottal opening at release and thereby the onset of glottal vibrations in relation to the explosion". (1980:486)

In Löfqvist's account, the difference between preaspirated, unaspirated and postaspirated stops can be entirely accounted for in terms of the timing of the laryngeal opening/closing gesture. If this starts before oral closure, preaspiration results. If it starts at oral closure, and if peak glottal opening occurs early during the stop closure, the stop is unaspirated; if peak glottal opening occurs late during closure, the stop is postaspirated. Peak glottal opening (PGO) Löfqvist argues, is an important index of the timing of laryngeal articulation. As the start of the adduction gesture occurs generally during stop closure, he concludes that no aerodynamic forces can be responsible for its initiation. Therefore, the timing of PGO in relation to stop closure and release should correlate with aspiration duration. In the case of postaspirated stops, the later the PGO, the longer the aspiration duration. For preaspirated stops, the converse should be true; one should expect earlier glottal opening to correlate with longer preaspiration duration. It follows from Löfqvist's account that, all else being equal, one might expect greater peak glottal opening for an aspirated than an unaspirated stop. These differences in glottal opening degree would however be secondary consequences rather than the primary control parameters. Löfqvist's schema is illustrated in Figure 3.5.

It was felt that a comparison of the preaspirated and unpreaspirated stops in these languages across different stress rates might provide a testing ground for these two models of aspiration control. As described in the earlier part of this chapter, the duration of preaspiration can vary considerably with changes in stress level, being much shorter in relatively unstressed than in stressed syllables. Therefore it is of interest not only to describe any differences there might be in laryngeal behaviour across stress level, but to consider also which of the two models might best account for such differences.

3.2.1 Linguistic materials

Icelandic:

In Icelandic, words containing the possible medial intervocalic bilabial stops were inserted into carrier frames whose purpose it was to ensure that the word was uttered at different stress levels. The words recorded were:

'V^{h}CV	lappa	[la^{h}pa]
'VCV	labba	[lap:a]
'V:CV	skapa	[ska:pa]

The frames used were such that the word in alternate frames did and did not receive main sentence stress. These were:

Frame 1 "Hann sagði 'lappa við mig". (He said lappa to me).

Frame 2 "Hann sagði 'ekki lappa við mig". (He did not say lappa to me).

Irish:

There were three subgroups in the Irish data. In the first, data set 9a), the medial fortis and lenis stops in the words [ba^{h}t^{h}a] bata (stick) and [bada] b'fhada (it was long) were looked at. These were inserted into a carrier frame, which was then repeated so that alternate repetitions of each of these two words received either normal sentence stress or emphatic stress.

"Dúirt sé '--- liom"
"He said --- to me".

In data set 9b) only the fortis stop in the word bata was looked at, and a further frame was used in addition to the above,

"Dúirt sé bata 'beag liom".
"He said small bata to me".

As sentence (nuclear) stress in this last frame falls on _beag_, _bata_ is in a relatively unstressed (pre-nuclear) position. The intention here was to get three stress levels on the word _bata_, in order to obtain an emphatically stressed token, a token with normal nuclear stress and a relatively unstressed token.

Data set 9c) was similar to that of 9a) in that normal sentence stress and emphatic stress were obtained, but this time for the initial fortis stop. The frame used was:

" 'Tá, a dúirt sé". (Yes, he said).

and as in data set 9a) _tá_ received normal sentence and emphatic stress in alternate repetitions of the sentence.

For terminological convenience, tokens occurring in relatively unstressed (pre- or postnuclear) positions will be referred to as _unstressed_. Those with the normal main sentence stress will be termed _stressed_, or _normally stressed_; those with emphatic stress will be labelled _emphatic_.

Measurements

The comparative amplitude of the glottographic waveform was measured at the following points:

- During the preceding vowel (except in the initial stops of data set 9c. This point was taken as a baseline from which the amplitude of the glottographic trace was measured.
- At consonant closure (for the preaspirated stops).

- At peak glottal opening(s). (The plural here refers to the fact that some of the Irish data exhibited more than single peak.)
- At consonant release.
- At voice onset.

The time intervals between these points were also measured, as well as the durations of pre- and postaspiration, and of the BV portion of preaspiration.

As it is not possible to calibrate the glottographic trace, caution is needed in interpreting glottal opening amplitudes from it. Factors which could cause artefacts in the results have been hopefully minimized. These are discussed later in conjunction with the results. At any rate, only large and consistent differences are here being considered as likely to be reliable.

3.2.2 Results

Icelandic: data set 8

Figure 3.6 shows results for the three Icelandic stops, [ʰp], [p:], and [p] under the two stress conditions, i.e. stressed and unstressed as explained in section 3.2.1. Glottographic amplitudes are shown on the vertical axis measured at the points mentioned above, in mm deflection on the mingograph paper. Time in ms is on the horizontal axis. All traces are lined up to the moment of oral closure, which is given the time value 0. For the

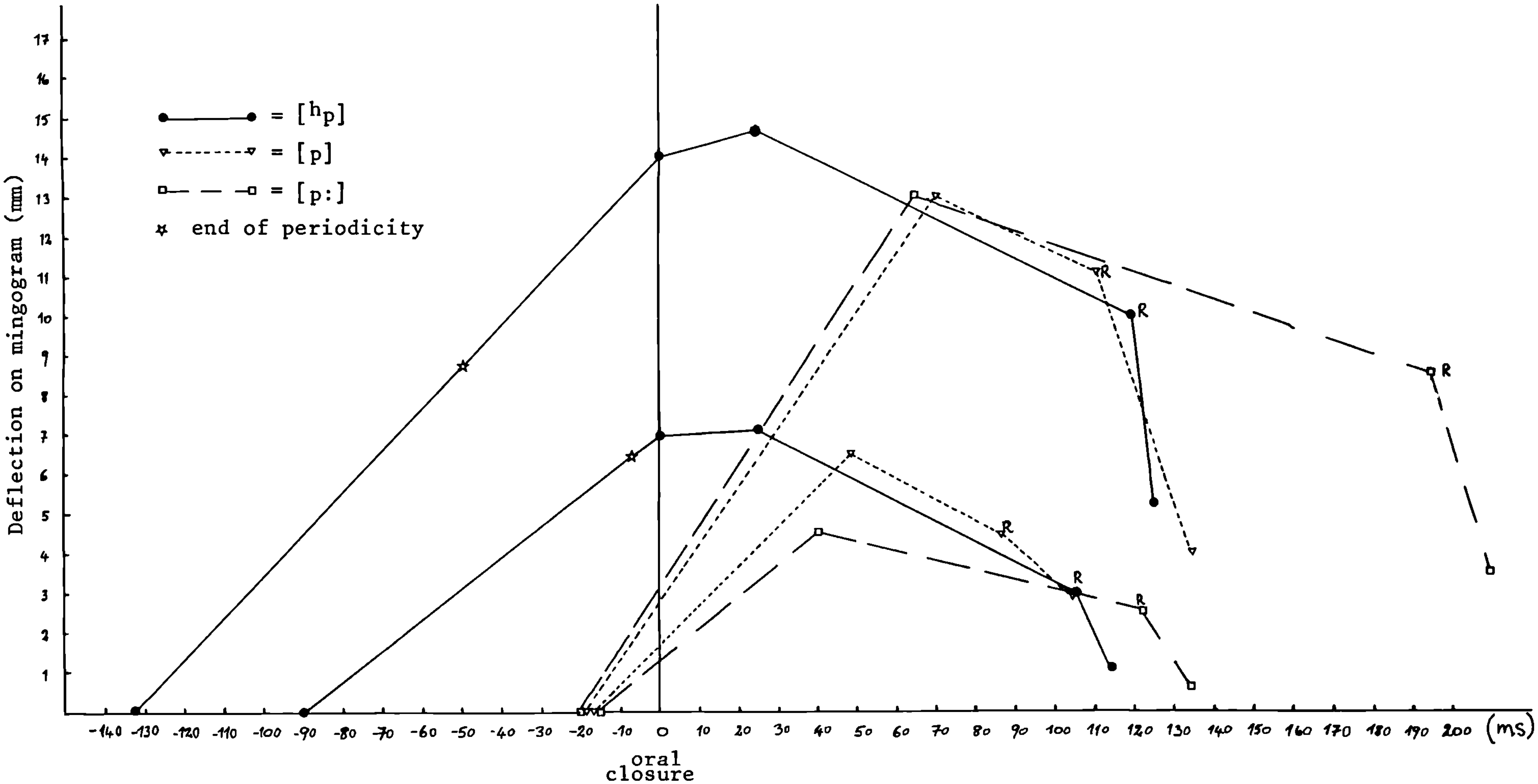


Figure 3.6 Averaged glottographic curves for Icelandic medial stops for stressed (higher peaks) and unstressed (lower peaks) environments N = 11 R = point of oral release

preaspirated stops, the point at which the vocal folds cease vibrating is marked by a star on the glottographic trace. Stop release is shown by a vertical stroke which cuts the glottal waveform.

The most striking feature in this figure is the very large difference in the amplitude of the trace between the two stress conditions. It is quite consistent and would suggest that peak glottal opening (PGO) is less for the unstressed tokens than for the stressed.

Although glottal area at stop release would seem to be also widely different for the two stress conditions, voice onset time, or postaspiration duration (measured from consonant release to voice onset) varies very little. Averages for all three stops in both stress conditions range only between 10 ms and 25 ms, and are not longer for the stressed than unstressed tokens, a fact which might seem somewhat surprising at first glance. The very short postaspiration durations here are likely to be below or just above the perceptibility threshold (see Chapter 1.3).

For the preaspirated stop, the time taken to effect the transition from voice --> voicelessness is fairly constant in both stress conditions. This point has been marked with a star in Figure 3.6. It would appear that the end of vocal fold vibration occurs at a greater amplitude of glottal opening in the stressed condition.

One might mention here some rather similar results concerning differences in glottal opening degree, which were reported recently by Andersen (1981). The investigation involved words uttered in isolation at different loudness levels. Greater glottal opening was found for the voiceless consonants in the words spoken at louder levels. Andersen's findings were largely based on measurements of the amplitude of electroglottographic signals.

The timing of PGO does not vary very much across the two stress levels. Although the duration of preaspiration is shorter in the unstressed condition, PGO does not in fact occur later than for the stressed.

Irish: data set 9a)

Figure 3.7 presents contrasting results for this data set in a fashion similar to the last figure. The data here contrast emphatic and normal sentence stress.

Tokens with emphatic stress invariably exhibit a double peak opening, as opposed to the single peak characteristic of the tokens with normal stress. (A single instance of what we might regard as a double peak appeared among the normally stressed tokens, but was omitted from the averages given.) Figure 3.8 is a sample recording, illustrating the type of double peak exhibited in the emphatic tokens. Although, as can be seen in Figure 3.7, the averages of the two peaks are not very different in amplitude, in many instances the peaks were not of equal

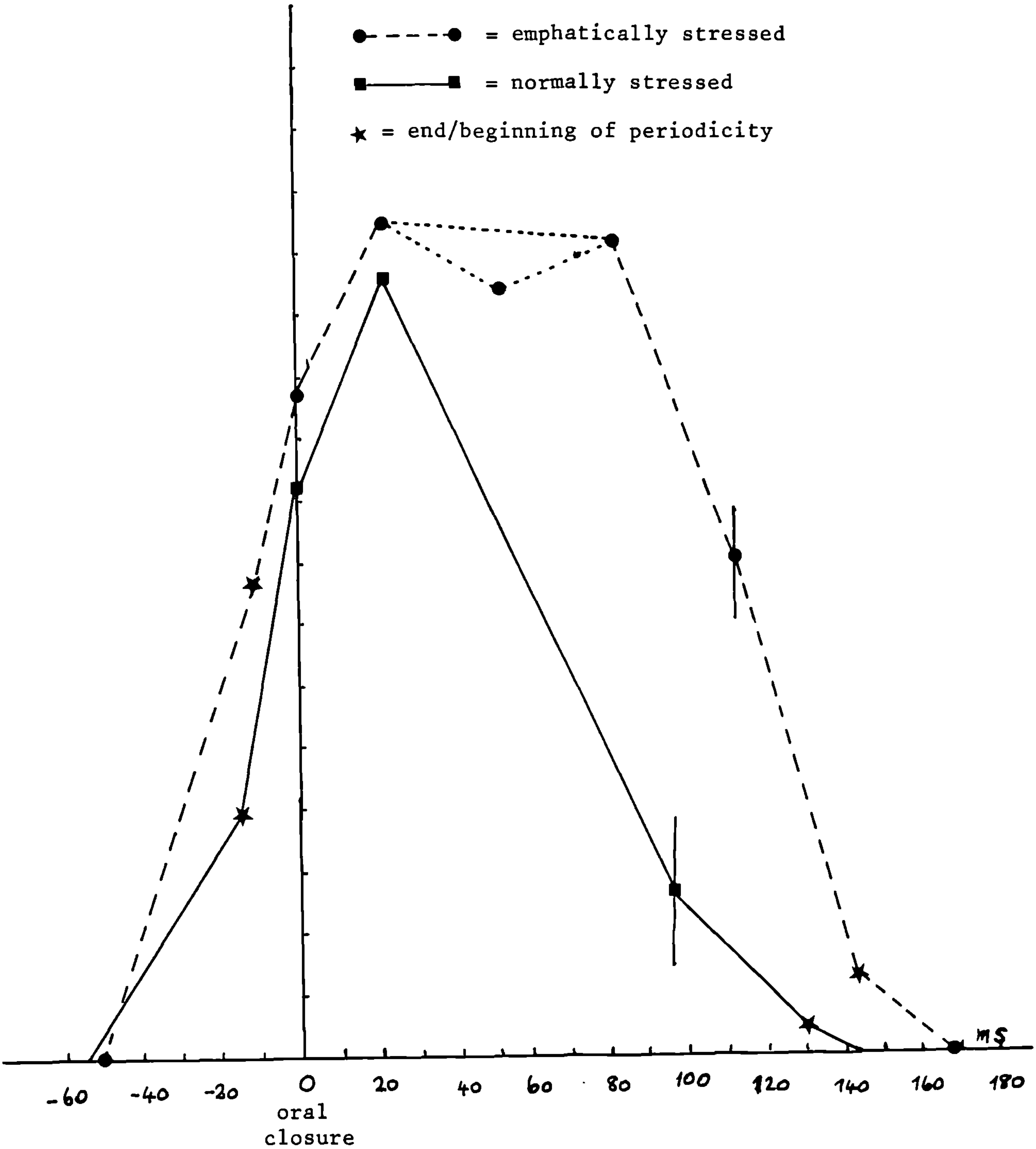


Figure 3.7 Averaged glottographic curves for medial [$^h t^h$] in Irish. Vertical bars mark oral release N = 20

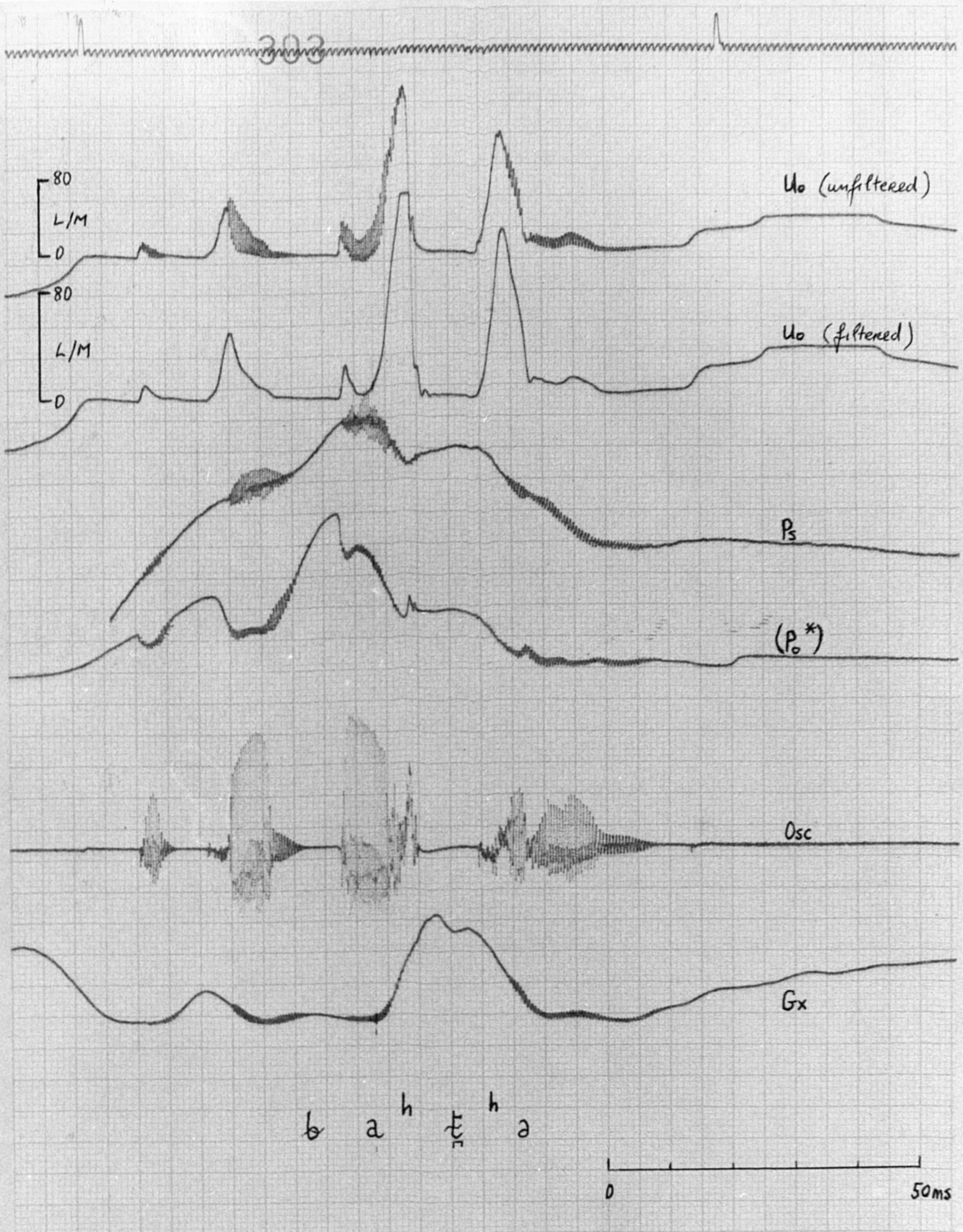


Figure 3.8

Mingogram of the Irish word [ba^h tə] spoken with emphatic stress in the carrier frame: "Dúirt sé -- liom." Note the double peaking of the glottographic signal.

Uo = oral airflow
Ps = subglottal pressure
(Po*) = (oral pressure transducer: not correctly positioned)
Osc = audio oscillogram
Gx = photoelectric glottogram

amplitude, and not always well separated by an intervening "valley". This is the reason for the two alternative sets of dotted lines joining the peaks in Figure 3.7.

Between the two stress conditions, the amplitude of glottographic deflection is not greatly different. However, the degree of glottal opening at which vocal fold vibrations cease (again marked in Figure 3.7 by an asterisk) would seem to be considerably greater for the emphatic tokens, so the speed of glottal opening may be different. The duration of the interval for which vocal fold vibration continues during the glottal opening gesture is very similar in both conditions. If there is any difference, it is fractionally longer for the emphatically stressed tokens.

The resumption of vocal fold vibration seems to occur at a much lesser degree of glottal opening than that at which vocal fold vibration decayed. The duration of postaspiration, i.e. the interval from closure release to the onset of vocal fold vibration did not appear to be affected by the emphatic versus normal stress difference.

The timing of PGO in the normally stressed tokens, was the same as for the first peak in the emphatically stressed tokens.

Irish: data set 9b)

Figure 3.9 presents results for the Irish data set, which included (for the fortis stop) in addition to normal sentence stress and emphatic stress, tokens in relatively unstressed (pre-nuclear position).

Looking at this figure, it would appear that the unstressed tokens are well differentiated from the others in the amplitude of glottal opening. The differences between stressed and unstressed tokens in these Irish data seem comparable to those found for Icelandic.

As was the case for data set 9a), presented in Figure 3.7, postaspiration durations for the normally and emphatically stressed tokens are again very similar. For the unstressed tokens postaspiration durations are considerably shorter, a fact which seems in line with the literature on VOT.

The emphatic and normally stressed tokens are not as clearly separated in terms of double versus single peaks of glottal opening as they were in data set 9a), illustrated in Figure 3.7. However, although it is not too evident from looking at Figure 3.9, the twin peaking was better defined in the emphatic instances. It is likely that, in production terms, the emphatic versus normal stress difference was not being maintained as well as in the previous data set, where this was all the speaker had to attend to.

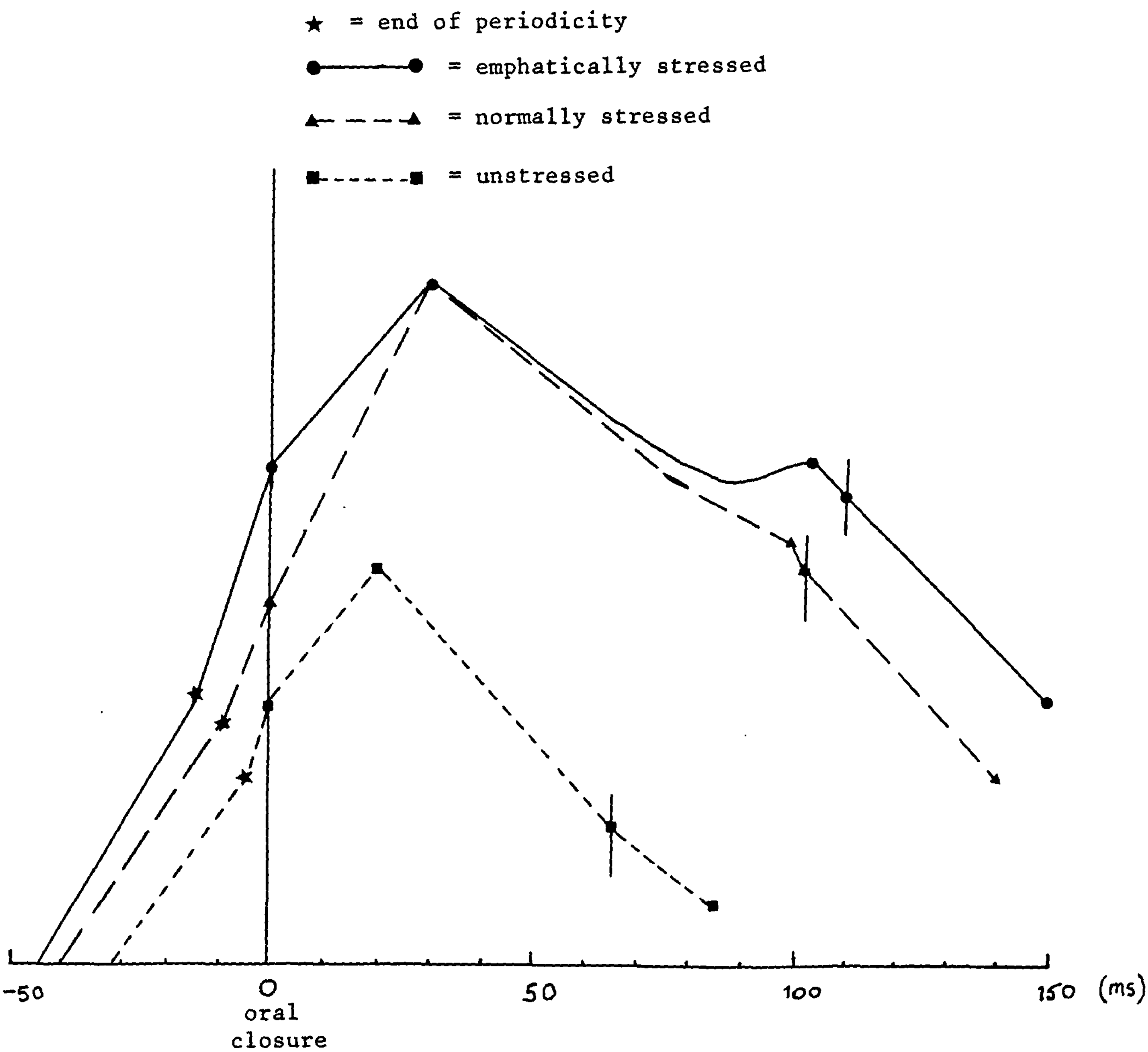


Figure 3.9 Averaged glottographic curves for medial [$^{h}t^{h}$] in Irish. Vertical bars mark oral release N = 16

Irish : data set 9c)

Figure 3.10 presents results for this data set which contrasted initial postpausal fortis stops for syllables with emphatic versus normal stress. Postaspiration durations differ for these two stress conditions in the initial stops, unlike the comparable medial cases.

There is a striking difference in the amplitude of PGO as ascertained from the glottographic waveform. It has also been noted in Chapter 2 that although these stops are postpausal, and the glottis widely adducted for inspiration prior to the utterance, the glottis narrows to a fairly adducted position and then proceeds to abduct again for the fortis stop.

In Figure 3.10, in addition to the fairly striking difference in PGO amplitude in the emphatic and normal stress conditions, there is a difference in PGO timing. In the normally stressed tokens PGO occurs before the moment of oral release; for the emphatically stressed tokens which have longer postaspiration duration, PGO occurs after oral release.

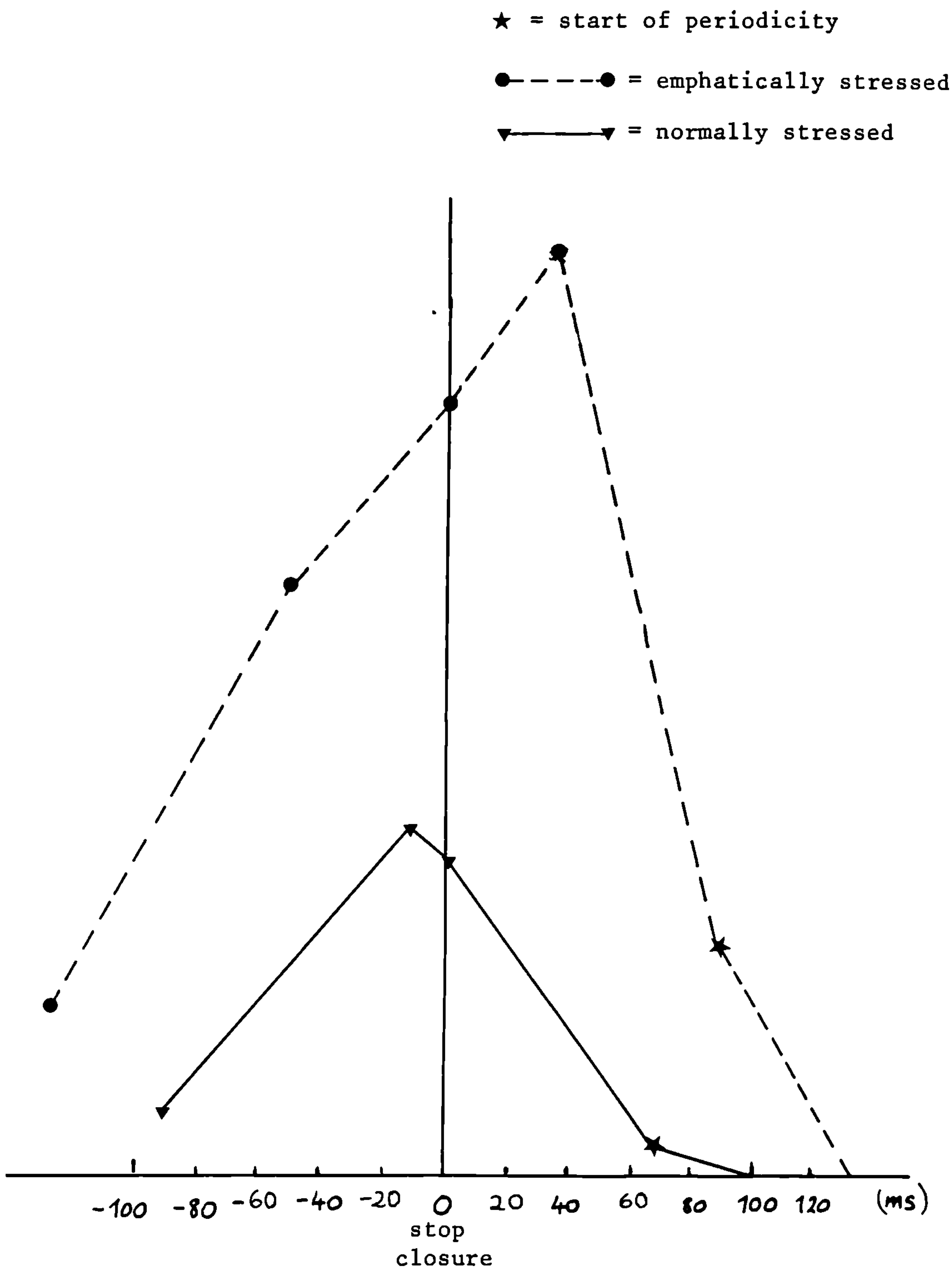
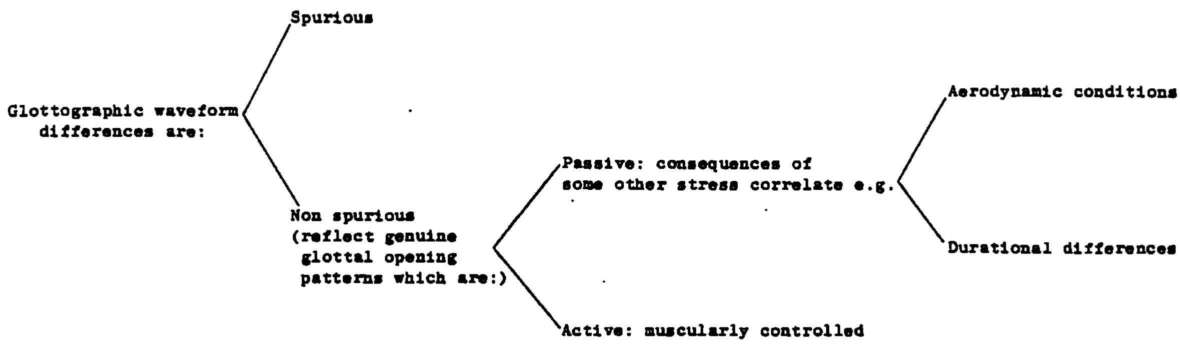


Figure 3.10 Averaged glottographic curves for initial [t^h] of Irish N = 12

3.2.3 Interpretation of results

Stress variation in the two languages correlates with either quantitative or qualitative differences in the glottographic waveform. But to what extent can these differences be seen as reflecting genuine differences in glottal behaviour? A number of possible alternative interpretations will be considered for the variation in glottal opening patterns at different stress levels, as measured from the glottographic waveform. The possibilities considered in the following discussion might be schematized as follows:



Totally spurious

One must consider the possibility that apparent differences in PGO could be attributable to a shifting of the catheter containing the glottographic light sensor. This is something that may happen in the course of an experiment. If the catheter shifts, it would affect the amount of light getting to the light sensor, and hence the amplitude of the recorded glottographic trace. Any such long term catheter shift can however be ruled out, one feels, as the material was read so that stress varied in alternating sentences. If the catheter did shift, it should not cause the consistent differences noted.

One must further, however, consider the possibility that some other articulatory difference might have systematically affected the glottograph's response curve. A conceivable correlate of stress could be larnyngeal movement in the vertical dimension (for example, larynx lowering with increased stress). If this were so, it could affect the amplitude of the glottographic response curve in a systematic way, and give an erroneous impression of glottal area differences. Such an explanation must be borne in mind as a possibility until such time as it is possible to investigate laryngeal behaviour directly (for example, using a stereo (and thus calibratable) fibre-optics system). However, although this possibility cannot be ruled out, it does not seem all that likely. Even if one wished to explain the apparent quantitative differences in glottal area noted for Icelandic in terms of stress related laryngeal movement, the complex double peak associated with the emphatically stressed tokens of Irish would require quite a stretch of the imagination (and of the larynx) to accommodate this explanation.

Furthermore, there is some corroborative evidence in the literature to suggest that differences in the amplitude of peak glottal opening may correlate with differences in stress level. In a study already mentioned above, Andersen (1981) found greater glottal opening for voiceless stops in words spoken at louder levels. Although Andersen's findings were based mainly on glottographic evidence also, they were to some extent backed up by fibre-optic and EMG recordings.

Non-spurious

The observed differences in the glottographic traces might genuinely reflect glottal opening patterns. But if so, can we translate these patterns into differences of degree and kind of muscular activity, or might they simply be passive consequences of some other stress correlate? Two candidates spring to mind here as to what these other stress correlates might be, namely, changes in the aerodynamic conditions, or, changes in duration.

Passive consequences of the different aerodynamic conditions associated with stress variation, e.g. an increase in Ps.

One might expect the types of stress differences looked at here to have respiratory and aerodynamic correlates. Lehiste (1970:106) remarks that, "ultimately differences in stress are due to physical effort. The effort is reflected directly in the activity of the muscles involved in respiration, and indirectly in subglottal pressure".

Ladefoged, Draper and Whitteridge (1958) found that bursts of intercostal muscle activity precede the principal stresses of an utterance, and that there is some variation correlated with degrees of stress. Respiratory effort and subglottal pressure (Ps) may also differentiate between stress and emphatic stress (see Lehiste 1970: 110).

Increased respiratory effort (reflected in Ps level) may not necessarily correlate with stress in every language. Recent work by Williams (1982) on the acoustic correlates of stress in Welsh would lead one to expect the opposite to be true in this instance. However, the stress variations reported here for Icelandic and Irish do seem to be accompanied by increases in Ps. For stressed versus unstressed tokens of Icelandic (data set 10 in Table 1.1), the Ps level of the stressed vowel was approximately 6 cm Aq higher than that of the unstressed. Similarly for Irish (data set 11 in Table 1.1 of Chapter 1) the Ps level of the vowel in the stressed tokens was about 4 cm Aq higher than for the unstressed, and about 8 cm Aq lower than for the emphatically stressed tokens.[1]

Having established that a higher Ps level does correlate with stress for the type of data presented here, one must ask the question whether the higher Ps causes the vocal folds to be blown wider apart, or cause the second opening noted in the Irish tokens with emphatic stress ?

It would at first glance seem reasonable to suggest that the simple glottal amplitude differences are the result of the vocal folds being blown wider open by the higher Ps and Po levels. One piece of evidence which militates against such an explanation

------

[1] Data sets 10 and 11 (specifically recorded to include Ps) involved the same words and carrier frames as data sets 8 and 9b) respectively (see p.224).

comes from Löfqvist et al.(1981). Having observed, in the course of a study which involved glottographic and Po traces, a correlation between their amplitudes, the author similarly wondered whether the greater amplitude of the glottographic record might not be a simple consequence of higher Po. He tested such a hypothesis by using the time-honoured Ladefogedian technique of unexpectedly pushing the subject in the chest, and found that the sudden large increases in Po made very little difference to the amplitude of the glottal opening as indicated by the glottographic trace.

The double peaks of the emphatic medial stops in the Irish data are even less plausibly attributable to pressure differences. Ps is higher with emphatic than with normal stress. This is illustrated in Figure 3.11, where the average Ps curves have been superimposed on the glottographic curves of Figure 3.7. The recording for data set 9a) included a Ps trace, and it was measured at the same time points as for the glottographic traces. Although Ps is higher for the emphatic tokens, during the stop closure itself there is no particular Ps perturbation in the time interval between glottographic peak 1 and peak 2 which would account for the glottal pattern. The Ps increase during this interval is small and about the same for both stress conditions.

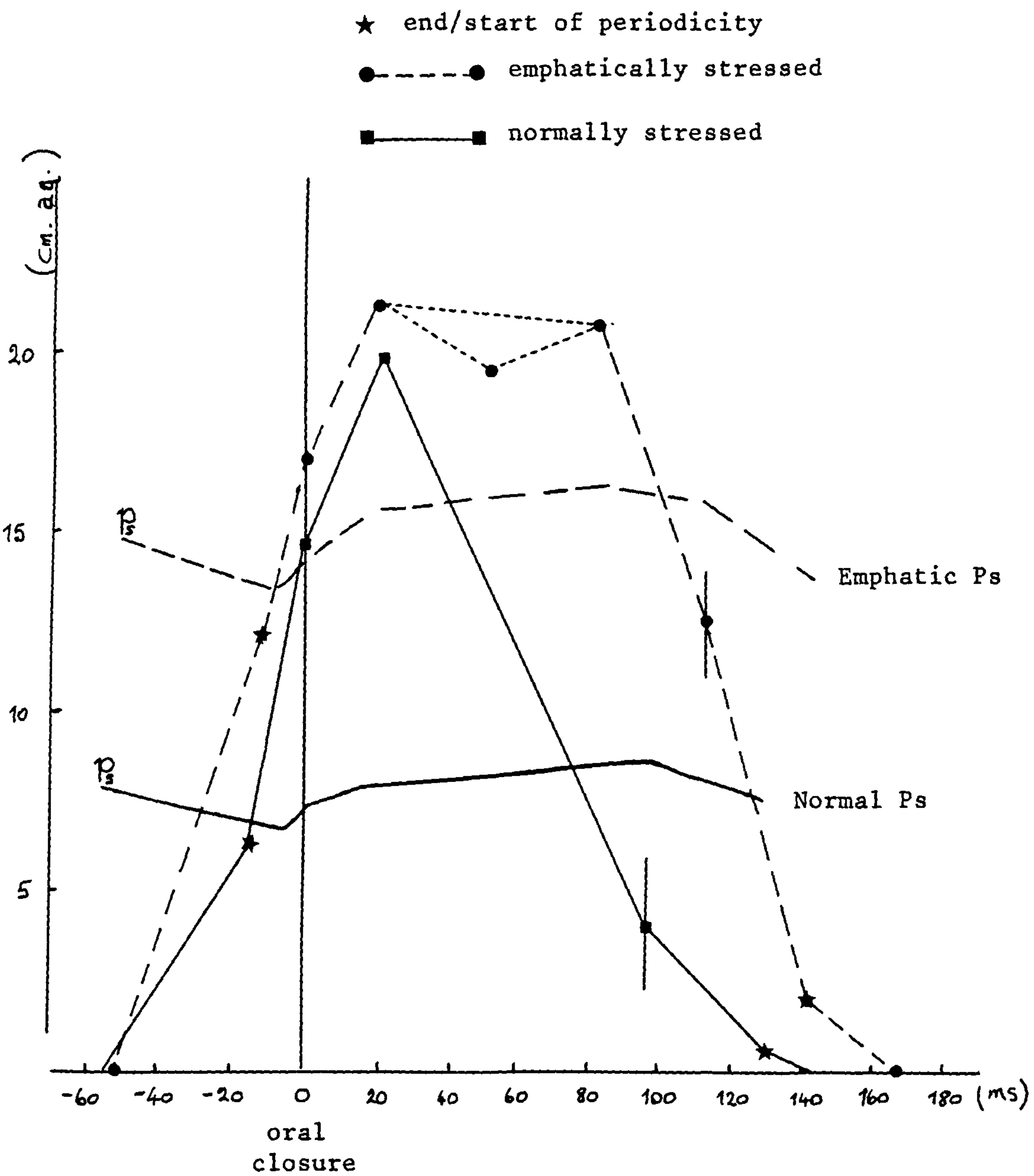


Figure 3.11 Ps traces superimposed on Gx traces of Figure 3.7 N = 20

Passive consequence of timing differences which are stress linked

The stress level at which a syllable is uttered affects the duration of the segments in that syllable. As described already in this chapter, stops in stressed syllables have somewhat longer duration than those in relatively unstressed syllables. If muscular activity is essentially the same, but lasts longer, i.e. abductors and adductors working at the same rate but over a longer period, then one should expect greater glottal opening with greater degrees of stress. One must therefore consider the possibility that the different glottal opening patterns are passive consequences of the stress-related durational differences.

Considering first of all the differences in glottal opening amplitude found in the comparison of stressed and relatively unstressed tokens in Icelandic and Irish, a close inspection of the data in Figure 3.6 shows that this can hardly be the case. Unstressed [p:] in Icelandic has slightly longer duration than stressed [p], yet its glottographic peak is comparatively very low and patterns with the other (relatively) unstressed tokens. Therefore, peak glottal opening can not be a simple function of stop closure duration.

One might also ask whether the double peaks, evidenced particularly in the Irish emphatically stressed tokens (see Figure 3.11) might be a consequence of the longer duration of the stops in this environment. Again, this seems highly unlikely. First of all, the durational difference between the normally and emphatically stressed tokens is not great. Secondly, the durations are dramatically less than for the Icelandic geminates which did not have double peaking.

<u>Voluntary differences in muscular activity</u>

On balance therefore, it seems likely that the glottal opening patterns do vary with stress and that the observed variations are the result of active differences in muscular behaviour. What might be happening is schematized in Figure 3.12.

- The difference in glottal opening degree, as between the stressed and relatively unstressed tokens in Figure 3.6 (Icelandic) and Figure 3.9 (Irish), might simply result from higher muscular firing levels for the voiceless stops in the stressed condition.

- The double peaking of the emphatically stressed Irish tokens in Figure 3.7, may involve, not so much higher rates of muscular firing, but a second burst of muscular activity (or of abductor activity at least).

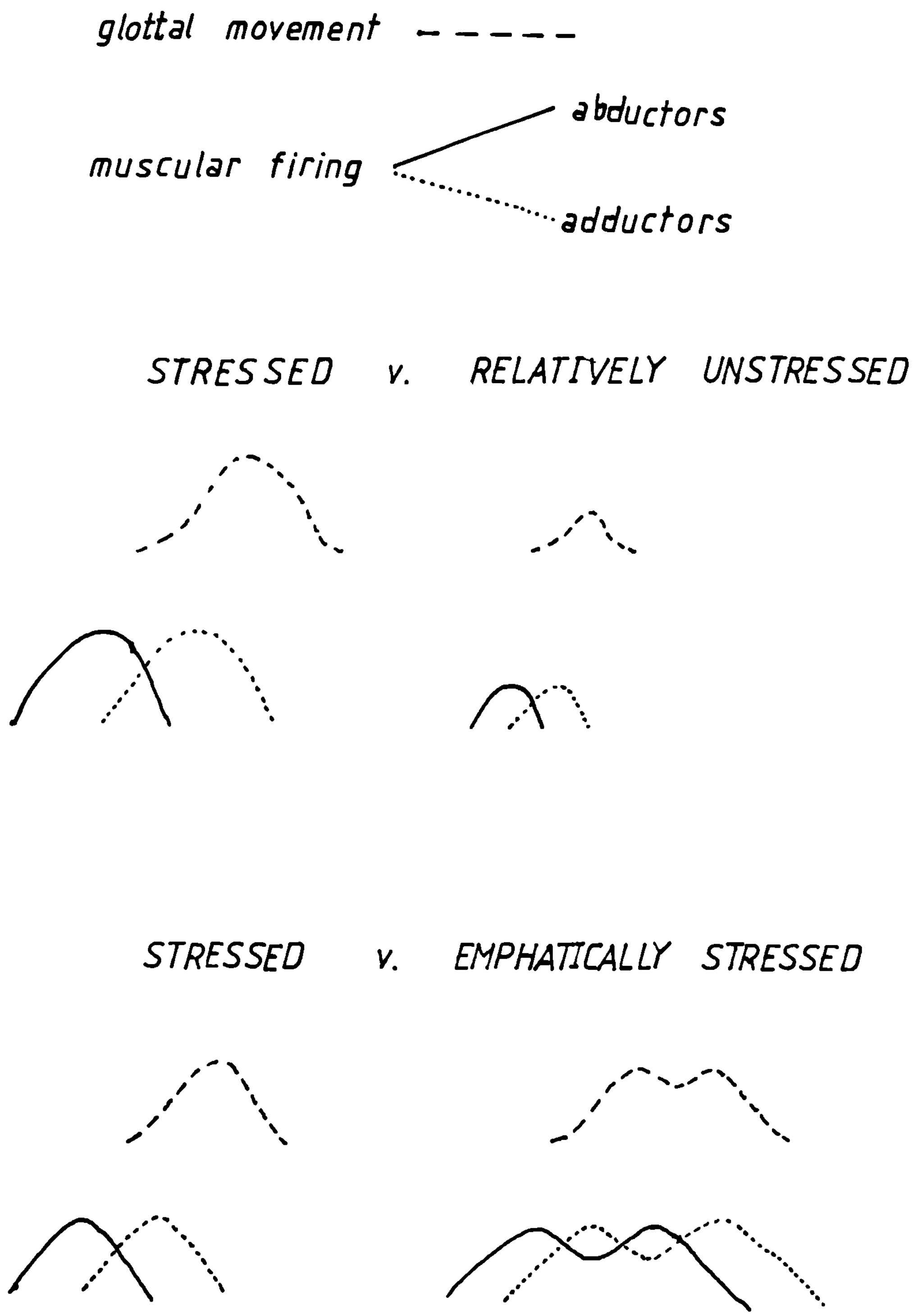


Figure 3.12 Suggested representation of muscular activity across stress levels

3.2.4 Discussion

If the above suggestions are correct, one must ask why such active differences in glottal behaviour would occur with changes in stress level. A possible answer to this question might be phrased in terms of the following hypothesis:

> The glottal gesture change is a necessary response to altering aerodynamic conditions, i.e. in order to maintain the desired/necessary targets, different glottal strategies are required.

The target in all medial voiceless stops can be divided into two subtargets,

1) the cessation of vocal fold vibration,
2) the resumption of vocal fold vibration.

1) The cessation of vocal fold vibration takes a certain amount of time to accomplish. When the vocal tract is open, i.e. for preaspirated stops, the transition from normal voicing to voicelessness is quite slow (see Figures 3.6, 3.7, and 3.9, and the discussion in Chapter 2.2.5). For voiceless stops that are not preaspirated, the process is speeded up, as oral closure helps to neutralize the transglottal pressure drop. Even so, Westbury (1979) describes a "voice tail" of 10ms to 40ms for voiceless stops in American English.

2) The second subtarget of the voiceless stop is the resumption of vocal fold vibration at the appropriate point in time subsequent to closure release. As discussed in Chapter 2.2.5,

the transition from voicelessness to voice appears to be much more rapid than that of voice to voicelessness. At voice onset, the initiation of vocal fold vibration results from glottal adduction and the Bernouilli effect; at a given stage of glottal narrowing, the vocal folds get sucked together. The point in time at which this will happen (which will be referred to here as the Bernoulli point) depends on the following two factors working in an inverse relationship:

airflow rate through the glottis, and
degree of glottal narrowing.

This may explain why, in the Icelandic data (Figure 3.6) and in Irish data set 9a) (Figure 3.7), the actual duration of postaspiration is the same across the differing stress conditions, even though glottal aperture at consonant release would seem to be quite different. Glottal closure, in the higher stress tokens may be "stealing a ride", as it were, on the higher airflow and Bernoulli effect.

The basic suggestion is, therefore, that voice onset targets (or postaspiration targets) are being maintained precisely by adjustments in degree of glottal aperture. Therefore, at higher stress levels (given the higher Ps and airflow rates) wider glottal opening may be not just tolerated, but actually necessary if VOT is to remain constant. At lower stress levels, too much glottal opening may be counter indicated, as it could lead to unwanted aspiration.

The double peaks of glottal opening noted with emphatic stress in Irish may also be simply a necessary glottal adjustment to prevent overshort aspiration at the very high airflow levels. At higher stress levels the Irish fortis stop may be a particularly demanding articulation, given that it has both some pre- and postaspiration. Peak glottal opening occurs early during stop closure, as with preaspirating stops generally. If the ballistic opening/closing gesture were to proceed uninterrupted, the degree of glottal opening at stop release might not be sufficient to ensure the appropriate duration of postaspiraton.

The maintenance of target 1 may be another constraining factor. If the glottal gesture did not vary, the higher Ps and airflow rates might complicate the effective voice --> voiceless transition, and lengthen its duration. Therefore, at higher stress levels, greater glottal opening may additionally assist to ensure that the voice tail doesn't become too intrusive.

If this line of argumentation is correct, one might further hypothesize that fricatives should either display wider glottal opening than stops, or be more prone to intrusive breathy voicing. This is because there is less passive assistance to devoicing through neutralization of the transglottal pressure drop, given that the vocal tract is open.

There seems to be some evidence for the first of these predictions. A greater velocity of glottal opening, as well as greater peaks in the amplitude of glottal opening have been reported for fricatives as compared to stops (see for example, Löfqvist and Yoshioka, 1981b)).

The hypothesis suggested here should equally account for the greater degree of glottal opening amplitude found with increased loudness in the work of Anderson (1981). Loudness variation would entail similar changes in aerodynamic conditions, and according to the present hypothesis would necessitate similar compensations in the glottal gesture.

A caveat must be included at this point. The hypothesis must be understood to predict changes in glottal behaviour, not as an absolute correlate of stress variation, but as an active response to the altered aerodynamic conditions (which are often concomitant with stress variation). The higher Ps for stressed than for unstressed syllables and for emphatically than for normally stressed syllables was found for the Icelandic and Irish data here, and may indeed be frequently found in languages. However, it has been mentioned already that all languages may not conform to this pattern. Clearly, the hypothesis would not predict the same glottal adjustments in cases where increased stress is not accompanied by higher respiratory forces. On the other hand, such changes would be predicted whenever respiratory levels are higher, even when this is not marking linguistic stress in a language.

The implication of the hypothesis put forward here is that glottal articulation is tailored to meet the prevailing aerodynamic conditions. This in turn might imply some sort of active system monitoring aerodynamic conditions. How this might be effected, is not clear, but a suggestion by Wyke (1967) mentioned in Fowler (1980) could be one kind of possibility:

> "receptors in the mucosal membranes of the larynx are sensitive to changes in air pressure. Wyke (1967) has suggested that the afferents from these receptors may trigger reflex adjustments in the tone of the laryngeal and respiratory musculature during speech". (from Fowler:125)

Fine interplay of respiration and articulation has already been suggested in Ladefoged's work (1967) with respiratory forces being tailored to articulatory needs. This then is something similar, but with reversed directionality, as the suggestion here is that the articulatory gestures are tailored to the respiratory demands.

3.3 CONCLUSIONS

In section 3.2.0, two models of aspiration control were discussed. One model, suggested by Kim (1970) and elaborated by Catford (1977) was that aspiration duration was controlled essentially by controlling the degree of glottal opening, particularly at closure release. The other model, a "timing" model proposed by Löfqvist (1980), suggested that aspiration and its duration was basically determined in terms of the timing of the glottal opening/closing gesture.

The findings reported here, and the interpretation suggested for these findings, lend support to Kim's type of explanation, insofar as they suggest that degree of glottal opening is being varied as a means of controlling voice onset and offset times across differing stress conditions. And the degree of glottal opening at the consonant's release would seem to be a crucial target, as evidenced by the complex double-peaking gesture of the glottis for the emphatically stressed tokens of Irish. This is at variance with the suggestion by Löfqvist et al. (1981) that speakers cannot sufficiently control degrees of glottal opening for this to be a linguistically relevant control parameter. His experimental method may not so much tell us about speakers' capability of controlling the degree of glottal opening, as about their <u>conscious</u> control of this parameter.

Although the hypothesis offered here is in accord with Kim's position, one would probably want to expand his basic thesis to

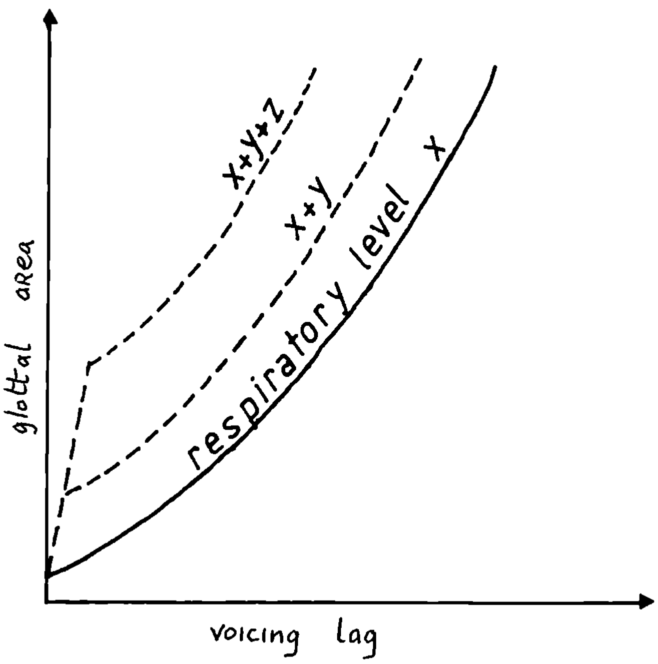


Figure 3.13 Proposed modification to Figure 3.4. The additional curves (broken lines) allow for different respiratory levels

take aerodynamic factors into account. Catford's graph (presented earlier as Figure 3.4) would need to be modified in the ways indicated in Figure 3.13. Note, however, in the latter figure, the representation is schematic, as one cannot at this stage formulate precise mathematical relationships. Figure 3.13 represents a modification of Figure 3.4 in the following ways.

> Firstly, to allow for voice onset at greater glottal apertures when respiratory forces are higher.
>
> Secondly, to allow for a sudden acceleration in glottal adduction, due to the Bernouilli effect. Again, respiratory levels would determine the point at which this would happen. Therefore, the relationship between voice onset times (aspiration) and glottal area cannot be shown by a single curve, but would need a number of such curves for differing respiratory levels (and these could correlate with stress, loudness, or whatever). Furthermore, simple curves would not best describe the trajectory. Rather, the graph should display a sharp dip at the left hand side, to reflect the acceleration described above, due to the Bernouilli effect.

This assertion of the importance of glottal aperture control is not an attempt to suggest that timing differences in glottal abduction/adduction commands have no role to play. Timing differences obviously do occur. In Figure 3.10 especially, it looks as if both timing and amplitude of glottal opening may be interacting as complementary strategies to yield the durational differences in postaspiration duration.

To sum up, it would appear that the laryngeal control of voicelessness and aspiration may involve different strategies. The critical articulatory target is twofold:

1) To achieve sufficient glottal opening to ensure supression of vocal fold vibration, under the prevailing aerodynamic conditions.
2) To achieve appropriate degrees of glottal aperture at stop release to match aerodynamic conditions, and ensure the desired aspiration duration. The means to this articulatory end may include direct control of glottal aperture, timing of opening/closing commands, and where the need arises, even the initiation of an additional burst of abductor activity.

Lenition

As described in the introduction to this chapter, one initial motivation for looking at stress induced variation in the stop consonants was the insight it might afford to diachronic lenition changes which involve voicing oppositions. Some of the findings of this chapter may indeed be relevant to this question.

In the first section, which dealt with durational consequences of stress variation, it seems that the duration of preaspiration (and presumably its perceptibility) is greatly reduced. And across stress level, the time taken to effect the transition from voice --> voicelessness remains roughly contant.

As regards the lenis stop, which in the case of Irish is half-voiced, the duration of voicing is not adversely affected by a lower stress level. Absolute durations of voicing are the same or slightly longer for the unstressed condition; as stop closure is slightly shorter, the perceptual importance of the voicing may be increased.

In the second part of this chapter it was found that unstressed tokens seem to be characterized by a lesser degree of glottal opening than stressed tokens. It was hypothesized that the wide glottal opening of the stressed tokens was aerodynamically required to maintain appropriate voice onset times (target 1) and furthermore, that the greater opening may assist the attainment of voicelessness (target 2) at the higher airflow levels.

In the unstressed condition, if and when the respiratory levels are lower, there may be a conflict in maintaining both targets of the voiceless stop. A wide degree of gottal opening is contra-indicated, as it would lead to unwanted postaspiration. However, a small degree of glottal opening may seriously interfere with the effective devoicing of the stop (target 2).

To this one must add the fact that stop closure duration is also somewhat reduced in the unstressed condition. This effectively means that there is less time for passive devoicing to take effect (through buildup in oral pressure and neutralization of the transglottal pressure drop).

To sum up therefore, it would seem that the successful attainment of the (presumed) target for a voiceless (and for a preaspirated) stop is not facilitated at lower stress levels. Destressing does not seem to have adverse consequences for the attainment of a voiced stop. These conclusions relate to medial intervocalic stops, and do not necessarily hold for other word positions. They will be picked up again in the discussion of voicing lenition in Chapter 4.2.

CHAPTER 4

DIACHRONIC ASPECTS OF PREASPIRATION AND OF VOICING

4.0 INTRODUCTION

The objective of this chapter is rather different from that of the more experimentally oriented Chapters, 2, 3 and 5. Rather than experimental elucidation, the aim is to discuss and reconsider matters of a diachronic nature. The first part of the chapter contains a discussion on the possible origins of preaspiration in the languages studied. Past explanations of the evolution of preaspiration in these languages are discussed in some detail. An alternative, production based account is proposed, namely, that preaspiration arose as a result of an unstable opposition of voiced and voiceless geminates. The loss of voicing in a geminate stop would not be a surprising development ; the occluded vocal tract of stop consonants presents unfavourable aerodynamic conditions for voicing (see Chapter 1.1.1). The intrinsic difficulties would be exacerbated when the stop is of long duration. It is therefore proposed that preaspiration of the fortis series developed as a means of maintaining the phonological opposition, when, under adverse conditions, voicing proper of the lenis was lost.

The second part of this chapter contains more general reflections on the types of changes that tend to occur in voicing oppositions, usually referred to by phonologists as lenition/fortition type changes. Although lenition processes are most frequently assumed to be phonetically motivated, surprisingly few attempts have been made to characterise precisely what the range of phonetic motivating factors might be.

The objective in Section 4.2 is not to prove or test a specific hypothesis, but rather to draw together some disparate strands of information which may go some distance towards identifying areas of the phonetic basis for lenition processes. Explication or demonstration of these areas is not the purpose here, but some of the results reported in Chapters 2 and 3 are pertinent to the discussion. These, as well as some important insights arising out of experimental work by researchers such as Ohala, Lindblom, Keating and Westbury are incorporated into this attempt to scetch the broader canvas of the phonetic motivation of lenition. The proposed outline in Section 4.2 is not intended as a definitive account, but rather may serve as a step towards a composite statement of lenition processes.

4.1.0 THE origins of preaspiration in these languages

4.0 Introduction

The contrasts which now involve preaspiration in the languages and dialects looked at, are generally thought to derive from an earlier opposition between voiced and voiceless geminates. (A dissenting proposal by Marstrander (1932) will be discussed in section 4.1.1.2). Seen within the broader context of the stop systems in these languages, the development was one among a number of changes which can be described as strengthening or weakening within a lenition schema. These changes are:

- The shortening of the geminates (a weakening in lenition terms). This process was not completely carried out in Icelandic. The original voiced geminate of Old Norse is still a geminate, though now completely voiceless (see Chapter 2). Most other derivatives of Old Norse, like Norwegian and Swedish still retain an opposition of voiced and voiceless geminates. Gemination has been lost in the derivatives of Old Irish although there has been occasional mention of phonetically long stops (not phonologically contrastive) in some dialects of modern Irish. This will be discussed again later in section 4.1.3.

  The loss (total or partial) of "voicing proper" in the "phonologically voiced" member. This would rate as a strengthening in traditional lenition terms. The differing degrees of voicing loss in the languages and dialects of this study are described in Chapter 2.

- The spirantisation of the original single stops of Old Irish. In Icelandic the original single voiceless stop has not spirantised. Spirantisation has traditionally been regarded as a weakening in lenition terms.

As mentioned already, the second part of this chapter deals specifically with lenition. In the first part, an attempt is made to set out a possible chronology of the development of preaspiration in Icelandic and Celtic. The present suggestions are considered in relation to some past explanations of preaspiration development in the languages studied, and these past treatments are discussed in some detail in the first few sections.

4.1.1 Preaspirtion in Scottish Gaelic: a Viking influence ? The Borgstrom/Marstrander account

Scandinavian scholars have offered the suggestion that preaspiration may be one of the very rare instances of Viking influence on the Gaelic language. Borgstrøm (1974) is a more elaborated version of proposals put forward by Marstrander (1932). As there are a number of points one might query in their arguments, they will be summarised here in some detail.

Before proceeding with the Borgstrøm/Marstrander account, it is perhaps worth noting how little in fact, Norse is considered to have influenced Gaelic. This has been pointed out, for example, by Oftedal: "Norse has influenced Scottish-Gaelic vocabulary far less than Latin or English, in spite of five centuries or more of close contact" (1962:125). Borgstrøm also points out that Gaelic syntax is entirely uninfluenced by Norse and mentions that apart from some Norse names and loan words, it is "difficult to find conclusive proof of other kinds of linguistic influence from Norse" (1974:92). Borgstrøm explains the lack of Norse influence on Gaelic as follows:

> "For my part I believe that there was no long period of Gaelic-Norse bilingualism, in other words, that Norsemen and Gaels lived in relative isolation from each other until the time when the Norsemen finally adopted Gaelic." (:92)

For reasons that will be mentioned later, Celtic scholars have generally expressed reservations about the proposed Viking origin of Scottish Gaelic preaspiration, but counter-explanations have not been plentiful.

4.1.1.1 The Lewis / South West Norway connection

The basic hypothesis is that preaspiration was brought to Lewis and to dialect Area B of Scotland (see Chapter 1.2.2.3) by Viking settlers from the South West of Norway. The other "preaspirating" Scottish Gaelic dialects would have adopted it from Area B through imitation at some later stage. The basic reasons underlying Borgstrøm's theory that preaspirtion came to Lewis from the South West of Norway, are:

- Firstly, certain pitch patterns occur in Lewis Gaelic which are reminiscent of toneme 1 found in South West Norwegian dialects.

- Secondly, this area includes the dialect of Jaeren which has been reported by Oftedal (1947) as having preaspirated stops. As will be mentioned in 4.1.1.2 below, Borgstrøm considers that preaspiration may have been present and even widespread in Old Norse, and hypothesises that South West Norway is likely to have been a "preaspirating" area.

- Finally, the geographical proximity of South West Norway to Northern Scotland is at least a partial factor in Marstrander's and Borgstrøm's reasoning that the Viking settlers in Lewis and area B were of South West Norwegian origin (see Borgstrøm 1974 : 93).

4.1.1.2 <u>The Old Norse system:</u>

Borgstrøm states that the set of obstruent oppositions in postvocalic positions in Old Norse was as follows (using velar symbols to exemplify) :

/kk/

/k/

/gg/

He further states that depending on the dialect, there were two systems for phonetic realisation of the above oppositions;

(a) a system which differentiated by voicing proper, and

(b) a "preaspirating" system.

These he schematises as follows (:95)

a)		b)	
	T:		cT:
T		T	
	vT:		T:

using T for any stop, v for voice, c for preaspiration and : for length. The suggestion of two systems in Old Norse, a preaspirating and a non-preaspirating (voicing) one is based on the authority of Marstrander (1932) who was also postulating that preaspirating in Scotland was a Viking influence.

According to Marstrander, preaspiration might have arisen in some Old Norse dialects, through the non-completion of one of the processes whereby geminate stops were formed. Geminate stops already existed in Proto-Scandinavian (pre 550 A.D.) and in the

Common Scandinavian period (550 A.D. - 750 A.D.) further geminates arose from the following sources (see Haugen 1982:57-61).

- sharpening of geminated glides: both **jj** and **ww** gave **gg**
- voiced geminated spirants became geminated stops **ðð** --> **dd**
- gemination of velars **k** and **g** before the high vowels **i** and **u**
- assimilation of **xt** to **tt**
- assimilation of nasals to following stops : **mp** to **pp**, **nt** to **tt**, and **nk** to **kk**.

In the last two of these, Marstrander proposes to see the origin of preaspiration in Old Norse; (he characterises the fourth process slightly differently as an assimiltion of **ht** to **tt**). The fifth process he deals with in some detail. His treatment can be schematised as in figure 4.1. Taking the assimilation of **nt** --> **tt** to exemplify, it proposes that the first segment of the cluster, **n**, passed through the intermediate stages, **ð̃** --> **o**-->**h**. In the preaspirating dialects, the process would simply not have progressed beyond this point. In other dialects, the final stage would be **h** --> **t**.

The reason, Marstrander supposes, why the process might have been arrested in some dialects, was to prevent original **nt** type clusters being confused with those geminates which already existed in the language. These clusters did however fall together with the older geminates in any case, as the modern dialects yield either geminates or preaspirated stops but not both. Figure 4.2 builds on Figure 4.1, showing the two possible

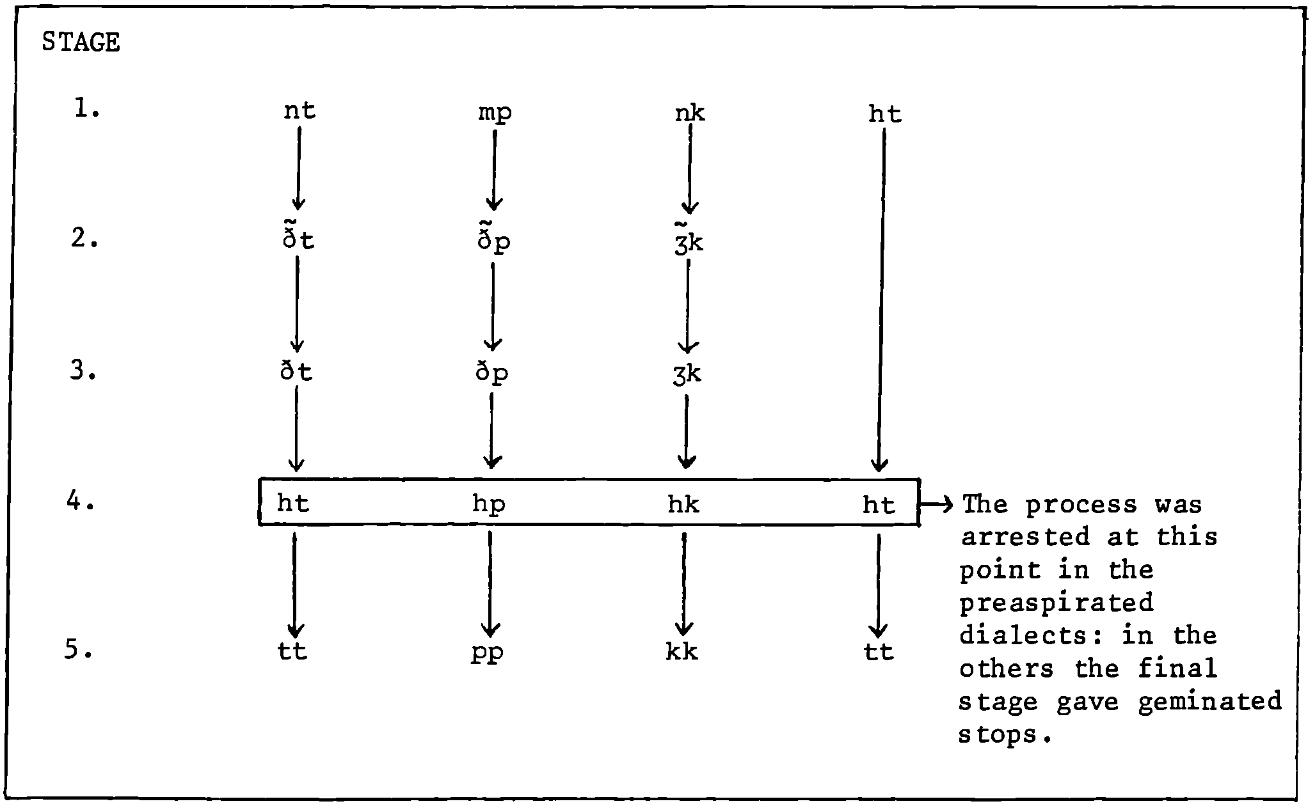


Figure 4.1 Schematic representation of the origin of preaspirated stops, as deduced from Marstrander (1932).

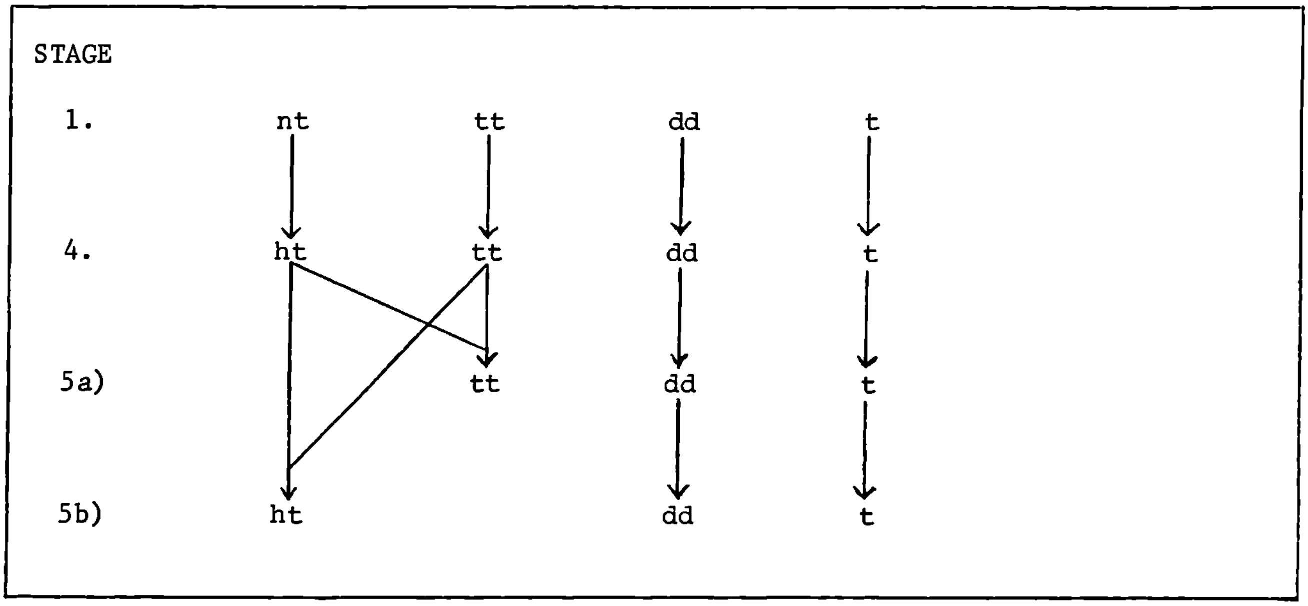


Figure 4.2 Schematic illustration, continuing on from Figure 4.1 and deduced from Marstrander (1932), showing the later coalesence of the original voiceless geminates and the hypothesised preaspirated stops (proposed as deriving from clusters such as nt as illustrated in Figure 4.1). Alveolar symbols are used to exemplify.

routes dialects would have taken (after stage "4" in Figure 4.1). These two routes, labelled 5a) and 5b) here would yield Borgstrøm's systems a) and b) described above. In order to explain the later coalesence in the case of 5b) of the original geminates with the preaspirated stops, Marstrander suggests that the latter may have provided a sharper contrast with the single voiceless stop of Old Norse.

Borgstrøm takes Marstrander's position a little further in suggesting that, although preaspiration in modern Norwegian is only attested in a few small areas, it might have been much more extensive in the Viking period, but simply lost at some subsequent stage. His grounds for suggesting this are somewhat vague, and therefore probably best expressed by the original text:

> "In system b), the long preaspirated stops (cT:) would be marked, and the long unaspirated would be unmarked. The short stops would then tend to be interpreted as the short forms of the unaspirated long stops (the mediae), and to be realised as unaspirated lenes, sometimes more or less voiced, as they are in the greater part of Iceland today (Benediktsson 1961-62, pp. 82f: Chapman 1962, pp. 60 f.). The Norwegian dialects in which such more or less voiced lenes are used, e.g. those along the south coast including Jaeren, may therefore be supposed to have originally known system b), with preaspiration, even where it has now been abandoned." (:96).

And so, the presence of preaspiration in parts of Scotland, as in Icelandic, is to be explained in terms of Vikings with preaspirating dialects. But as will become clear in the next section, Borgstrøm does not wish to regard all the preaspirating Scottish-Gaelic dialects as a direct result of Viking influence.

4.1.1.3 The mechanism of preaspiratin adoption in Scotland: direct and indirect borrowing.

Borgstrøm notes first of all the distribution and types of preaspiration in the Scottish-Gaelic dialects (see Chapter 1.2.2.3). Borgstrøm argues that preaspirated stops in Lewis (and area B in general) should be interpreted as single phones, as opposed to the preaspirated stops of other areas (the C dialects) which he would interpret as clusters of [h], [c] or [x] plus stop. (For a discussion of this, see also Chapter 1.2.5).

The introduction of preaspiration into the Scottish Gaelic dialects, Borgstrøm views as occuring in two phases. The majority of Viking settlers in Lewis and Area B coming, as he surmises, from South West Norway, and speaking with "preaspirating" dialects introduced preaspiration into Gaelic when that language was adopted. He implies that the shorter, weaker, Lewis preaspiration was the type originally introduced and that it has not undergone change since then. This would apparently be because it was introduced at the bilingual stage - so that Norse speakers of Gaelic simply "carried" their Norse system into Gaelic.

> "preaspiration was at first introduced into Gaelic in the parts of the country where it still preserves its original form viz., in the B areas. If the Norse settlers who lived there had pre- aspiration as an integral and stable part of their Norse phonetic system, then it is probable that in their Gaelic, too, preaspiration would be a stable element not liable to undergo spontaneous changes." (:99)

The realisations of preaspiration in the dialects of areas C1 and C2 would represent a development from the "original" preaspiration found in Lewis. These "developed" forms are seen by Borgstrøm, not as a subsequent development of preaspiration, once it was adopted, but rather as the result of the substitution of the nearest native segments giving us the observed range of clusters.

> "This new pronunciation must have enjoyed considerable prestige and was widely imitated. But those who did not have the short preaspiration in their own speech, would naturally substitute their /h/ for it; or since /h/ did not in Old Gaelic occur before stops, they might substitute their /x/ and /x'/ (i.e.[c]) particularly before /k/ on the analogy of the Gaelic cluster cht, pronounced /xk/." (:99)

4.1.2 Problems with the Borgstrøm/Marstrander account

There are a number of issues one might query in the Borgstrøm /Marstrander account, and these will be dealt with in the order of the points and headings of the previous section, 4.1.1.

4.1.2.1 The Lewis South West Norway connection

The Lewis/South West Norway connection hinges to a large extent on Borgstrøm's perception of a similarity between a particular Lewis pitch pattern and South West Norwegian toneme 1. The importance of this "clue" seems to be grossly overestimated for a number of reasons.

Firstly, there are strong reasons for believing that the similarity between the pitch patterns is a surface coincidence, as the Lewis pattern is easily accounted for in language-internal terms. As pointed out by Cathair Ó Dochartaigh (personal commmunication) it occurs only in monosyllables which derive from original disyllables, through the vocalisation and loss of a medial fricative. What seems to have happened, is that with this loss of a medial consonant, some disyllabic words may have fallen together with segmentally similar monosyllabic ones. However, in losing the fricative, the words in question retained their original disyllabic pitch pattern of a high pitch on the initial stressed syllable, followed by a fall in the unstressed second syllable. So this new monosyllabic pitch pattern contrasted with the more or less level tone found in original monosyllables, e.g. <u>bogha</u> [bo:] as contrasted with <u>bo</u> [bo:]. It is not clear that the suggestion of a Norse influence necessarily adds anything to this internal explanation.

As described, the phonological function in the Lewis pitch pattern is related to its origin and the loss of medial [h]; the original disyllabic words have retained their previous pitch-pattern, even though now monosyllabic. The fact that these pitch-patterns don't occur in the other Scottish Gaelic dialects simply relates to the fact that they haven't lost medial [h]. In Norwegian, the tonemes function quite differently, and occur in disyllabic words only.

A further problem with the pitch-pattern argument concerns its geographical distribution. As Borgstrøm points out, these pitch-patterns are not found over the whole of area B in Scotland. Thus, Borgstrøm has to postulate a later loss of such pitch-patterns in these instances.

Icelandic doesn't have any evidence of the Norse toneme 1 pattern either. Borgstrøm seems surprisingly unworried by this fact, (given that it is the lynch-pin of his account of Scottish Gaelic preaspiration) and simply comments that, either "the distinction of tonemes never existed in Icelandic" or, "if it did, it may have been lost at an early date... In either case we need not be surprised that Icelandic has preaspiration but not the rising pitch pattern" (1974:100).

Geographical proximity was a factor which contributed to the earliest suggestion by Marstrander that the "preaspirating" Norsemen must have come from South West Norway. This particular argument loses most of its appeal when one realises that, according to Borgstrøm, the South West Norwegian Vikings would simply be those who settled in Lewis and Area B. Viking settlers in other parts of Scotland (e.g. in area C 1) would not, in his account, come from those near parts of Norway. This just doesn't make much sense in view of the fact that Lewis (area B) and Harris (area C 1) are one island.

4.1.2.2 The Old Norse System

The positing of two systems in old Norse by Marstrander and Borgstrøm - a "preaspirating" one and a "voicing" one, is, to the best of my knowledge, a rather idiosyncratic interpretation of the Old Norse system, and seems rather like a post-hoc reconstruction for the purposes of the argument at hand. Haugen, (1982:69) and (1976:203), presents preaspiration as a comparatively later innovation in Icelandic, alongside the devoicing of the voiced stops. He makes no reference to a possible dual system of the type suggested by Marstrander in the old Norse period. Árnasson also (1980:26), would seem to imply that the development of preaspiration must be a later innovation - indeed that it would postdate the quantity shift (which is thought to have occurred after 1300 A.D.). On the face of it, the view of preaspiration as a later innovation seems to make more sense than to postulate, on dubious evidence, that it was once much more prevalent but disappeared almost everywhere in the Scandinavian peninsula.

The actual process suggested by Marstrander, whereby nasal and stop clusters became geminates via a preaspirating stage is not phonetically very plausible. The change, for example of the cluster nt -> tt is in itself not a hugely complex one. As illustrated schematically in Figure 4.3, it need only involve two changes; the loss of the velar lowering gesture in the first segment of the cluster, and the assimilation of voicing. The latter process is common in languages anyway (see Westbury and

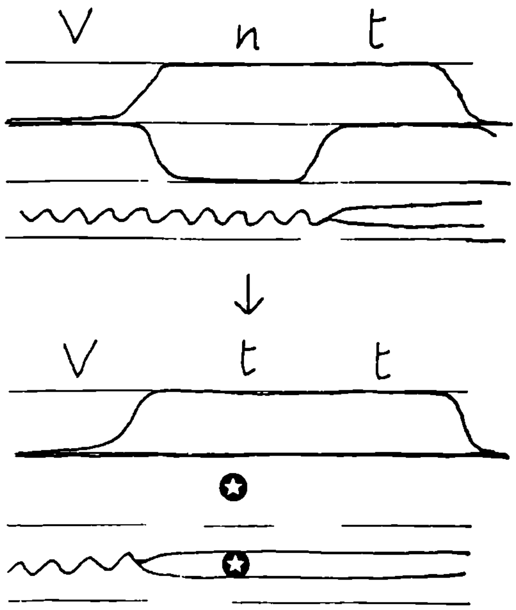


Figure 4.3 To account for the change nt ⟶ tt, two articulatory changes are required (each marked by ✪)

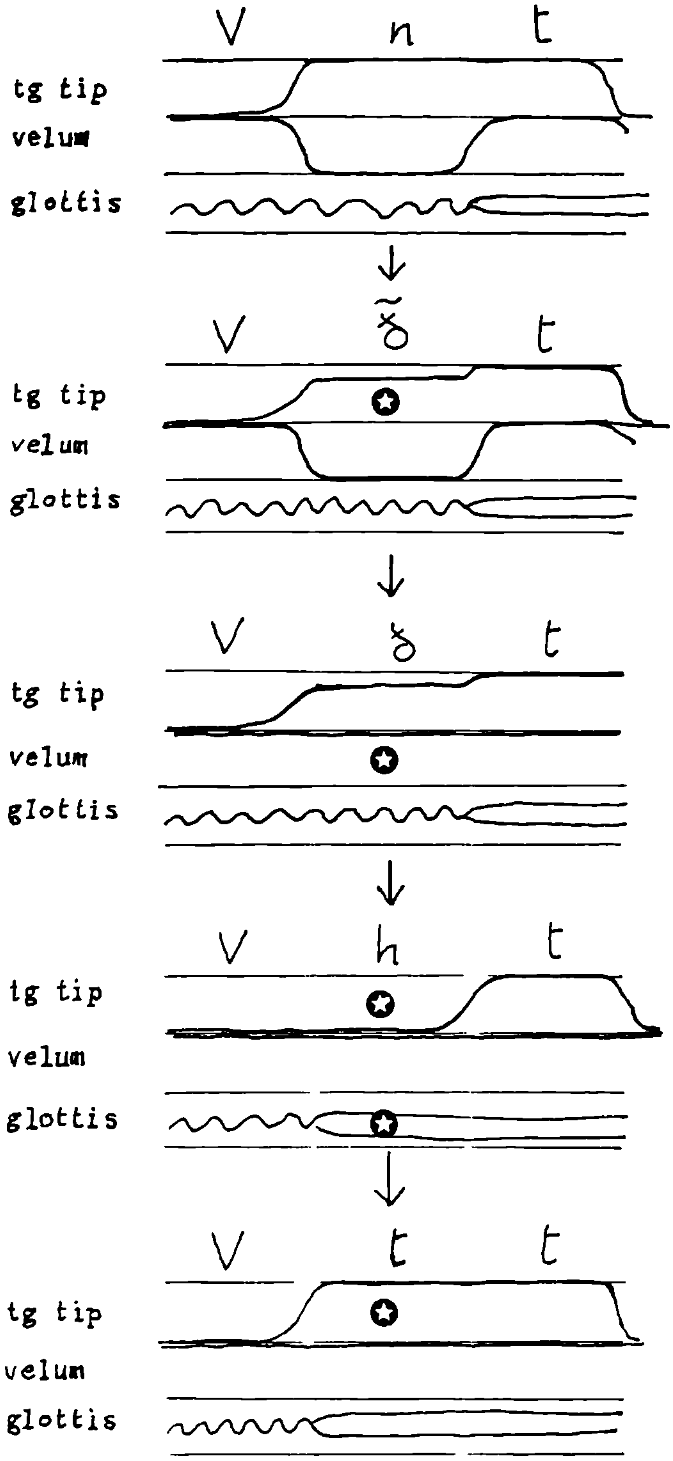


Figure 4.4 Marstrander's account of the change nt ⟶ tt (each step of the change is marked by ✪)

Keating, (1980); furthermore, as is argued in section 4.1.4 of this chapter, in a geminate stop aerodynamic constraints would make devoicing a likely development.

The much more complex derivation of the geminate **tt** from **nt**, suggested by Marstrander and illustrated schematicaly in Figure 4.4, seems only motivated to provide a source for the postulated preaspirated stops. The gradual lenition of the first segment in the cluster, from nasal stop, to dental fricative, to glottal fricative, seems extremely unlikely. First of all, a sequence of nasal plus homorganic stop, involving as it does , a single oral articulation would seem a highly unlikely environment for the gradual weakening of the nasal's oral gesture. Lass and Anderson (1975) specifically cite the environment of nasal plus homorganic stop as a non-leniting environment in languages.

Marstrander's account is rendered even less plausible if one remembers the fact that, in the vast majority of Norwegian dialects, the last stage of the development would have to be back to an oral stop. Therefore, for these dialects, the apparently rather simple change would in Marstrander's account, involve a gradual weakening of the oral aritculation (i.e. less and less oral occlusion) followed by a return to complete oral occlusion. (In "lenition" terms, this means a lenition followed by a counter lenition : lenition processes are discussed further in the second half of this chapter.)

Even if one were to accept Marstrander's account of the development **nt** -> **tt**, the reason why the process should have halted, temporarily for some dialects, at the **ht** stage (stage "4" in Figures 4.1 and 4.2), seems also unconvincing. The halting of the gemination-forming process was caused, Marstrander suggests, by a pressure within the language not to confuse the original **nt** type of cluster with original geminates. If such a pressure did operate within the language, there is no evidence of it. As Marstrander acknowledges, in both Norwegian and Icelandic, whether one speaks of an opposition involving geminates (and voicing) or an opposition involving preaspiration, the reflexes of the clusters in question have not been kept separate from the original geminates (stages 5 a) or 5 b) in Figure 4.2).

In dialects which would have taken the 5 b) option (i.e. the preaspirating option), the original geminates would have become preaspirated stops, thus in Marstrander's account, falling together with the original **nt** type cluster which had developed to a **ht** stage. To explain the coalesence, Marstrander suggests that the preaspirated stop may have provided better differentiation with the single voiceless stop. This seems again a rather arbitary and unconvincing explanation and prompts the following question: if preaspiration originally involved single stops, why would it get generalised to the geminate, and not to the single stop (if the phonological "need" was simply to heighten the contrast between these two)?

Finally, one might question Borgstrøm's grounds for suggesting that a "preaspirating" system might have been much more extensive in Old Norse than in present day Norwegian, i.e., the apparent occurrence of "more or less voiced lenes" stops in both South-West Norwegian and Icelandic.

First of all, it is not clear how one should interpret the terms "more or less voiced lenis". According to Kjell Gustafson, this is a reference to the fact that the original single voiceless stop is becoming voiced. If so, one would raise the following objections:

- Voiced stops are <u>not</u> found "in the greater part of Iceland today" (see for example Haugen, 1982; Éinarsson, 1945; and Árnason, 1980, as well as the data of Chapters 2 and 3). Indeed, the stop system of Icelandic is remarkable for the lack of voicing proper. Borgstrøm's statement refers back to two other earlier authors, Benediktsson and Chapman. The second of these has clearly been misinterpreted. Chapman speaks of "voiceless unaspirated" or "voiceless aspirated" stops as reflexes of the single (presumed) voiceless stops of Old Norse in the "linmaeli" and "harðmaeli" dialects respectively of Modern Icelandic. The confusion here may have arisen by the rather misleading phonetic symbols used by Chapman. The second of Borgstrøm's references does indeed mention partly or fully voiced stops, but refers in turn to earlier work, which, insofar as it has been possible to ascertain, does not in fact describe these stops as being phonetically voiced. One cannot of course exclude the possibility that some voicing may occur occasionally in Icelandic stops, either as an idiosyncratic feature of the speech of some individuals and/or as a rather restricted allophone in some specific enviromnents. However, a more likely explanation for a reference to voicing in an early description of Icelandic could be that such comments were intended more as phonemic than phonetic statements.

- Apart from the apparent error, this paticular suggestion of Borgstrøm's seems rather irrelevant. Even if Icelandic did have voiced or partly voiced stops, it is not at all clear why this should point to an earlier preaspirating system. Many languages, e.g. English, have voiced or partly voiced stops.

- Most importantly, I would argue that Borgstrøm is ignoring the crucial point that, preaspiration seems closely connected with the <u>loss of voicing</u> in any particular language, rather than, as he implies, the <u>voicing of stops</u>. This devoicing tendency is, I would feel, a phenomenon which is fundamentally related to the development of preaspiration, a point which is missed in the accounts of both Marstrander and Borgstrøm. Oftedal (1947) has pointed out that it is precisely in those preaspirating dialects of Jaeren that devoicing of the lenis stop is found. Haugen (1982) also implies this connection, in treating preaspiration of fortis stops together with devoicing of the lenis as innovations from Old Norse. The data presented in Chapter 2 suggests that there is indeed an intimate relationship between the development of preaspiration in the historically voiceless geminate, and the loss of voicing proper in the cognate. In any of the modern languages looked at, the extent of preaspiration of the fortis series seems to correlate with the extent to which voicing in the lenis has been lost. Preaspiration would seem to function, and presumably did function as the realisation of a voicing opposition. This contention forms the basis for the proposed derivation outlined in section 4.1.4.

4.1.2.3 <u>The mechanism of preaspiration adoption in Scotland</u>

Lewis preaspiration supposedly represents the "original form" of preaspiration, adopted at the bilingual stage by simple transfer *of the L1* system of stop oppositions to L2 (L1 = first language, *in this case Norse;* L2 = second language, in this case Gaelic). Preaspiration in the C1 and C2 areas represent, according to Borgstrøm, something quite different, namely the substitution of the nearest Gaelic segments for the aspiration of the preaspirated stops, presumably at a later, non-bilingual stage.

Firstly this argument rests on the basis of regarding Lewis preaspiration as quite a disparate phenomenon from that of areas C1 and C2, rather than as different degrees of the same phenomenon. This relates to the monophonemic/biphonemic discussion in Chapter 1.2.5. It has been argued there that the grounds for a differential treatment of the Scottish Gaelic dialects are not particularly valid or useful. But even if there were sensible reasons for choosing different phonological analyses of preaspiration in the B and C dialects of modern Gaelic, this would hardly justify an assumption that there were historically two different modes of preaspiration adoption.

There are a number of other problems connected with the Borgstrøm account, mainly concerning the geographical distribution of preaspiration in Scottish Gaelic dialects. These have been the main source of scepticism on the part of Celtic scholars in accepting the "Viking theory" of preaspiration development in Scotland. Celtic scholars have pointed out the lack of correlation between areas of Norse settlement and preaspiration in Scottish - Gaelic dialects. (For the dialect areas alluded to here, see map in Chapter 1.2.2.3.)

- There is strong preaspiration in areas where the Norse are are not thought to have settled. The Central Highlands (area C2), an area not particularly "visited" by the Norsemen, is widely held to have the strongest preaspiration. Jackson would claim it as the probable centre of diffusion of this feature in Scotland (reported in Oftedal (1962:116). But in Borgstrøm's account, the presence of preaspiration in these areas must necessarily be explained as a later adoption - through imitation and substitution.

- Some areas of dense Norse settlement do not have preaspiration. The Arran dialect (area A2) would present such a problem. This is an area thought to have been inhabited from the 10th or 11th to the 13th Century by the Gall-Gaidil, a population of mixed Norse-Gaelic extraction, probably bilingual (see Marstrander 1915:8 cited by Borgstrøm). If the lack of Norse influence on Gaelic is attributable, as Borgstrøm would argue, to a sudden language shift without a period of bilingualism, then surely the Gaelic of Arran might be expected to exhibit most Norse influence. This dialect however shows no trace of preaspiration, and may in fact have lost the voicing opposition among stops altogether (see Chapter 1.2.2.3).

- Norse settlements in the C1 areas were almost as dense as in Lewis, and these areas do in fact have strong preaspiration. Yet Borgstrøm claims, these settlers would have come from a different, non-preaspirating area of Norway, and the preaspiration in these Gaelic dialects developed later through imitation of Lewis speech and substitution of Gaelic segments. As already mentioned, such a claim seems even more implausible when one remembers that Lewis (in area B) and Harris (in area C1) constitute a single island.

When it comes to linking Gaelic phonetic features to Viking adstratum there is a separate argument of this type which would militate against Borgstrøm's theory that the Norse settlers in Lewis came from South West Norway. Retroflex apicals are a feature of the Lewis dialect, which Henderson (1910:108) regards as evidence of a Norse influence. But, as Borgstrøm points out, these occur in the East of Norway, not the South West. Given the "choice" of types of conflicting evidence Borgstrøm simply decides that the similarity of the pitch patterns are a more important feature to go by, and so suggests that the retroflex apicals of Lewis are probably not of Norse origin anyway, but simply a spontaneous development in Lewis Gaelic.

There is one final point worth mentioning here, which Borgstrøm does not address. The production data in Chapter 2 and the perceptual experiments in Chapter 5 would suggest that Icelandic preaspiration resembles that of Harris, Skye and North Uist more than that of Lewis. The logical extension of Borgstrøm's argument would then be that Icelandic preaspiration can not be the true "original" preaspiration either. If, on the other hand, Icelandic preaspiration does derive from the "original" type of Old Norse, the fact that it developed quite spontaneously as it did in Iceland makes nonsense of the claim that the similar preaspiration in areas Cl of Scotland came about through a *different mechanism*, i.e. by substitution of a Gaelic phoneme.

Proponents of the language contact theory have always presumed that the direction of the influence was from Viking to Gael. However, while on the topic of the provenance of Icelandic settlers, some interesting points have begun to emerge from recent studies in genetics, which could have implications for such an assumption. Although Icelanders have traditionally seen themselves as the descendents of Viking kings, these recent studies have shown that they may owe more of their roots to their Celtic slaves than was ever thought to be the case.

Recent study of genetically determined blood sub-groups by a team of researchers would seem to show that Icelanders may be racially much more closely related to the peoples of the West of Ireland and of Scotland, than to their fellow-Scandinavians. To quote some of the conclusions of this study:

> "In the ABO and secretor systems Iceland resembles Ireland and Scotland much more closely than it does Norway... The most straightforward interpretation is to assume that the present populations of Norway, Ireland and Scotland are the direct descendants of the populations of 1000 years ago, and that neither in these countries nor in Iceland has selection or genetic drift substantially altered the gene frequencies. If that is so, then the Icelanders are predominantly descended from the peoples of the British Isles." (Bjarnason et al., 1973:451)

The genetic evidence is apparently reliable, and compatible with earlier anthropological findings (ibid:428). If correct, it presents us with some interesting enigmas. How and when might such large numbers of Celts have settled in Iceland ? And why would they have had so little effect on the Icelandic language?

Answers to the first type of question might be one (or both) of two kinds: very large numbers of Celtic slaves brought from Ireland and Scotland by the Vikings, or, pre-Scandinavian occupants of Celtic origin in Iceland. These possibilities are both discussed in the above study which mentions that according to the Book of Settlement (<u>Landnámarbók</u>, written about 1130 A.D.)

settlers brought with them at least 20-30 slaves each. Pre-Scandinavian settlers of Celtic origin are also attested, in the form of hermits called Papar by the Norsemen, and who are thought to have occupied islands around the coast. Being hermits, it is unlikely the latter did a lot to propagate Celtic genes. The part of Iceland known as Westmannyjaer (which translates as Irishman's Island) was thought in the local tradition to have got its name for having been the site of a rebellion of Irish slaves against their masters. The possibility that the name derives not from such an incident, but from previous inhabitants of Celtic stock is currently being investigated by some archaeologists (personal communication).

These types of speculation and interpretation of genetic findings, are clearly outside the domain of this study; for further discussion the reader is referred to the Norwegian Archaeological Review, (1972 and 1973). Here, one would simply wish to note the implication for the present discussion: if preaspiration is to be explained in terms of "language contact", this could conceivably be argued in either direction. Thus, when it comes to considering the second question posed above, might not this feature be seen to represent an innovation in Icelandic, triggered through contact with "preaspirating" Celtic dialects?

However, that is not the substance of the hypothesised derivation of preaspiration put forward in 4.1.4. Rather, it is felt that, although contact may have been a (reinforcing perhaps) factor, there are reasons to think that the development of preaspiration might have arisen spontaneously within both languages.

4.1.3 Preaspiration: A Strategy for Maintaining Length ?

The preceding sections have outlined a number of reservations concerning the "Viking" theory of Gaelic preaspiration as proposed by Marstrander/Borgstrøm. Celtic scholars have also on the whole been sceptical of the account, mainly because of the lack of correspondance between extent of Norse settlement and distribution of preaspiraton.

A counter-explanation of preaspiration in the Scottish Gaelic dialects has been proposed by Ó Baoill. Instead of positing a Viking influence, this explanation tries to account for the development in terms of factors internal to the structure of Old Irish. Ó Baoill's basic contention is that the development of preaspiration is "an attempt ... to maintain a unified syllabic length within the original syllables".(:80) Ó Baoill further claims that "the innovating factor ... was the Old Irish geminated consonants, i.e. that the breakdown of these originally geminated consonants brought with it a restructuring of the syllable ... and that at all costs the original length of the syllable should be maintained".(:80)

The suggestion that preaspirated stops developed from earlier geminated stops is of course not new and was suggested by Pedersen (1897), who did not however, outline what process might have been involved, or what its motivation might have been. Ó Baoill not only provides a motivation, but also gives some specific details on the actual process which process he presents as a release of the oral contact in the first part of the geminate (:88-89). He further seems to imply that the oral release would have occurred gradually. Thus he proposes that in the case of velar and palatal stops, the "original form" of preaspiration would have been velar or palatal fricatives. In the case of the dental and palato-alveolar (and presumably the bilabial) stops, he suggests that the forms with homorganic fricative realisations of preaspiration were lost, leaving the glottal fricative realisations of most modern dialects. Instances where velar/palatal fricative realisations are found with stops other than velars or palatals see description in Chapter 1) are explained as later innovations by Ó Baoill. (These are the C2 dialects; see Chapter 1.2.2.3.)

In this account, it is worth noting the following:

- although Ó Baoill does not mention it, his account of the changes that occurred to the first part of the geminate conforms to the classic lenition route **k** ->**x** ->**h**, typically found for single stops in languages. (Section 4.2 of this chapter deals in detail with this topic.
- if one accepts Ó Baoill's account, the C1 dialects would come closest to representing the "original" form of preaspiration. This contrasts with Borgstrøm's view that the weaker, non-preaffricating B dialects are "heirs" to the true preaspiration.

This historical account by Ó Baoill looks very similar to the synchronic phonological account of preaspiration in Icelandic by Thráinsson (1978), who argues for a rule whereby preaspiration is derived from the geminate by deleting the supralaryngeal features of the first of two identical stops.

The motivation for the change from geminated to preaspirated stop in Ó Baoill's account is also similar in some respects to a suggestíon in Allen (1973:70) that preaspiration in Icelandic developed through a voiceless lengthening of the vowel in forms like <u>brattur</u>, which arose to compensate for a shortening of the historically long plosive.

Ó Baoill's analysis is not without problems. The first serious objection concerns whether or not geminated stops did in fact exist in Old-Irish. They did exist in Primitive Irish; in fact the consonant system as a whole opposed single and geminate types. However, the single stops of Primitive Old Irish are thought to have lenited (spirantised) approximately around 450 A.D. And in the Old Irish period (600 A.D. - 900 A.D.) scholars of Old Irish such as Pedersen and Thurneysen were certainly of the view that there were geminates although, Thurneysen (1946) does point out that there was a tendency towards shortening, as evidenced by some inconsistencies in orthography, with a tendency to replace the double letters with single ones.

However, how early or how completely the degemination occured has been differently interpreted by some other scholars. Borgstrøm, (1974) argues on the authority of Marstrander (1932) that the process of shortening was accomplished quite early on; needless to say, both scholars are arguing for the Viking influence hypothesis, and would wish to refute Pedersen's claim that preaspiration derived from the geminates of Old Irish. Marstrander cites some examples of words, which were written with double letters in Old Irish but were adopted into Norse with single consonants.

Greene (1956) would appear also to argue against gemination in the Old Irish period. It is however clear that the main thrust of his argument is, in fact, that there was not a phonemic or morphophonemic opposition between geminated and non-geminated stops in Old Irish, whatever might have been present at the phonetic level.

But does the spirantisation of single stops, by leaving the phonology "free" as it were to shorten geminates, necessarily mean that shortening did occur immediately after, or in every dialect ? Might not other types of (e.g. prosodic) constraints conceivably be working in the language to counteract the "shortening" pressure?

There is rather a lot of evidence in some of the decriptions of individual Irish dialects to suggest that length in stops has persisted right up to the present day. Sommerfelt, in his description of the Irish of Torr, Co. Donegal, mentions that he found "traces of the original double stops in the manner of articulation of the present day".(1922:449) Quiggin (1906), in his description of the dialect of Glenties, Co. Donegal, also mentions finding geminate consonants. More recently Wagner (1959) in his description of the dialect of Teilionn (also in Co. Donegal), mentions that stops are geminated, as are the other consonants which historically are thought to have been geminated. He concludes,

> "Is cosamhail nár athruigh córas chonsana na Sean-Ghaedhilge i nGleann Ch. C. ar chorr ar bith. Ach tá cuid mhaith den chóras seo coinnighthe i dTeilionn féin (C. 8)." (:15)
>
> Translation: "It appears that the consonantal value of Old Old Irish did not change at all in Gleann Colm Cille. And Teilionn has retained much of this system also."

O Baoill, in his article, cites evidence of his own to show that geminated consonants are to be found in Mín a Chladaigh and Leath Caite in the eastern margin of Gweedore parish in Co. Donegal. He presents material taken from the speech of an 89 year old informant recorded in 1974.

So far, all the observations concern Donegal Irish. But this might well be true of some of the other Irish dialects too; e.g., Dr. D. Ó Sé has spoken to me of similar "long stops" in the Irish of Corca Dhuibhne, Co. Kerry.

The earlier of these claims regarding gemination in modern Irish dialects (e.g. Sommerfelt and Quiggin) were of course known to

Marstrander, but he rejected them as unlikely.

> "il semble peu vraisemblable qu'après la disparation des brèves, alors que leur quantité ne jouait plus aucun rôle dans le système, les anciennes longues aient survécu , dans leur splendide isolement, tout un millénaire." (1932:305)

Another, different, objection levelled by Greene (1956) at the suggestion that preaspirated stops might derive from earlier gemination, is that preaspiration is also found for modern reflexes of some non-geminate stops. Clusters of liquid or nasal plus stop (historically thought to have been a non-geminate) also show preaspiration, in the form of devoicing of the preceding liquid or nasal.

Ó Baoill's response to this objection is to suggest that stops in that particular environment may have been geminated also in Old Irish, although this would represent a rather novel departure from the orthodox view.

> "What evidence is there to prove the non-existence of geminated stops in words of the type olc, cearc, folt, aplan, etc. ?" (:89-90)

He argues that these were on occasion written with double letters, and points out that the particular dialect of Donegal, for which he already cited evidence of long stops, also has length in this environment. He concludes that "such pronunciations are undoubtedly a survival of older pronunciations which stretch back all the way to the Old Irish period and even further"(:91) and that "this gemination may have been the major factor that prevented the conversion of these stops to [x]". (:90)

Even if one goes along with Ó Baoill's arguments that preaspiration derives from gemination, one might raise questions regarding the posited motivation for the development. His basic hypothesis is that preaspiration developed as a means of maintaining the original length of the syllable (:80).

If that was the case, however, one must ask why syllables which historically contained voiced geminates did lose their length. The fact that they did is clear from the durational data presented in Chapters 2 and 3. In the Scottish Gaelic dialects, in most environments, the modern reflexes of the Old Irish long voiced stops have about the same duration as the closure duration of the preaspirated ones (see Chapter 2.5). And although vowel durations tend to be somewhat shorter in the "preaspirating" syllable, there is little evidence of any strong tendency to equalise syllable length (with and without preaspiration). So much is clear from the fact that vowel duration differences are tiny or inconsistent in short vowel environments - the very environments where preaspiration durations are longest (see Chapter 2.6). Thus for these dialects, there is quite a difference in total duration between the modern reflexes of Vgg and Vkk (i.e. Vg and V^hk). This difference is of course at its greatest in the environments and dialects where preaspiration is longest. Note that, of the derivatives of Old Irish looked at, only Irish seems to retain a roughly equal duration for both syllable types. And Irish is the one which exhibits the least preaspiration (see also Chapter 2.6). Effectively therefore, preaspiration has resulted in a disparity of syllable lengths. If there was a tendency operating in the language to maintain syllable length (as Ó Baoill posits), this simply shouldn't happen.

Finally I would argue that the process proposed by Ó Baoill whereby geminates developed into preaspirated stops is not phonetically plausible. The gradual lenition of the first half of a geminate, as proposed by Ó Baoill, is unlikely for much the same reason as the lenition of the oral articulation of the nasal in clusters such as **nt** (proposed by Marstrander) would be unlikely. The second part of this chapter deals in greater detail with the topic of lenition and the likely causitive factors involved. As will be seen there, these factors would lead us to expect the lenition of single stops, and the shortening of geminates, (with the subsequent possibility of lenition), but not the gradual lenition of the first half of a long stop.

4.1.4 An Alternative Chronology

This section outlines an alternative proposal to account for the development of preaspiration within the languages of this study. I share with Ó Baoill the view that, whatever the potentially reinforcing effects language contact might have had, there are simple factors, internal to the systems of Old Norse and Old Irish, which might anyway have triggered the development of preaspiration. I will argue for all these languages, as Ó Baoill and Pedersen have done for Gaelic, that preaspiration is somehow related to the previous gemination of these stops. But the precise motivation and the process involved (i.e. the stages of its development) I would see as being completely different from those suggested by Ó Baoill. The triggering factor (or the internal pressure as it were) came, not from the shortening of the geminates, combined with a need to maintain length of syllables, but rather from a phonetic tendency towards devoicing of the voiced geminate, and a consequent pressure to maintain the voiced/voiceless opposition. I would see the process of preaspiration development as being intimately linked to the devoicing of the previously voiced member of the opposition and suggest that both these features developed along parallel lines. (Indeed, this tendency to develop devoicing and preaspiration, may also relate to general tendencies towards devoicing of other segments in these languages. This last point however, lies outside the scope of the present discussion.) The actual shortening of geminates when and where they did, I would view as a comparatively separate matter. The devoicing and the shortening tendencies, could however be connected in the sense that they could interact; any dramatic shortening would probably reduce the tendency towards devoicing and hence the related tendency towards preaspiration of the cognate. The nature of these processes (and others described within phonology as weakening or strengthening lenition processes) and the way in which such processes interact, form the subject matter of the second part of this Chapter.

As has been pointed out earlier, devoicing of a voiced geminate stop would not be a very surprising development to find in a language, for simple production reasons. As described in Chapter 1.1.1, during oral closure for a stop, oral pressure builds up, so that the difference between it and subglottal pressure (the transglottal pressure-drop) is reduced. For voicing to continue, the transglottal pressure-drop must not fall below 2 cm Aq, approximately (see Catford, 1977:29). The longer the stop duration, the more likely it will be to develop voice breaks for the passive aerodynamic reasons just mentioned. A positive correlation between voice breaks and the duration of long stops in Swedish has been pointed out by Løfqvist (1976). Similar findings have been reported for the voiced geminates of Italian by Carminati (1984). Ohala (1983) also talks about the likelihood of voiced geminates becoming devoiced. He suggests that the development of implosives in Sindhi may have resulted from an exaggeration of the larynx lowering adjustment. This adjustment is frequently concomitant with voiced stops and is generally regarded as a voice-maintaining strategy (see Chapter 1.1.0). The relationship between stop duration and voicing is central to the discussion of lenition in the following section of this chapter.

The data presented in Chapter 2 suggests that there is an intimate link between loss of voicing proper in the originally voiced geminates of these languages, and the development of preaspiration in the reflex of the old voiceless geminate. In each language looked at, there is extensive devoicing of the lenis series. The extent of this devoicing correlates well with the extent to which preaspiration is found in the fortis. Effectively, it looks as if preaspiration functions, and has functioned as a voicing opposition. The stages envisaged in the development from geminates to their modern reflexes in the languages in question are presented in Figure 4.5.

<u>Stage 1 -> 2</u>

Stage 1 represents an opposition of voiced and voiceless geminates. Such an opposition is still found in the vast majority of Norwegian and Swedish dialects today. The voiced member of such oppositions are prone to voice breaks (see Löfquist,1976). In the second stage, the voice-breaks in the voiced geminate may reach a point where the voicing opposition may be threatened.

<u>Stage 2 -> 3</u>

Along with the loss of voicing proper in the voiced geminate, preaspiration begins to develop in the voiceless member as a means of preserving the opposition.

<u>Stage 3 -> 4</u>

As preaspiration develops and becomes longer one could speculate further that there might be some pressure on the voiceless geminate to shorten. This is because the duration of preaspiration would add to the duration of the syllable in which the preaspirated stop occurs, making it longer than the syllable which contained the originally voiced geminate. This suggestion

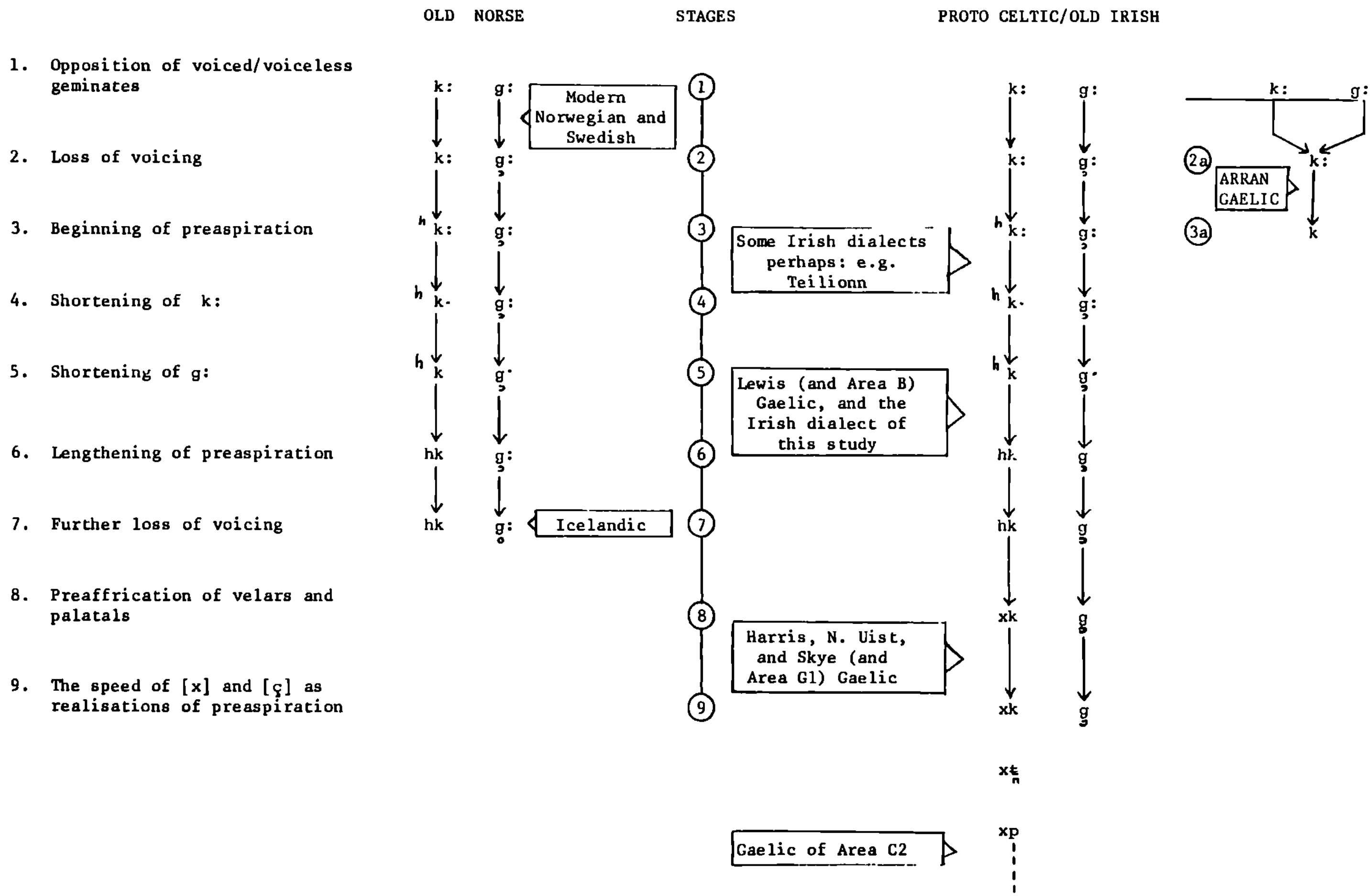


Figure 4.5

Schema proposed to show the development of preaspiration from the geminates of Old Norse and Proto Celtic is the complete reverse of the sequence of events proposed by Ó Baoill. Whereas Ó Baoill proposed that preaspiration developed as a means of maintaining the original length of the syllable after the geminate had shortened, it is being suggested here that the shortening of the geminate might have followed upon the development of preaspiration to reduce the durational difference between the syllable with and without preaspiration.

In addition to any "pressure" on the voiceless geminate to shorten, it would also now be more "free" to shorten, once the preaspiration had developed to the point where it was perceptible enough not to risk, for example, in Icelandic being confused with the single voiceless stop. (In Irish, it will be remembered, the single stop has already spirantised).

The present day situation is as follows: the original voiced geminate of Icelandic has retained its length, and the earlier voiceless geminate has shortened : in the Scottish Gaelic and Irish dialects looked at, both of the earlier geminates have shortened. Of course, this is not a full picture for Irish at any rate; as the discussions above have pointed out, geminate stops may still be found in some dialects, and as far as we know, for both stop series. This clearly warrants future research. So Stage 3 -> 4 might represent the stage at which those dialects find themselves, where gemination of stops is still found (e.g. the Irish of Gleann Colm Cille or of Teilionn, mentioned above).

The timing and the order in which the original geminates shortened is not in fact crucial to the account proposed here for the development of preaspiration. The link I would wish to posit is an indirect one, already mentioned. If preaspiration was triggered by a devoicing tendency in the lenis stops, such a devoicing tendency is likely to have predated the shortening of the geminates. Or in other words, as an opposition of voiced and voiceless geminates is, for production reasons, unstable with regards to the voicing feature, a devoicing tendency would most likely have originated at a stage where the stops were still long. The devoicing tendency in the lenis stops would, in turn, have provided the trigger for preaspiration.

Stage 4 -> 5

This stage would represent the full shortening of geminates for those dialects where this happened. This stage might be represented by Lewis Gaelic and Irish; i.e., the opposition involves some voicing of the lenis, and some preaspiration of the fortis stops. The decision as to whether the opposition should be characterised phonologically as "voicing" or a "preaspiration" one could be a fairly open question. From the phonetic point of view the "problem" is hardly very interesting.

Stage 5 -> 6

At some point the preaspiration becomes perceptible in its own right and may be further lengthened. It is at this point that one might argue for a new status as a separate phoneme, although for reasons outlined in Chapter 1.2.4, I do not feel these arguments are particularly valid. Therefore, the convention I have adopted above in Figure 4.5 of indicating the preaspiration on the line as a full segment, as opposed to the suprascript version, is intended as a means of indicating the durational difference, and not as a phonological statement. (Elsewhere in this thesis, the suprascript symbol is used).

Stage 6 -> 7

Once the preaspiration is very long and perceptible, voicing in the other stop series should become redundant, and this in turn would permit of further voicing loss. The process has been completed in Icelandic (which I would see as representing stage 7). In the Scottish Gaelic dialects of Harris, Skye and North Uist there is comparatively more, but still very slight remnants of voicing. What voicing there is in these dialects, appears to be no more "edge vibrations" of the opening vocal folds, and is unlikely to be perceptible (see chapter 2.3.3).

Stage 7 -> 8

Long preaspiration might further give rise to preaffrication, i.e. the development of homorganic friction before the stop. Two factors could play a role here. (These have already been alluded to in Chapter 1.2.4 and illustrated schematically in Figure 1.3.)

The first would be the actual duration of preaspiration as such; the wider the vocal folds have had time to open, the higher will be the rate of airflow through the oral cavity and hence, the greater the liklihood of local oral friction. Place of articulation (more precisely, the size and mobility of the articulator, and hence, the speed with which it moves) may contribute to the duration of preaspiration. Observation of some data presented in Chapter 2.2.3 would seem consistant with the expectation that preaspiration would be longer for segments articulated with the sluggish articulators (tongue front or back) than for segments articulated with the more mobile tongue tip or lips.

Place of articulation is directly linked to the second factor. As was illustrated schematically in Figure 1.3, in the closing phase of the preaspirated stop, local oral friction should dominate over glottal friction for that final portion where the oral aperture is actually smaller than the glottal aperture. For slow-moving articulations (e.g. tongue front or back) the duration of this portion will be longer and any oral local friction should be more perceptible. (Data showing slower oral closing times for tongue body articulations are presented in Chapter 2.2.3 and in Figure 2.6.) Therefore, one should expect preaffrication tendencies to begin with 'tongue body' segments such as palatals and velars. And this is what is found in the dialects of Harris, North Uist and Skye; preaspiration is realised as preaffrication for these places of articulation. These dialects represent stage 8.

<u>Stage 8 -> 9</u>

Some dialects (those represented as C2 by Borgstrøm) have a velar or palatal fricative as the realisation of preaspiration for each place of articulation. This is not an altogether surprising development in a language such as Scottish Gaelic, where all the consonants are either palatalised or velarised (see description in Chapter 1.2.2). Thus, even for segments whose primary articulators are highly mobile, (e.g. the tongue tip), the tongue body is high. As discussed in Ní Chasaide (1979) there is typically a noticable palatal or velar on-offglide to these consonants.

In dialects which have long preaspiration, and consequently high airflow, it is not too surprising that these onglides should become audible and reinforced through time. On the basis of the glottographic data and discussion in Chapter 3.2, I would tentatively suggest here that emphatically stressed utterances (i.e. tokens with widest glottal aperture and highest airflow) would be the most likely source of variants which might give rise to such a development.

<u>Stage 2a -> 3a</u>

The dialect of Arran would represent a branching from the chronology outlined so far. Here, the devoicing tendency of the lenis stops in the language was not counteracted by a compensating preaspiration tendency of the fortis. The result was a neutralisation of the opposition in this dialect. Note that neutralisation of the opposition is described by Borgstrøm (1974); Holmer (1957) however, implies a disappearing rather than a completely neutralised contrast (see Chapter 1.2.2.3). Stage 3a) would represent the ultimate shortening of the geminate.

4.2 REFLECTIONS ON LENITION

4.2.0 Introduction

Languages exhibit regularities of sound change; in the case of voiced and voiceless segments, certain changes in certain directions have been attested with overriding frequency. These changes have traditionally been treated by phonologists and language historians as instances of a phonological process called lenition.

Lenition processes are usually assumed to be phonetically motivated. However, although many phonetic findings, and especially results of instrumental studies have in recent years afforded insights into aspects of lenition processes, there has been surprisingly little attempt to draw together the various threads to form a composite theory of the interacting conditions which culminate in lenition. The remainder of this chapter represents such an attempt, and is offered not as a definitive account, but as a move towards identifying the complex web of factors/conditions which may form the phonetic basis of lenition. Experimental demonstration or testing is not the purpose here; this would represent a vast task, given the complexity of the network of possibly interacting causitive factors. However, as will become clear, these comments on lenition are at least in part prompted by some of the experimental results of Chapters 2 and 3, providing as they do yet another segment to the jig-saw which is lenition.

The specific proposals as to what a composite phonetic theory of lenition might contain are presented in sections 4.2.1, 4.2.2 and 4.2.3. Before proceding, and in order to contextualise these proposals, this introductory section contains:

4.2.0.1 a brief discussion on phonetic explanation in phonology, and on the underlying assumptions (or differing viewpoints?) regarding the relationship between the two disciplines.

4.2.0.2 an outlne of some of the salient and less controversial "facts" about lenition which arise out of the traditional phonological descriptions.

4.2.0.3 a summary of points in the form of questions which a composite phonetic theory of lenition would need to address.

4.2.0.1 Phonetic Explanation in Phonology

The assumption that a phonetic explanation of lenition is possible or relevant is not uncontroversial. One school of thought (usually represented by non-phonetician linguists) adopts the view that the structural patterns and processes of phonology exist independently of the physical minutiae of phonetics. To quote Bolinger :

> "The science of phonetics, whose domain is the sounds of speech, is to linguistics what numismatics is to finance: it makes no difference to a financial transaction what alloys are used in a coin, and it makes no difference to the brain what bits of substance are used as triggers for language" (1968:13).

An extreme example of this position is exemplified by Foley (1977) who insists on the abstract nature of phonology and of phonological processes. In this work, Foley offers a detailed phonological account of lenition, which the following subsection will draw on. In his view, any attempt at phonetic explanation of processes like lenition would be misguided folly; the phonetic nature of segments is seen as almost irrelevant to the patterns they exhibit in languages. In words reminiscent of Bolinger, he insists that

> "the elements of a phonological theory must be established by consideration of phonological processes, without reduction to the phonetic characteristics of the superficial elements. Though in practice the phonological elements manifest themselves phoneticaly, it is quite possible to conceive of other manifestations of an abstract linguistic system. A phonological theory based on the phonetic composition of the manifest elements would exhibit the reductionist fallacy and fail to yield insight into the nature of language". (1977:25)

Much phonological work, however, does implicitly or explicitly espouse rather a different outlook on language and therefore on the relationship between phonetics and phonology. In the work of natural phonologists, there is an explicit claim that phonological rules must be natural, in the sense that they are ultimately motivated by physical constraints of our speech production and perception systems. Although most frequently there is no attempt to specify what constraints might be operating in a particular instance or why, there is a growing body of work by experimental phoneticians, e.g. by Ohala or Lindblom, which attempts to show how such a gap might be filled. The proposals in sections 4.2.1 to 4.2.3 lie within such an approach, and I would share with such authors the viewpoint that one of the more challenging long-term objectives of the discipline is that of contributing to explanatory theories on why sound systems in languages pattern and change in the ways they do. To quote Lindblom :

> "... language theory cannot do without its substantive phonetic basis. Languages are the way they are partly owing to the structure of our brains, ears and mouths. To be successful, theories aiming at explaining how languages are built must at least recognise that fact" (1978:151).

Clearly, not every sound change in language is phonetically motivated. Some changes may be extra-linguistic in origin. Figure 4.6, taken from Ohala (1974) is an attempt by that author to show the domain of phonetic explanation within the broader network of possible factors which may play a role in determining the ways in which language evolves.

Nevertheless, the sound changes which should be most amenable to phonetic explanation are those of quasi-universal occurrence (lenition is known to be near-universal and therefore provides an area where phonetic explanations ought to be explored). Such phonetic explanations might be in terms of production constraints, the acoustic properties of speech sounds (or of the transmission medium) or of processes of auditory analysis and human perception of speech.

In a recent discussion on lenition, Bauer has pointed out that attempts at purely phonological definitions of lenition tend to be circular and to result in disputes as to whether certain

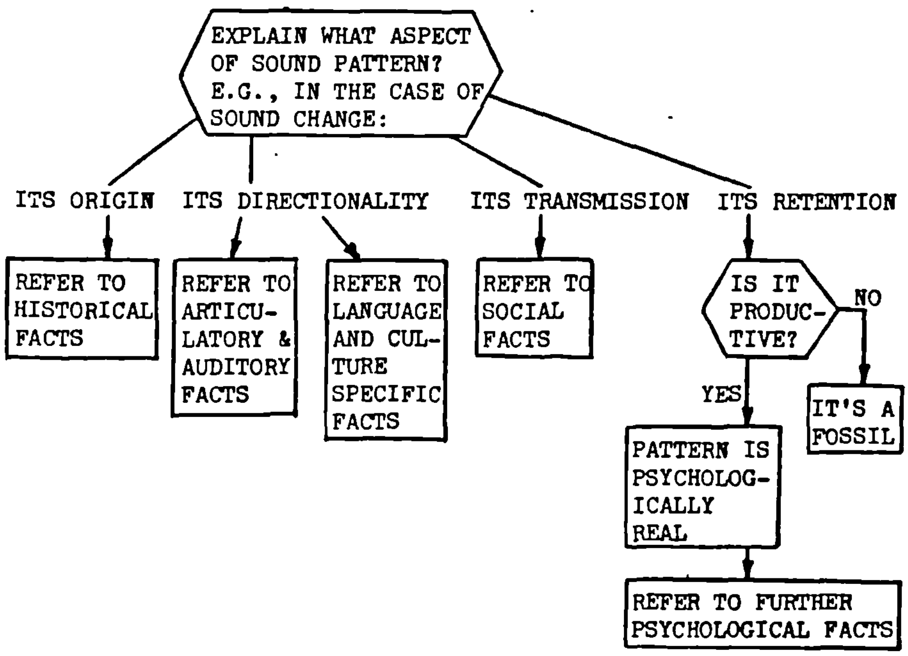


Figure 4.6 The domain of phonetic explanation within the broader network of language change (from Ohala, 1974)

changes constitute instances of lenition or fortition. Bauer concludes that

> "a phonetic characterisation of lenition is necessary if the term 'lenition' is to become explanatory in linguistics, and not just a piece of mumbo-jumbo used to hide our ignorance of the real causes of phonetic change". (1982:MS)

The proposals in sections 4.2.1, 4.2.2 and 4.2.3 can be considered a first, ground-clearing attempt to provide such a phonetic characterisation of lenition.

4.2.0.2 <u>The salient "facts" of lenition, as traditionally described</u>

Some of the main points concerning lenition, upon which there would be general consensus among phonologists, can be outlined as follows. This account draws mainly on Lass and Anderson (1975), henceforth referred to as L & A, and on Foley (1977). (See also Lass 1984 for a brief summary).

Lenition, when referring to changes involving voicing or voicelessness of (typically) obstruents, is a process where change occurs in the direction of voiceless to voiced, e.g. **k** -> **g**. This process is also sometimes called sonorisation (see for example L & A: 157) and is considered to involve a "weakening" of the segment, as indeed the term lenition implies. This process of sonorisation will be referred to here as Vo. It is not expected for all positional variants, but seems to be characteristic of medial intervocalic position. In the environments of #CV and VC#, the reverse tendency is far more likely, i.e. the devoicing of a previously voiced segment. This latter trend is typically described as a "strengthening"; the environemnts where strengthening is more likely to occur (and weakening less likely) are described as "strong" or "protected" environments (see L & A: 166).

A composite discussion of lenition must also take account of a second process, separate from sonorisation (Vo), but also called lenition and thought to be related. This is a process whereby stops become fricatives and may eventually disappear, passing through a glottal fricative stage (see L & A: 159). This process, which seems to involve a gradual weakening of the supraglottal articulation, will be mnemonically referred to here as W. It can be schematised as follows,

$$k \rightarrow x \rightarrow h \rightarrow \emptyset$$

with segments to the right of the arrows being weaker than those to the left.

As with the Vo process, W would not be equally expected for all positional variants. Like Vo, it is most likely to occur in VCV. Unlike Vo, W lenition does also occur in VC#, although it is less consistently attested here than in VCV.

Geminates are less prone to W lenition, or, to put this slightly differently, when they lenite, they tend to degeminate (i.e. shorten) before undergoing the W lenition route of single consonants (L & A: 161-2; Foley: 34). It is also noted by L & A that stops are likely to undergo W lenition when adjacent to a homorganic nasal (:164).

The place of articulation of a stop would seem to affect its susceptibility to W lenition. Foley , for instance, points to the fact that velars are more likely to undergo W than are bilabials or dentals (:28).

Both W and Vo are typically treated as two aspects (or options) of a single process - lenition. Schematisations of lenition routes, from L & A (:159) and from Foley (:34) are given below:

Figure 4.7 <u>Schematisation of lenition by Lass and Anderson (1975)</u>

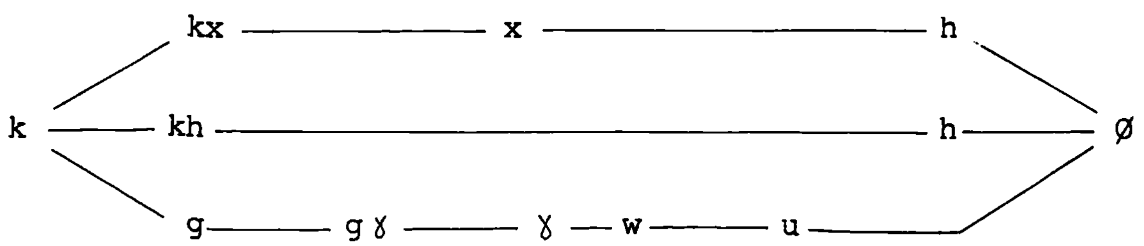


Figure 4.8 Schematisation of lenition by Foley (1977)

β			
4	kk	tt	pp
3	k	t	p
2	g	d	b
1	ɣ	ð	β
	1	2	3
		α	

The higher the number (on the horizontal or vertical axes, the greater the phonological strength; the β parameter (on the vertical axis) indicates relative propensity to lenition of different segment types; the α parameter (horizontal axis) shows relative strength of different places of articulation. For further explanation and exemplification of these, see Foley (:25-35).

A minor divergence in the accounts by Foley and L & A may be noted here. As can be seen from the lenition schema in L & A, aspirated and affricated segments are weaker than the voiceless unaspirated ones. Foley, on the other hand, treats these as stronger (this is not evident from the particular lenition schema included above, but see Foley 1977:145). This is an issue for further investigation, but will not be dealt with here, where the proposals will be restricted to a discussion of the "consensus" view on lenition.

4.2.0.3 Questions which a composite phonetic theory of lenition must address

To conclude this introductory section, the following list of questions are proposed as the ones which a phonetic theory of lenition should attempt to provide answers for.

Question: A What are the conditions which may lead to an occurrence of W lenition ?

B What are the conditions which may lead to an occurrence of Vo lenition ?

C Do W and Vo have a similar phonetic content to justify their unified treatment as a single phonological process? Or have they simply been grouped together on the basis of a superficial coincidental co-occurrence?

D Why do certain environments increase the likelihood that lenition (or fortition) will occur?

E Why are geminates and stops adjacent to homorganic nasals less prone to W lenition? Also, why do different places of articulation vary in their susceptibility to W lenition?

F Are W amd Vo appropriately described as <u>weakening</u>? Conversely, should the reverse process (e.g. devoicing in the case of Vo) be describ^e^d as strengthening ?

4.2.1 Towards a composite phonetic theory of lenition

The proposals ourtlined in the following sections represent a positive answer to question C above: do W and Vo share a similar phonetic content? The basic contention is that at the phonetic level W and Vo can perhaps be considered as resulting from **Target Undershoot.** The target is purely articulatory in the case of w, and articulatory/aerodynamic for Vo (see, however, the text of 4.2.2 for some refinement of this statement). It is proposed that undershot (or incompletely executed) targets (e.g. fricative realisations of a stop) are part and parcel of the synchronic variation of segments, and that diachronic change can be simply a matter of such sub-dominant allophones becoming the dominant ones, i.e. the new targets. This process could be visualised as in Figure 4.9. In this figure, the proportion of the triangle enclosed by a particular realisation should represent its relative frequency of occurrence. For example, a large percentage of the realisations of the phoneme /g/ might be realised as [g], a smaller percentage might have a [ɣ] realisation, and a small number of [ɰ] realisations might also be present.

A characterisation of lenition as undershoot will probably not appear surprising for W-type lenition; the concept has already been fairly frequently invoked in the literature, although more usually applied to the type of reductions which occur in vowel targets (see Lindblom 1983). The suggestion that Vo type lenition might also be characterised as undershoot may constitute

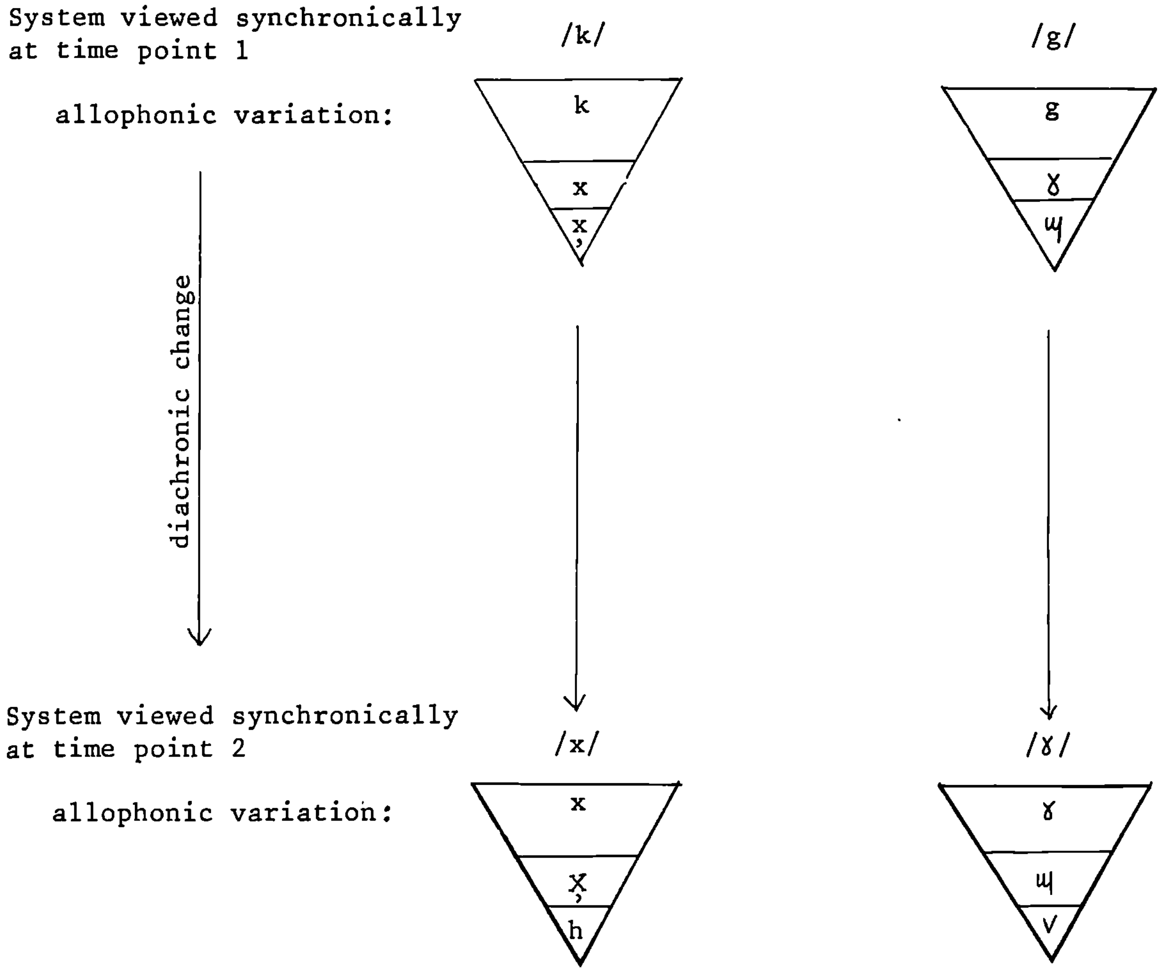


Figure 4.9 Schematic representation, showing suggested relationship between diachronic change and synchronic variation. Velars are used to exemplify

more of a novelty. As the argument here is for a unified account of W and Vo lenition, it is proposed that the same factors (more or less) give rise to the synchronically "lenited" allophones, and in time to the new targets. These factors are listed below (1 to 6). The account of W (section 4.2.2) and Vo (section 4.2.3) which constitute an attempt to answer questions A and B of the preceding subsection, are in fact an elaboration of how these factors may interact to yield target undershoot.

Factors which contribute to Lenition (W and Vo)

Articulatory	1.	Target Gesture Complexity
	2.	Mobility of Articulator
	3.	Independence of Articulator (only relevant to W)
Temporal	4.	Durational characteristics of segments as determined in turn by factors such as place of articulation, positional variation, presence/absence of gemination in the system
Aerodynamic	5.	(This is mainly relevant to Vo lenition.) Aerodynamic conditions are relevant to the successful accomplishment of both voicing and voicelessness in targets

Triggering Environment 6. Certain features of **Allegro Speech** (specifically, increased tempo and destressing) may provide a triggering environment for "lenited" allophones.

Factor 6 differs from factors 1 to 5 in the way that it contributes to undershoot. It is proposed that certain segmental targets are inherently more unstable than others, in that they are less likely to be fully executed within the time available. Factors 1 to 5 are the type of factors which determine the basic stability of a segment, and hence its propensity to weakening. (Needless to say the list may not be exhaustive.) Factor 5 is primarily relevant to Vo, although it may also contribute to one of the stages of W, as will be discussed in 4.2.3 below; factor 3 is relevant to W only. Factor 6 is suggested as a triggering factor for both W and Vo, in that it provides an environment which may tip the balance towards undershoot of unstable segments. Before proceeding to the more detailed account of W and Vo presented in 4.2.2 and 4.2.3, the reasons for proposing factors 6 as a triggering environment are discussed.

Factor 6: <u>Allegro</u> <u>(Rapid/Casual)</u> <u>Speech</u>

Tempo and stress levels are modulated during naturally spoken utterances. Discussed below is some of the recent research which suggests that differences in a) rate, and b) <u>stress</u> <u>level</u>, have consequences for the execution of articulatory gestures that would appear to be very important for lenition. The electroglottographic results, reported in Chapter 3.2, would seem to indicate equally important consequences of stress level for glottal activity. On the basis of such experimental findings, it is further proposed here that syllables in an utterance which are more rapidly uttered and are either unstressed or at least do not carry the primary stress, may provide a triggering environment for synchronically lenited allophones. This is because increased rate and a comparativley lower level of stress on a syllable ("lower stress" in the sense exemplified in the data of Chapter 3) may involve changes which exacerbate the already existing instability of certain targets. The targets most likely to be first affected are those which might be described as inherently more unstable in any case.

This suggestion may tie in with a proposal by Lass (1984:299), which could be termed the "Allegro Speech Hypothesis". This hypothesis postulates that "allegro speech" (i.e. a rapid casual speech register) spawns a large number of synchronic variants which are taken up in language change. This does seem compatible with the suggestions in the last paragraph, as, not only is there obviously an increase in rate of articulation in allegro speech, but it seems likely that there would also be a tendency to reduce the number of syllables in a particular utterance receiving stress, and/or a tendency to reduce the stress level on particular syllables.

Whether or not they do tie in with the allegro speech hypothesis, the specific proposals here are that the lenited variants are likely to be triggered in rapidly uttered and relatively unstressed speech tokens.

Stress

There is a considerable amount of instrumental phonetic work which suggests that stress level may affect the amount of muscular energy expended (or muscular driving force).

At the respiratory level, the investigations carried out by Ladefoged and his colleagues, reported in Ladefoged (1967), showed that peaks of activity in the respiratory muscles (the internal intercostals) were associated with stressed syllables in an utterance. Insofar as reduced respiratory effort does correlate with the unstressed syllable, this will have consequences for Vo lenition and for one of the stages of W lenition.

At the articulatory level, more recent studies suggest that the muscular energy expended by the supraglottal articulators may also covary with stress. This would seem uncontroversial in the case of vowels. For example, Sussman and MacNeilage (1978) and Sussman (1979) report an increase in the number of active motor units in the production of the vowels of stressed syllables, and a higher discharge rate for the individual motor unit. It would appear that the muscular energy expended in consonant production may also show similar tendencies. Experiments reported by Tuller et al. (1982) show that for repetitions of syllables with bilabial stops, the amplitude of EMG activity for the orbicularis oris muscle is higher in stressed than unstressed syllables in nearly all cases. This effect is, however, not unambiguously attested for consonantal articulation, or at least, not all the muscles associated with consonant production need be affected in a particular instance. For example, in the same study, the muscles associated with jaw opening/closing did not consistently exhibit increased muscular activity for these same bilabial stops. This is an area of much current research, where one can hope for answers in the not too distant future.

The fairly strong suggestions that stress differences may correlate with differences in muscular activity in consonant production could be quite relevant to a discussion of W lenition. The same is likely to be true for Vo lenition, judging from the findings reported in Chapter 3. Electroglottographic data in that chapter seemed to indicate that there may be greater amplitude of glottal abduction for voiceless stops at higher stress levels. Some corroborative evidence by Andersen (1981) has also been alluded to. This would be in keeping with the hypothesis that there is overall less energy expended in unstressed articulations. It was argued in the discussion of Chapter 3, that the differences in glottal activity may be necessitated by the changes in aerodynamic conditions which correlate with differences in stress level. But regardless of the explanation adopted, a reduced degree of glottal abduction in unstressed environments has implications for Vo lenition, as it lessens the likelihood of successfully effecting the targeted voicelessness in post-sonorant positions.

Increased Rate

By compressing the time in which an articulatory gesture is to be executed, an increase in speaking rate may increase the difficulty in successfully achieving the intended target. In terms of mechanics, to transverse a similar distance at faster rate, the driving force would have to be increased. The more complex the gesture, and the more sluggish the articulator, the more likely should be the risk of undershoot.

Variations in rate may in fact entail differences in muscular driving force. However, the results of experimental studies of rate variation tend to show either inconsistent or contradictory tendencies.

Tuller et al (1982) report increases, decreases, and no change in amplitude of EMG activity for different muscles involved in consonant production. Gay et al. (1973 and 1974) report increased labial muscle activity and increased rate of labial movement with increased speaking rate. Al-Bamerni (1983) reports increased Ps and Po levels with increased rate, which suggests that respiratory effort must be higher. Such results might appear to mean that if there are differences in muscular driving force with increased rate, these might be the reverse of those caused by destressing, and so they could cancel each other out in rapid casual speech. However, these results may not be all that relevant to a discussion of rapid casual speech, as in the laboratory experiments carried out on rate variation, rapid casual speech was not being obtained, nor was it necessarily what the experimenters were trying to obtain. Tuller et al. (1982) mentions that two out of the four naive subjects had difficulty in producing fast speech. Gay (1978) makes similar comments. The same problem was encountered by Al-Bamerni (personal communication). Subjects in these experiments were presumably trying to speed up but articulate "well" or "properly", i.e. maintain the same speech targets. As pointed out by Kuehn and Moll (1976), at rapid speaking rates "speakers have the option of either increasing velocity of movement or decreasing articulatory displacement". Those results which showed increased muscular effort with increased rate, allied to the difficulty reported by subjects in carrying out the task, suggest that these speakers were opting for the former option and attempting a careful rapid speech mode.

In rapid casual speech, the speaker is presumably not as concerned to articulate "properly" and so, not necessarily attempting to maintain the same speech targets. Therefore, the occasional finding of increased muscular effort with increased rate may not be all that relevant. One might here quote Lindblom who points out that in speech

"...extreme displacements and extreme velocities are avoided. The system is indeed capable of raising the level of its performance, but as any phonetician will testify, it "prefers" not to. Generalising from the physics of the spring-mass system to speech, we find that speech production appears to operate as if physiological processes were governed by a power constraint limiting energy expenditure per unit time." (1983:231)

For the purposes of the following outline, the position will be adopted that in rapid casual speech, the only known effect of increased rate is that of temporal compression of whatever articulatory gesture is involved, whereas a comparatively lower stress level may well correlate with less muscular energy expenditure.

Some clarificaton may be needed regarding the use of the term Target Undershoot here. Lindblom (1963) postulates a Target Undershoot model to explain the centralisation of vowels in unstressed or rapidly uttered syllables. In his model, articulatory undershoot of a vowel target was a simple consequence of the temporal shortening, concomitant with rate increase and stress decrease. His model could perhaps be termed a "passive" target undershoot model, and inspired much of the experimental work on stress discussed in the last few pages.

Clearly the suggestion of "Target Undershoot" as a characterisation of W and Vo lenition of consonants does not carry with it any intended implication that undershoot is induced "passively"[1] by purely temporal contraints. Rather, passive and active motivations for undershoot are being suggested here.

------

[1] By the term "passive" is meant here: without change in muscular driving force.

Before leaving this discussion, one should mention a possible counterargument to an "undershoot" formulation of W lenition. A fricative is articulatorily a more difficult segment to produce than a stop: a finer balancing of the articulators is required in order to achieve the right degree of constriction which provide the correct auditory effect. Experimental evidence has shown that repetitions of say, alveolar stops, can be produced more rapidly than repetition of alveolar fricatives (see Lehiste 1970).

To this I would respond that there may be a world of difference between a lenited stop and a targeted fricative. In the former, the fine articulatory control necessary for the successful accomplishment of the acoustic target, is <u>not</u> required, precisely because the fricative here is not the target, and so the degree of local friction is not being carefully controlled. Such "undershot" forms would be free to vary along the fricative - approximant continuum.

The next two sections 4.2.2 and 4.2.3 outline a more specific description of W and Vo respectively, detailing how the factors listed at the beginning of this subsection (4.2.1) may culminate in lenition.

4.2.2 W lenition: weakening of the supraglottal articulation

4.2.2.1 The basic outline

As interest in this thesis is primarily on voicing oppositions, the account of W lenition will be given in brief outline. The process to be explained can be schematised as follows:

$$\mathbf{k} \rightarrow \mathbf{x} \rightarrow \mathbf{h} \rightarrow \emptyset$$

Figure 4.10 shows schematically how the relevant factors (i.e. 1, 2, 3, 4 and 6 listed in 4.2.1 may lead to articulatory target undershoot. The inherent instability quotient of a target has to do mainly with its vulnerability to temporal compression, and is a culmination of the factors 1 to 4. Rapidly uttered, unstressed tokens (which may occur particularly frequently with allegro speech) provide a triggering environment (factor 6) which leads to undershoot of the more unstable targets. W lenition occurs when an undershot allophone becomes the dominant one, i.e. the new target. The lenition process forms a loop whereby the "new" target output may serve as input to the cycle.

As against traditional treatments, it is proposed here that the final stage of W lenition, **h** -> Ø, would best be treated as an instance of Vo lenition and will be discussed in section 4.2.3. As represented in figure 4.10, the W lenition cycle continues only as far as **h**. The loss of **h**, seems more likely to involve increasing voicing and loss of friction, with consequent non-differentiation from the vowel. A characterisation of this stage of the process as **h** -> ɦ -> V might be more accurate than **h** -> Ø.

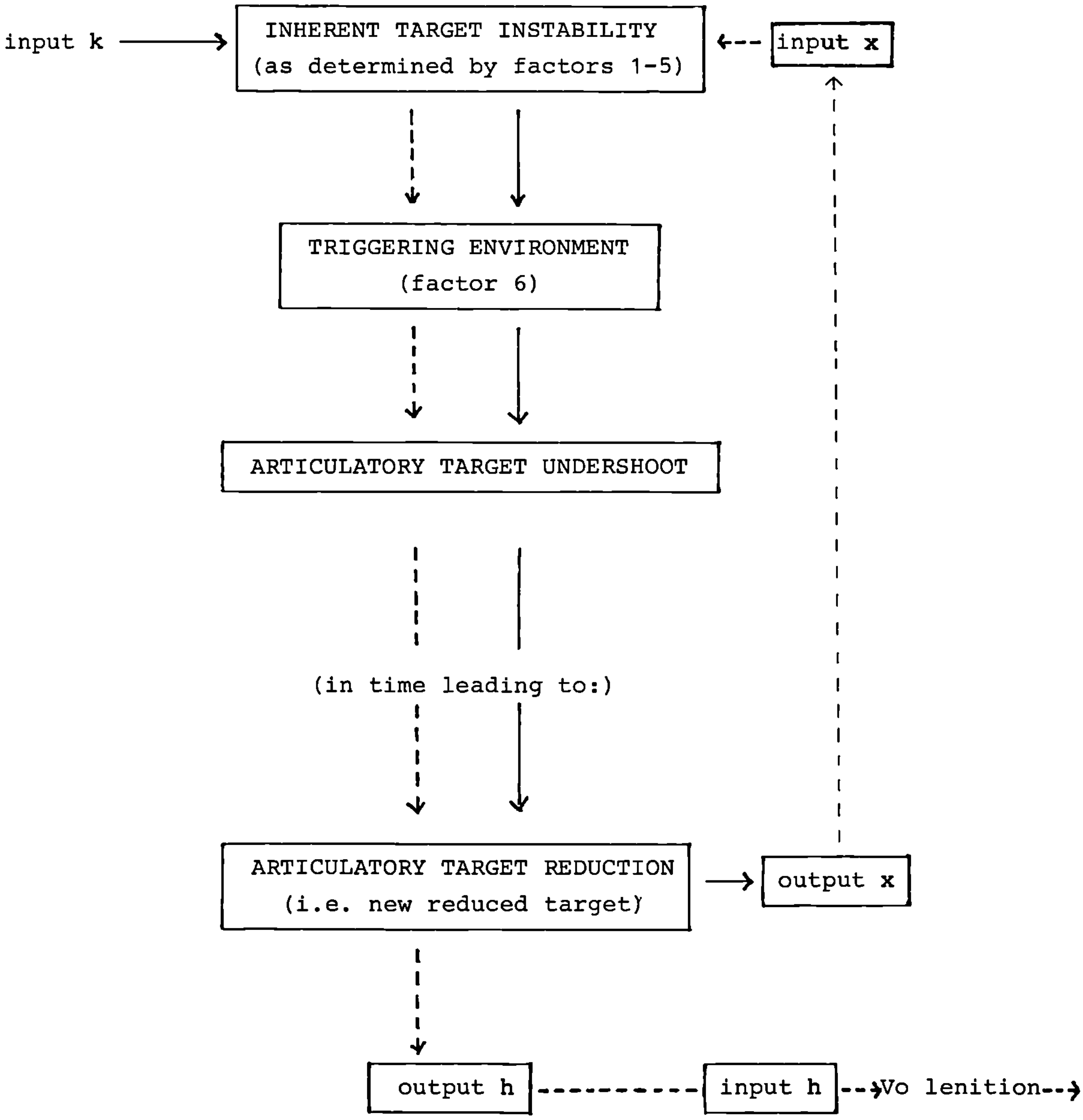


Figure 4.10 A schematic representation of the W lenition route

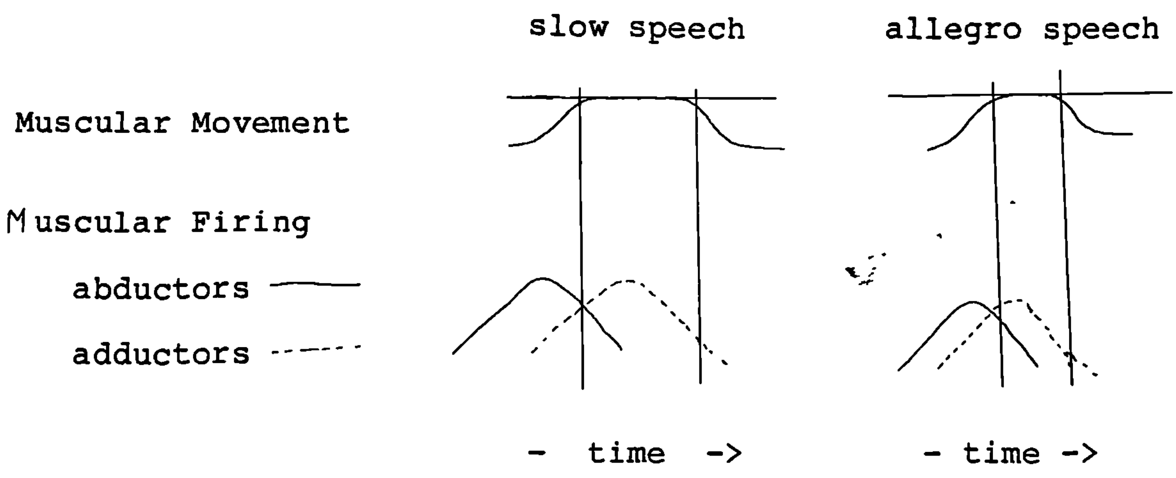
k ——→ x ------→ h ----------→ see text

Similarly, what would traditionally have counted as the final stage of W lenition of the voiced stop might be more appropriately regarded as an absorbtion into the vowel than a loss. Thus one might replace the stage ɣ -> ∅ in Lass and Anderson (1975) by ɣ -> ɰ -> V.

A brief outline is given in the next few pages of why and how the various factors listed contribute to W lenition. Discussion will be restricted to the three environments, #CV, VCV and VC#.

4.2.2.2 Factor 1: target gesture complexity

The articulatory gesture for a stop or (non-glottal) fricative can be described as involving archetypically a closing/opening cycle. Such a cycle involves two antagonistic gestures, which presumably can not overlap beyond a certain point. Muscular firing in the two groups of muscles overlaps anyway, and precedes actual muscular movement by a given amount (see for example, Fujimura 1977). The fact that these consonantal targets involve antagonistic gestures would, in theory, render them vulnerable to the time-compression of rapid speech. Reduction in the time allowed for target execution should result in excessive overlapping of the two commands, so that they would partly cancel each other out. Schematically it could be represented thus:



4.2.2.3 Factor 2: articulator mobility

The minimum amount of time it takes any particular articulator to effect closure (and release) will vary depending on its innervation, its mass and its structure (Daniloff, 1973). As was seen in Chapter 2.2.3, tongue body articulations, i.e. velars and palatals, are more sluggish than are the bilabial or tongue tip ones. Similar conclusions are to be found in Daniloff et al. (1980:243) and Roach (1978). One would expect a slowly moving articulator to be more vulnerable to the effects of time compression than the rapidly moving one. This may in part explain velars are more likely to undergo W lenition than the alveolars and bilabials (see section 4.2.0.2). The extreme agility of the tongue tip offers this place of articultion an additional W lenition route, i.e. the ballistic flipping gesture of a tap. Thus for alveolar stops, W lenition can take the form of spirantisation, as exemplified in Hiberno English [ɹaɪs̱əɹ] "writer", or a tap, as exemplified in American English [ ] "writer".

4.2.2.4 Factor 3: articulator independence

Quite apart from the inherent mobility of an articulator, the propensity to W lenition may be affected by what one might term its independence. Vowel articulations involve adjustments of the tongue, front and back. Bilabial and tongue tip segments (especially the former) have an advantage over the palatal and velar ones, in that they employ independent and spatially compatible articulators which allow temporal overlap with the gestures of an adjacent vowel. This is mentioned by Lindblom (1983), who also points out that consonant clusters may also tend towards juxtaposition of segments executed by independent and spatially compatible articulators.

4.2.2.5 Factor 4: durational characteristics of segments

The basic duration of segments can vary according to a number of factors. The longer the time allocated, as it were, to the execution of a segmental target, the less vulnerable it is likely to be to the effects of time-compression due to accelerated speech rate. Among the factors wich determine the basic time allocation of a segment, one could list the following:

Environment:

Consonants in VC# tend to be the longest of all; Klatt (1979) estimates that they are 140% the duration of those in CV#. Medial intervocalic variants are the shortest of all. For further similar observations, see Oller (1973).

Segment place of articulation:

Closure duration for bilabial stops tends to be longer than for other places of articulation (see Lehiste 1970:27 and Westbury 1979:91). This fact may be related to, or a result of, the relative "independence" of the lips as articulators (discussed above in 4.2.2.4), which permits greater temporal overlap with the articulatory gestures of adjacent segments.

Voicing/Voicelessness of Segment:

Voiced stops and fricatives tend to be shorter than their voiceless counterparts (see Chapter 1.1.5). This is especially true in VCV, where overall durations are shortest in any case.

Phonological Length:

Some languages have a distinction between long (geminate) and short consonants. Clearly, long consonants should be more resistant to articulatory undershoot, given that they have a longer time in which to carry out the targeted oral gesture. The same would of course be true of stops adjacent to homorganic nasals.

The basic instability of a target, as regards W lenition, would be its vulnerability to temporal compression, as determined by factors 1, 2, 3 and 4 just described. (Factor 5 has not been mentioned, but may play a role; it will be discussed in the next subsection, in conjunction with factor 6.) Taken together, one can "retrodict" a number of the features of W lenition which have been described in phonological accounts, and which in section 4.2.0.3 were formulated as questions D and E.

To start with question E, it was asked why geminates (and stops adjacent to homorganic nasals) were less susceptible to W, and why velars were more susceptible to W lenition than are other places of articulation. The fact that geminates are less prone to W (or as Lass and Anderson (1975) would describe it, they shorten rather than spirantise under the same conditions) is hardly surprising, and would appear to be a simple consequence of the longer time available for execution of the oral target. The same explanation would obtain for stops adjacent to homorganic nasals. In both cases, temporal compression, as in rapid speech , should lead in the first instance, not to undershoot, but rather to shortening of the interval for which the target is held. As regards velars (and palatals), it is to be expected that they would be highly unstable (i.e. vulnerable to temporal compression). Not only are they executed by comparatively inert articulators, but as these same articulators are involved in the targets of adjacent vowels, they permit of least temporal overlap with them.

The greater duration of voiceless than voiced segments should, according to the proposed account, entail a greater propensity of the latter to W lenition. Judging by the examples given by Foley (1977:34), and by the fact that in his lenition hierarchy he places voiced segments lower down (i.e. weaker) on the lenition scale (:33), it would appear that this is indeed the case.

The greater propensity of W to occur in VCV than in #CV or VC# (question D in Section 4.0.3) would also seem to correlate with the fact that it is temporally the most constrained environment.

4.2.2.6 Factor 6: triggering environment: rapidly uttered unstressed syllables, as may be particularly characteristic of allegro speech

The reason why rapid and relatively unstressed environments should trigger W lenition have already been discussed in section 4.2.1 and will simply be referred back to here. Firstly, it imposes temporal compression, which, even if the muscular driving force were to remain constant, would reduce the likelihood of full target accomplishment. The least compressible (i.e. most unstable) targets should be the first to lenite.

Added to this is the fact (discussed in 4.2.1) that unstressed articulations tend to be characterised by a reduced muscular driving force, whose consequences for target undershoot needs no comment.

Lower respiratory forces would appear to be another characteristic of unstressed environments, which may be highly relevant to the operation of W lenition at the fricative stage (for some discussion on the link between respiratory levels and stress, see Chapter 3.2.3). A lower rate of airflow through the oral cavity will result in lesser amplitude of frication noise; this may add an additional perceptual mechanism in W lenition, as, regardless of whether or not articulatory undershoot has occurred, at lower stress levels weaker frication should render the fricative less perceptible. The production of turbulence and its level depends on both area of constricton and airflow rate - see the discussion in Catford (1977: 39 ff).

4.2.3 Vo lenition: voiceless obstruents becoming voiced

This account of Vo lenition will follow lines similar to the discussion of W lenition. The basic suggestion is again that particular targets have an inherent degree of stability/instability which can be delimited and which results directly from factors 1, 2, 4 and 5 (factor 3 not being relevant here). The operation of the same triggering environment will lead to the Vo lenition of the more unstable targets in the first instance.

Targets, in the case of voiced/voiceless obstruents, can not be seen as purely the attainment of some muscularly controlled articulatory gesture or configuration. Rather, they are the accomplishment of + or - vocal fold vibration, and this depends not only on the articulatory gesture but on other factors, such as satisfying the prerequisite aerodynamic conditions. Thus, the network of factors which determine the basic instability of a voiced or voiceless target are rather more complex than in the case of W.

4.2.3.1 Factor 1: articulatory target gesture

Unlike supraglottal articulation, where the articulatory gesture is a constant closing/opening cycle (at least for the three positions being discussed here), the glottal gestures vary widely, depending on the environment and on the intended presence or absence of voicing. It can involve a simple opening or a simple closing gesture, an opening/closing gesture or no gesture at all. Looking first of all at the intended voiced stops in #CV, VCV and VC#, the necessary gestures would be: adduction (at the beginning of the consonant), no gesture, and abduction (at the end of consonant), respectively. This means that in terms of glottal adjustment, VCV is the maximally facilitated of the three. Among the voiceless stops, the glottal gesture in VCV is the most complex, and presumably the most difficult, in that it demands a complete abduction/adduction cycle, whereas simple adduction or abduction would suffice for #CV and VC# respectively. (This last statement represents something of an oversimplification; the glottal gesture for all voiceless consonants, regardless of position, may be an archetypical opening/closing cycle, as may be recalled from the discussion of glottographic data in Chapter 2.) However, in the initial and final positions, the cycle need not be fully completed. For example, in VC#, although after opening, the glottis does not simply remain abducted for expiration but rather shows a dipping (closing) movement, this dipping does not usually approach anything like full closure. (In order to limit the discussion, glottalised voiceless stops are not considered here.)

4.2.3.2 Factor 2: Articulator Mobility

The rate at which the glottal opening/closing gestures can be accomplished appears to be rather slow. Roach (1978) has estimated that the closing time for the glottis is slower than for any of the supraglottal articulators. In the glottographic data presented in the earlier chapters, glottal opening times ranged between about 70 ms and 130 ms; similar results can be seen in the various studies published by Löfqvist (e.g. 1980). From results reported in Chapter 3.2, it would appear that glottal closing can be speeded up by the Bernoulli effect. At a given degree of narrowing, the vocal-folds are sucked together rather rapidly; the point at which this will happen will depend on the respiratory level and the transglottal airflow rate.

Although muscularly controlled opening/closing gestures of the glottis are not rapid, the highly elastic nature of the vocal-folds means that under suitable aerodynamic conditions they can vibrate together/apart very rapidly. Once set in motion, vocal fold vibration takes some time to subside; this was discussed in chapter 2, along with the differences in voice onset and offset. The fact that voice offset is not an instantaneous consequence of glottal abduction has implications for lenition and will be referred to again in the next subsection.

4.2.3.3 Factor 4: aerodynamic requirements for + or - vocal fold vibration

Some relevant aerodynamic factors will be outlined below, according to whether voiced or voiceless segments are targeted, whether (depending on the environment) initiation or simple maintenance of + or - voice is required, and whether the segment is a stop or fricative.

Voiced Stop Targets

VCV voice maintenance

As outlined in Chapter 1.1.1, of all the manners of articulation, stops present the most aerodynamically unfavourable conditions for voicing. To maintain voicing, a transglottal pressure drop of about 2cm Aq is required; with the complete oral occlusion of the stop, the buildup in oral pressure (Po) leads to the gradual equalisation of pressures below and beneath the glottis, and to passive devoicing. The longer the closure duration, the more likely such passive devoicing; this has been discussed in the earlier part of this chapter (4.1.4), and findings cited from Swedish and Italian which point to a correlation between stop duration and the tendency to voice-breaks. It will be recalled that, as geminates are particularly vulnerable in this respect, such a devoicing tendency was suggested there as a triggering factor in the development of preaspiration for the languages of this study.

The actual duration for which vocal fold vibration will be maintained depends to a large extent on the surface area and tenseness of the supraglottal cavity walls (by admitting passive expansion of the oral cavity as Po increases). In a computer implemented simulation of a circuit analog of the vocal tract, derived from Rotherberg (1968), Westbury and Keating (1980) estimate that voicing of a medial bilabial stop should continue for about 60 ms. This is without such additional active physiological adjustments (mentioned as features 11 and 12 in Chapter 1.1.0) as might prolong the interval for which vocal fold vibration will continue in voiced stops. As the volume of the oral cavity is greatest in bilabials and least in velars, one would expect a positive correlation with voicing continuation. This expectation is confirmed in a further study by Keating (1983).

VC# voice maintenance

Westbury and Keating (1980) have also estimated that, in utterance final position, if one allows for a gradual drop in subglottal pressure, vocal fold vibration in [b] will persist for only 35 ms (as compared to 60 ms in VCV, where Ps is not falling).

#CV voice initiation

The initiation of vocal fold vibration requires greater respiratory effort than its simple maintenance. Westbury and Keating (1980) estimate that a transglottal pressure drop of approximately 4 cm Aq is required to initiate voice (as opposed to the 2 cm Aq required to maintain it).

Voiced Fricative Targets

The effects of environment mentioned for stop voicing should also hold for fricatives. Voicing is aerodynamically more facilitated in fricatives than in stops; as there is not complete oral occlusion, there is less Po buildup, and consequently less neutralisation of the transglottal pressure drop.

In spite of the fact that vocal fold vibration as such may present an "easier" target for fricatives than for stops, there are reasons to expect that the combintion of + voice and + friction may be a particularly difficult (and unstable) target, and that the voiced fricative may be particularly susceptible to W-type lenition. The adducted vocal folds result in much lower airflow rates for voiced than for voiceless fricatives. The acoustic consequence of this is that the amplitude of local friction is much lower for the former, and for the nonsibilant fricatives [β v ð j ɣ ʁ] is often so weak as to be barely detectable (Pickett 1980, cited in Ohala 1983). For this reason, a rapid shift down the W lenition scale would be predicted for these segments, i.e. from fricative to approximant to absorption into the vowel. This may account for the fact that languages frequently do not have voiced fricatives, but nearly always have voiceless ones (Ruhlen 1975).

Voiceless Stop Targets

Voicelessness in #CV

The attainment of this target demands nothing of the system, either in terms of muscular adjustments or respiratory effort. Given the additional respiratory effort required for initiation of vocal fold vibration in this position, the trend towards voice-loss here is hardly surprising.

VCV and VC# cessation of voice

As the vocal folds abduct, vocal fold vibration diminishes in amplitude and then ceases. As discussed in Chapters 2 and 3, voice offset is not an instantaneous consequence of the articulatory gesture of vocal fold abduction, but rather lags some time behind, most likely because of the transglottal flow and the elasticity of the (already vibrating) vocal folds.

With stop closure, the time taken to effect voice cessation is speeded up "passively", due to the sharp rise in Po and neutralisation of the transglottal pressure drop. Even so, Westbury (1979) gives durations ranging between 10 ms and 40 ms for such intrusive residual voicing in the voiceless stops of American English. (This residual voicing has been called "Voice Tail" in the literature, and this term will be used in the following discussion). Westbury and Keating (1980) give slightly shorter voice tail values, ranging on average between 5 ms and 16 ms for voiceless stops in American English, Japanese and Swedish. In any case, one may simply note here that, as voicelessness takes time to be accomplished, the temporal factor will be important for voiceless targets in postvocalic (and postsonorant) positions.

Voiceless Fricative Targets

Without complete oral occlusion, there is less "passive" assistance for fricative devoicing. As a consequence, voicelessness should constitute a more difficult target for fricatives (in post sonorant positions), and voice tail should last longer. Photoelectric glottograms of stops and fricatives, presented by Sawashima and Hirose (1983:17) would seem to support this conjecture. These same glottograms also suggest that voiceless fricatives may be characterised by a greater degree of glottal abduction than voiceless stops. There are two reasons for which this might be a necessary/useful strategy. The first, relevant here and discussed also in Chapter 3.2, is that it may be needed to accelerate devoicing, given the unfavourable aerodynamic conditions. The second could be a response to the need for high airflow rates across the oral constricton, in order to produce the required amplitude of frication noise.

As **h** has no supraglottal constriction, this should be the most difficult fricative to render voiceless. The same set of conditions (open vocal tract and opening vocal folds) pertain as for preaspiraton, and the very long duration of the voice -> voicelessness transition (referred to as the breathy voiced interval) has been demonstrated in Chapters 2 and 3. Other instrumental studies also refer to the fact that what is auditorily classified as [h] in languages is typically breathy voiced (see Engstrand and Nordstrand (1984) for initial [h]; the glottograms presented by Sawashima and Hirose (1983) show a fully voiced intervocalic [h] despite considerable glottal opening.

It is for this reason that the final stage of W lenition (as traditionally described) **h** -> Ø, is here proposed as an instance of Vo lenition, whereby the glottal fricative becomes breathy-voiced and gradually absorbed as it were, into the vowel.

To sum up on the effects of factor 4 on Vo lenition:

<u>Voiced Targets</u>

In terms of aerodynamic requirements alone, fricatives are easier to voice than stops, and should be more prone to Vo lenition. Furthermore, phonetic environment will greatly affect the ease with which a voiced target can be achieved. Of the three environments considered, #CV is the most demanding, as voice initiation requires higher respiratory effort. VCV and VC#, requiring voice maintenance only, are comparatively facilitated, but in the latter, a falling Ps renders it more prone to voice break.

<u>Voiceless Targets</u>

These also vary in the degree of effort they may require. In #CV (or following any voiceless segment), the target of voicelessness does not demand any specific muscular adjustment, or special aerodynamic conditions. In VCV and VC# (and in post sonorant positions generally), a certain time is required to effect voicelessness due to the voice tail.

The degree of oral occlusion affects the speed with which voicelessness can be achieved; thus, not only are fricatives less facilitated (for devoicing) than stops, but the glottal fricative, with no supraglottal stricture, is the least easy to render voiceless, and therefore the most prone to Vo lenition.

4.2.3.4 Factor 5: durational characteristics of segments

These have already been outlined above in the discussion on W lenition. The duration of a segment is highly relevant to Vo lenition; in post sonorant positions a longer duration facilitates voicelessness. This is because, as pointed out above, it aids "passive" devoicing; thus for the voiceless target it ensures voicelessness, whereas for the voiced target, the risk of voice-breaks is increased. A longer segment duration allows more time for the voice tail in the voiceless target, and lessens its likely perceptual importance.

In production terms alone, therefore, the longer duration of voiceless than of voiced segments makes good sense. The greater propensity to devoicing in geminates has already been discussed. The devoicing of geminates is also discussed in Ohala (1983: 195-200) along with the asymmetry of different places of articulation in their propensity to voice/devoice. For the reasons alluded to in 4.2.3.3 above, velars allow of less voicing than bilabials. If, as traditionally has been the case, propensity to voicing is defined as a lenition, and devoicing as fortition, then velars, which appeared the weakest place of articulation as regards W lenition, emerge as the strongest as regards Vo lenition (but see comments in 4.2.3.6 below).

Finally, one might point out that the considerably greater duration of segments in VC# than in VCV, may be an important factor in the different tendencies they exhibit as regards stop voicing/devoicing.

4.2.3.5 Factor 6: triggering environment

Three aspects of the proposed triggering environent are of relevance here and will be outlined in turn; temporal compression, reduced muscular driving force (which appears to correlate with the unstressed condition) and reduced respiratory level (which may also correlate with the unstressed condition).

Temporal Compression

When consonant closure is of shorter duration, there is less assistance to passive devoicing, and the relative (perceptual) importance of the voice tail may be increased. In addition, for the voiceless target in VCV, temporal compression would (as was discussed for W lenition) result in greater overlap of antagonistic opening/closing muscular commands, thus increasing the likelihood of articulatory target undershoot.

Reduced Muscular Driving Force

As discussed in 4.2.1 above, unstressed articulations may be characterised by reduced muscular driving force. In Chapter 3, it was found that a lesser degree of glottal abduction did seem to characterise voiceless stops in relatively unstressed syllables. This has implications for the successful accomplishment of the voiceless target, particularly in VCV which is also temporarily the most constrained environment. Thus, in this environment (which one might regard as the Vo lenition environment par excellence), articulatory target undershoot (rather similar to that described for W) may be the basis for the failure to attain voicelessness.

Reduced Respiratory Levels

If one can generalise on the basis of the production data in 3.1, the lower respiratory levels associated with the unstressed syllable do not seem to militate against voicing continuation in the postvocalic stop (see also data presented in Keating et al. 1983). However, in #CV, where, it will be recalled, a comparatively high respiratory level is required, it seems reasonable to suggest that the unstressed condition would make a voiced target even more difficult to achieve.

4.2.3.6 Discussion

A similar model of Vo lenition has been suggested as for W lenition, as was illustrated schematically in Figure 4.10. It states basically that certain targets are inherently unstable (i.e. require more effort for their successful accomplishment). Under the conditions of the triggering environment (factor 6), the more unstable environments are the more likely to lenite.

The instability of targets on the Vo scale is rather more complex than on the W scale. It involves not just vulnerability to temporal compression as a consequence of durational characteristics and articulator mobility and independence, but an interacting network of articulatory, aerodynamic and temporal factors. Figure 4.11 represents a first attempt at drawing up an "instability table" for voiced/voiceless stop targets for the three environments discussed, showing how the different relevant factors might dispose for or against vocal-fold vibration. This table would form for Vo the first, topmost "box" to the lenition schema (illustrated for W in Figure 4.10). It is an unquantified approximation; some attempt at weighting the factors (across positional variants at any rate) has been incorporated by the use of double + or - symbols (see figure).

A similar instability table could be drawn up also for fricatives, and for different places of articulation, showing the extent to which the different factors will predispose towards voice/voicelessness. Such tables would serve as input to the

Factors	#CV		VCV		VC#	
	voiced	voiceless	voiced	voiceless	voiced	voiceless
articulatory gesture complexity	-	+	++	--	+	-
Basic differences in aerodynamic conditions	--	+			-	+
Closure of vocal tract	-	+	-	+	-	+
Effect of closure duration differences: as affecting aero-dynamics (passive devoicing)			-	+	-	++
Voice tail			+	-	+	-

Figure 4.11 Target Instability Table for voiced and voiceless stop targets.

+ = facilitates intended 'voiced' or 'voiceless' target
- = hampers intended 'voiced' or 'voiceless' target
++ or -- indicates suggested contrastive weighting for a given factor across positional variants.

second "box" in the lenition schema (as in Figure 4.10), i.e. the triggering environment, which provides a set of conditions which will further tip the balance in one or other direction. For example, in terms of inherent instability (as in Figure 4.11), VCV is the most unstable environment for the voiceless target. The triggering environment tips the balance further towards voicelessness in a number of ways, outlined in 4.2.3.5 above.

The direction of expected change is not the same across positional variants. In VC#, it is the voiced target which appears to be the most unstable; in VCV, this is undoubtedly not the case.

The traditional phonological treatment of devoicing as a strengthening, and of the environments where devoicing occurs as "strong" or "protected" environments may need reconsidering in this light. It would seem to make more phonetic sense to treat devoicing in #CV and VC# as weakenings (lenitions) as well. In these environments, it is the maintenance of the voiced target which would require increased effort: under the same sets of conditions as would yield a voiced realisation in VCV, one can here expect a voiceless one. Thus, rather than a unidirectional process of voiceless -> voiced, Vo might best be redefined to allow for bidirectionality of change, which we might term +Vo and -Vo. Clearly sonorisation is no longer an appropriate term to cover such a broader definition. Thus, the concept of strong/weak environments ceases to be meaningful; rather, the operation of the various factors outlined determine whether Vo lenition in a particular environment will be in the direction of +Vo or -Vo. Any linguistic change which goes against the predicted direction for a given environment, be it towards voicing or voicelessness, would then be considered a fortition.

4.2.4 Some Conclusions

I will conclude this discussion on lenition by summing up the answers that have been proposed to the questions asked in 4.2.0.3. In answer to questions A, B and C, i.e. what the processes of W and Vo involve and whether they share a similar phonetic content, it has been proposed that they do share a common content, and that the lenition processes can be characterised as target undershoot (or incomplete execution of target). The constraints and triggering environment responsible for both processes are proposed to be eminently comparable. Some differences do exist; for example, the target of + or - vocal fold vibration combines articulatory and aerodynamic targets, as compared to the simpler articulatory target involved in W. In VCV, the failure to attain a voiceless target may to a large extent be accounted for in terms of articulatory undershoot (i.e. insufficient vocal-fold abduction). But in #CV or VC# the failure to realise a voiced target would seem to be more a consequence of aerodynamic target undershoot (i.e. insufficient transglottal pressure-drop to initiate or sustain voice).

In answer to question D, regarding the reason why environments differ in their propensity to lenition, it looks as though the answer may lie in their durational characteristics (and in the case of Vo lenition, in their aerodynamic characteristics).

Question F asked whether it was appropriate to regard W and Vo as weakening processes, and the reverse of these processes as strengthening. It is proposed here that such a characterisation for W is undoubtedly appropriate insofar as, under the conditions where segments undergo W lenition, the maintenance of the original target would require increased effort. However, in the case of Vo, for this to be true, both voiceless -> voiced and voiced -> voiceless changes must be accepted as lenitions (in the appropriate environments). Thus, it is proposed that Vo lenition can be bi-directional, + Vo and -Vo, with directionality determined by the combination of the inherent instability quotient of a target and the effects of the triggering environment.

Question E concerned differences in susceptibility to W lenition of different places of articulation (velars being the most susceptible), and of geminates (and stops adjacent to homorganic nasals) compared to single stops. The greater susceptibility of velars would seem to be a matter of the comparative mobility and independence of the active articulator, which leaves them particularly vulnerable to temporal compression. Geminates, and stops adjacent to homorganic nasals, having a longer interval available in which to execute the supraglottal articulatory gesture, are least vulnerable to such compression.

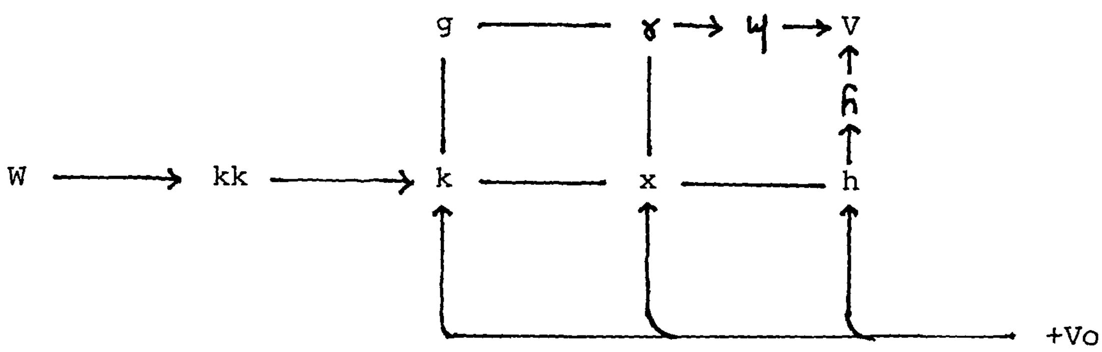
Certain interactions can be expected between the two lenition processes W and Vo, and these have been touched on in the preceding discussion.

+ Vo -> W: voiced segments are shorter than their voiceless counterparts, and particularly in VCV. This should make a segment which has undergone +Vo more prone to undergo W subsequently.

W -> +Vo: the further a segment has lenited along the W scale, the more it may be likely to undergo + Vo. As there is less supraglottal constriction, there is correspondingly less passive (aerodynamically assisted) devoicing. Therefore, fricatives should be more prone to +Vo than stops, and **h** should be the most susceptible of all. As pointed out earlier, the change of **h** -> Ø is probably best described as an instance of Vo.

To conclude, in Figure 4.12 the two lenition schemas illustrate the interaction of W and + Vo and of W and -Vo for the appropriate environments.

W and +Vo



W and -Vo

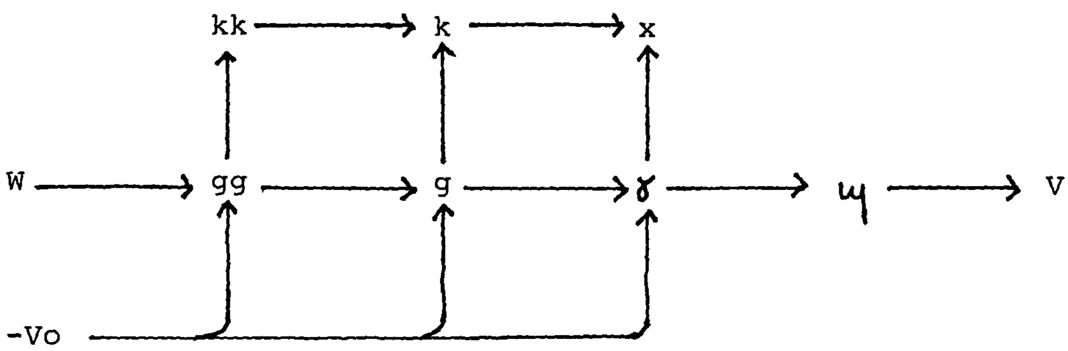


Figure 4.12 Lenition schemas, showing the interaction of W and +Vo, and of W and -Vo.

CHAPTER 5

THE PERCEPTION OF PREASPIRATED STOPS AND OF VOICING CONTRASTS

5.0 INTRODUCTION

This chapter concerns some aspects of the perception of preaspiration and of the perception of voicing contrasts in general. It assumes that preaspiration is a manifestation of a voicing contrast. Such an assumption might seem totally uncontroversial to some; yet it has, on occasion, been argued that preaspiration is a separate segment and functions just as another fricative. For a discussion on this, see Chapter 1.2.4.

Interest focusses on two topics, and the experiments reported were designed to investigate these. The first, prompted by the production data of Chapters 2 and 3, is the perceptual status of the breathy voiced portion of preaspiration. Experiments 1 and 2 of this Chapter address this aspect, and these are dealt with in the first half of the chapter (5.1).

The second topic (dealt with in 5.2) concerns the broader question of the perception of voicing contrasts in general, and a hypothesis is put forward which is suggested partly by the production data, and partly by a number of findings in the literature. This hypothesis, which will be called the V-ness/C-ness hypothesis, suggests that the perception of a phonological voicing contrast involves a judgment on the relative weightings of two components in a larger vowel plus consonant unit. The two components, V-ness and C-ness, are proposed to be the sums of the durations of the voiced and voiceless portions respectively, but weighted according to the acoustic nature and level of the sub-parts. The motivation for the hypothesis is discussed in some detail and Experiment 3 and one aspect of Experiment 1 are intended to test predictions which the hypothesis implies.

5.1 PERCEPTION OF THE BREATHY VOICED TRANSITION

Two experiments are reported here, both of which concern the perceptual status of the breathy voiced transition found with preaspiration.

5.1.1 Experiment 1

5.1.1.1 Objectives

The aims of this experiment were twofold:

1) to shed some light on the perceptual relevance of the breathy voiced portion of preaspiration, and to test a hypothesis (A), that the breathy voiced interval is perceptually part of preaspiration.

2) to test a hypothesis (B), that the amplitude level of aspiration contributes positively to the percept of a preaspirated stop. This hypothesis is really an offshoot of the V-ness/C-ness hypothesis which is dealt with in the second half of this chapter, and which forms the basis of Experiment 3.

Hypothesis A: the breathy voiced portion of preaspiration.

This particular question arose out of the production data, and was initially thought of simply as a retrospective check on the segmentation criteria used in Chapters 2 and 3. In looking at production data on preaspiration, it is clear that the switch from voicing to voicelessness is a gradual one, unlike the switch from voicelessness to voicing, which tends to be achieved comparatively rapidly. If voice offset (or the offset of periodicity) were taken as the point from which to measure preaspriation, this would exclude a discrete 'chunk of time' during which the glottis would be opening although still in vibration. It was argued that the breathy voiced transition was a non-avoidable aerodynamic/mechanical consequence of the fact that for preaspiration, a number of factors conspire which would make a quasi-instantaneous switch impossible. (This suggestion excludes of course glottalized stops: see discussion in Chapter 2.2.5) First of all the glottal mass is elastic in nature and is already vibrating. Also, in the case of preaspiration there is high airflow, as the glottal opening is not (at this stage) accompanied by supraglottal occlusion (as it would be for unpreaspirated voiceless stops, or to a lesser degree for fricatives).

In the earlier chapters, preaspiration was measured from the point where the oral air-flow trace rose sharply, as it was felt that this must reflect the beginning of glottal abduction. This was a production-based criterion which does not necessarily mean that the breathy voiced portion, included in our measures, is in fact perceived as belonging to preaspiration. If the breathy voiced interval is, as we have argued, a non avoidable feature of the voiced to voiceless transition, it seems entirely plausible to suggest (as Roger Lass has - personal communication) that it could be cancelled out by our perception. This could be true of all transitions from voiced segment to silence, as for example in VC#. This suggestion would gain support from the psychoacoustic experiment reported by Lindblom (1978), which was mentioned in Chapter 2.2.5. In this experiment, it was found that when the Swedish word nolla, "zero", was played backwards, listeners perceived hallon, "raspberry". The final part of the prepausal vowel in nolla may be similar to the breathy voiced interval in preaspiration: a transition from full voicing to voicelessness. In the postvocalic prepausal position it may simply be "cancelled out" because it is non-avoidable, whereas its perceptibility in initial prevocalic postpausal position may be explained by the fact that here it would be avoidable and therefore potentially available for linguistic contrast. The breathy voiced interval of preaspiration, may be "cancelled out" perceptually in a way similar to the final portion of the prepausal vowel, and therefore irrelevant to our perception of the preaspirated stop.

Of course the exact opposite is also possible. The breathy voiced transition, which was included in the preaspiration duration, is available to our perception and might contribute positively to the perception of the preaspirated stop. It might even be a major perceptual cueing factor. Beyond the need to relate the segmentation of production data to perception, there are some interesting ancillary questions one might seek answers to. As seen in the earlier descriptive chapters the actual duration of the truly voiceless portion of preaspiration can sometimes be very short indeed, and would seem to be determined by a number of factors, for example,

- length of the preceding vowel; preaspiration is never long after long vowels as is shown clearly in the Scottish-Gaelic dialects (see second Chapter, sections 2.2.2 and 2.2.4)
- degree of stress on the syllable (see Chapter 3)
- the language or dialect; Irish and Lewis Gaelic having considerably less than the others (see Chapter 2.2.1)

If our perception does indeed "cancel out" the breathy voiced transition, what happens in these cases? How much voiceless aspiration must be present for a stop to be perceived as preaspirated ? Or, phrased in terms of the possible evolution of preaspiration, at what stage would a stop become perceptible as preaspirated?

Pind (1982) conducted a series of experiments on the perception of preaspirated stops in Icelandic. In these experiments, he found that the VOFFT boundary for velar stops in Icelandic was in the region of 28 ms (by VOFFT boundary is meant the point at which listeners' positive identifications of a preaspirated stop cross 50%). However these experiments do not provide us with answers to the questions just raised, as none of the stimuli included the breathy voiced transition, and thus did not mimic the situation found in natural languages. What they do tell us is that if presented only with stimuli which have no breathy voiced transition, listeners will be capable of differentiating among these and labelling them as preaspirated or unpreaspirated, on the basis of the duration of voiceless aspiration.

An unstated hypothesis underlies the earlier decision on segmentation, namely, that the breathy voiced transition does belong perceptually to preaspiration and is not an irrelevant, cancelled out feature. This will be referred to as hypothesis A and Experiment 1 was designed to test it by using stimuli involving two sets of VOFFT stimuli, one of which contained the breathy voiced transition,the other of which did not. From both basic stimulus types, a set of VOFFT continua were prepared, where the truly voiceless aspiration ranged from 0 to 50 ms. In the case of the series which did contain the breathy voiced transition, the continuum extended beyond the point where all the voiceless aspiration was removed, and included stimuli where increasing intervals of the breathy voiced transition itself were missing. The preparation of these stimuli will be discussed in detail below.

Hypothesis B: relation between aspiration level and the perception of the presaspirated stop.

Hypothesis B is an offshoot of another, more general hypothesis - the C-ness/V-ness hypothesis which will be outlined in some detail in section 5.2. Here, let it suffice to state that hypothesis B proposes that the higher the amplitude of aspiration noise, the more perceptually potent it becomes. This proposal necessarily implies also that the perception of the voiceless aspirated member of a phonological "voicing" opposition involves positive detection of aspiration noise, and not just a detection of the relative timing of two events, a common conceptualisation in the literature. And if the percept of a preaspirated (or, for that matter, postaspirated) stop were to be enhanced the higher the amplitude of the aspiration noise, one would expect a trading relationship between the aspiration level and its duration, with higher aspiration levels "allowing" shorter aspiration times. So the VOFFT boundary should shift towards shorter VOFFT times as aspiration level increases.

The common assumption in the literature that VOT detection involves a task of judging the relative timing of two events (judging them as simultaneous/successive) has been discussed in Chapter 1.1.3. For example, Summerfield and Haggard (1974) reported that stimuli with aperiodic energy in the positive VOT range were not necessarily more effective perceptually than stimuli without.

This viewpoint has not gone completely unchallenged, however. In a study of Danish stops Fischer-Jørgensen (1968) concluded that aspiration constituted a more important perceptual cue than temporal separation. More recently Repp (1979) has reported findings for initial postaspirated stops, which, although not prompted by a hypothesis such as the C-ness/V-ness hypothesis (of which hypothesis B here represents an offshoot), would seem to lend it support nonetheless. Repp found that phoneme boundaries fell at shorter VOT durations when the amplitude of aspiration noise was increased.

It was felt that the prediction might be tested on preaspirated stops. Thus the second variable of the stimuli involved manipulation of the aspiration level (i.e. of the fully voiceless portion of preaspiration). This is described in more detail in the next section.

5.1.1.2 Preparation of Stimuli

The stimuli were made by computer-editing natural speech. They were prepared in the Phonetics Laboratory of Cambridge University Linguistics Department, with the assistance of Dr Francis Nolan (see Chapter 1.3.1.2 for details of the equipment). They involved a number of manipulations of the preaspiration and of the preceding vowel in the word pappa [pa^{h}pa], which had been recorded within the phrase:

"Hann sagði -- wið mig"

spoken by a male Icelandic informant.

To test hypothesis A, two sets of stimuli were prepared, one set (which will be termed the "breathy" stimuli) where the original breathy voiced transition was retained, and a second set (which we will term the non-breathy stimuli) where the breathy voiced transition was excised.

The breathy stimuli

These involved quite simply taking the word [pa^{h}pa] as it stood, leaving the breathy voiced transition intact. In the recording used, the duration of the truly voiceless portion of preaspiration was 35ms (i.e. of the portion where there was no evidence of periodicity in the waveform). This was augmented to 50ms by reduplicating 15ms in the middle of the voiceless aspiration. A series of stimuli was then prepared, where the voiceless aspiration ranged from 50ms to 0ms. This involved excising ten successive "chunks" of 5ms from the end of the voiceless aspiration. The convention is adopted of calling 0 time, the point where the voiceless aspiration has been totally excised, and Figures 5.1 and 5.2 illustrate stimuli with +50ms voiceless aspiration and 0ms voiceless aspiration. The process of removing chunks of 5ms was continued beyond the 0 point so that the breathy voiced portion, and possibly beyond, was also gradually removed. These were regarded as negative values, and range down to -50ms This last stimulus in the range is represented in Figure 5.3.

BREATHY STIMULI

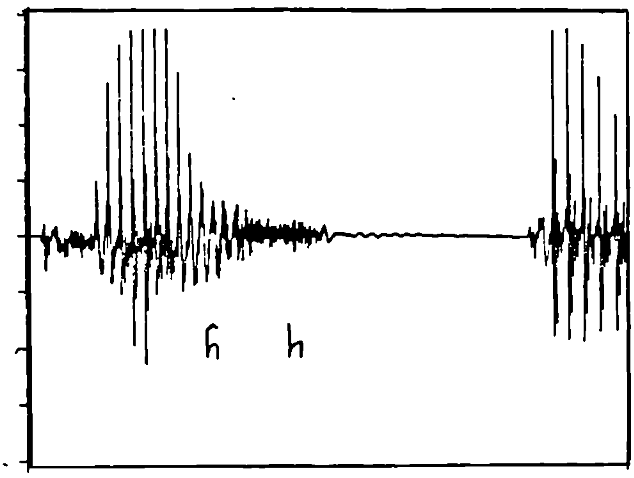


Figure 5.1
+50ms voiceless aspiration

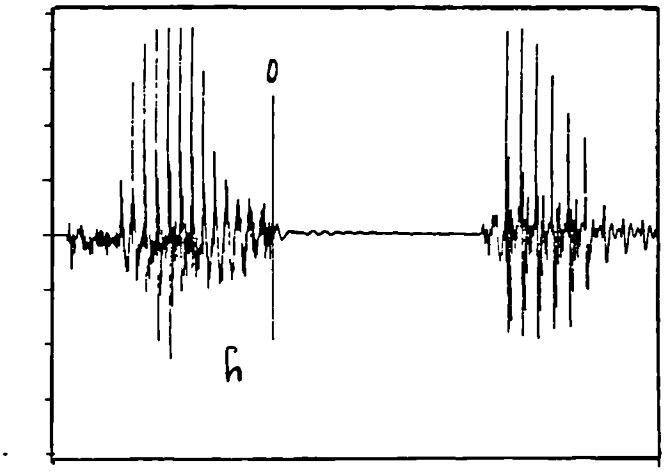


Figure 5.2
0ms voiceless aspiration

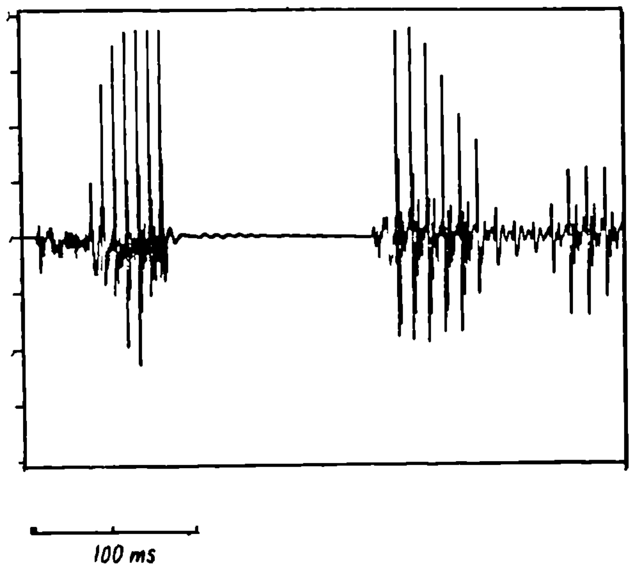


Figure 5.3
-50ms excised back from end of BV

Figures showing stimuli from the breathy voiced series

The non-breathy stimuli

In order for everything else to be maintained constant, the same [$pa^h pa$] token was used to create the non-breathy stimuli. The early portion of the vowel was kept, i.e., up to the peak amplitude of the waveform in the first vowel of [$pa^h pa$] (see Figure 5.1). This should eliminate the portion of the vowel for which the glottis is opening. The last cycle at that point in the vowel was then repeated to make up for the duration of the breathy voiced portion removed, so that the overall durations of vowel-without-a-breathy-transition as in these stimuli, and vowels-with-a-breathy-transition as in the other set of stimuli would be the same. The amplitude of the added vowel cycles was gradually reduced to simulate a natural vowel decay function.

To these non-breathy vowel stems were added the same continua of 0 to 50 ms voiceless aspiration (varying in 5 ms steps) as was used for the breathy stimuli. Figures 5.4 and 5.5 show breathy and non-breathy stimuli respectively where there is +50 ms voiceless aspiration.

To test hypothesis B, a further variable was added. From each of the stimuli which contained any voiceless preaspiration (that is all the non-breathy stimuli, and all the breathy voiced stimuli down to the time point 0), a further two stimuli were made, but with the aspiration level either attenuated or amplified by 6 dB. Figures 5.6, 5.7, and 5.8 are examples of non-breathy stimuli which have +50 ms aspiration noise at the three different levels.

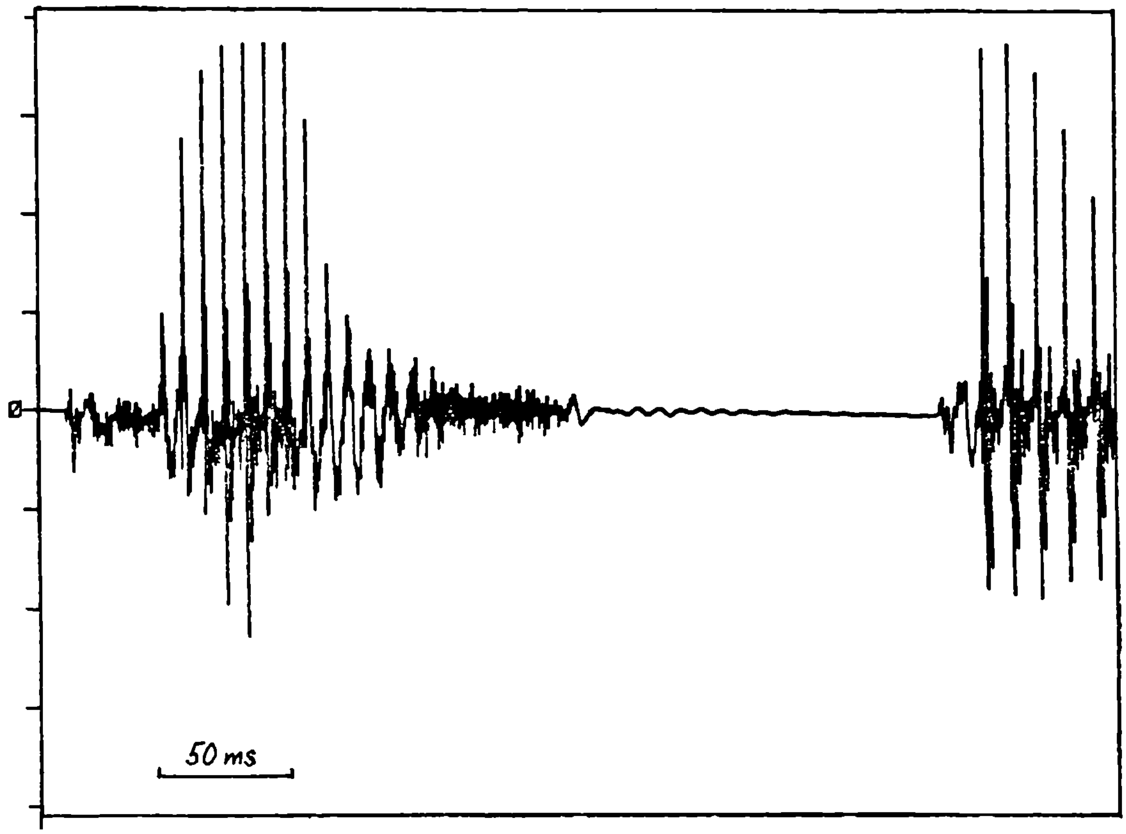


Figure 5.4: Breathy Stimulus +50 ms Voiceless Aspiration.

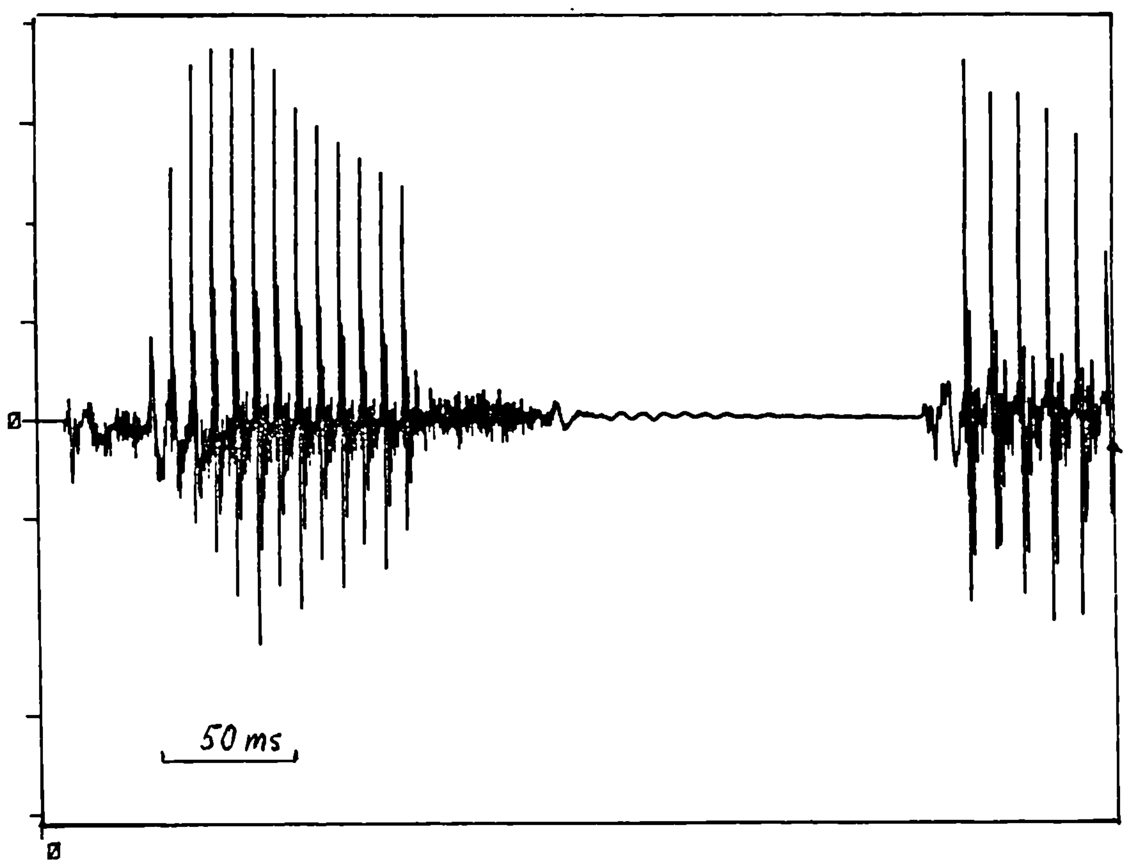


Figure 5.5: Non-breathy Stimulus +50 ms Voiceless Aspiration.

NON-BREATHY STIMULI

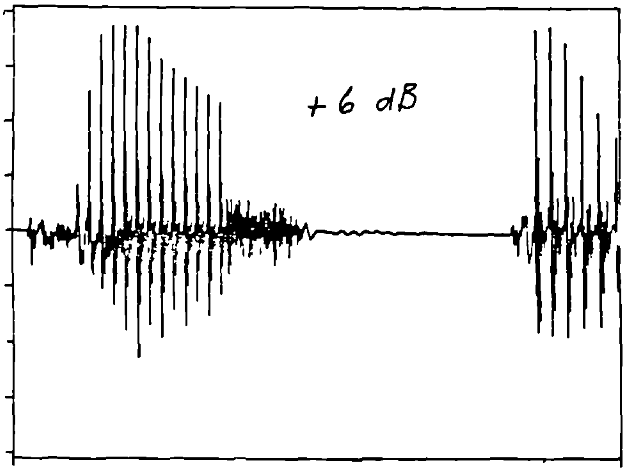


Figure 5.6
+6 dB

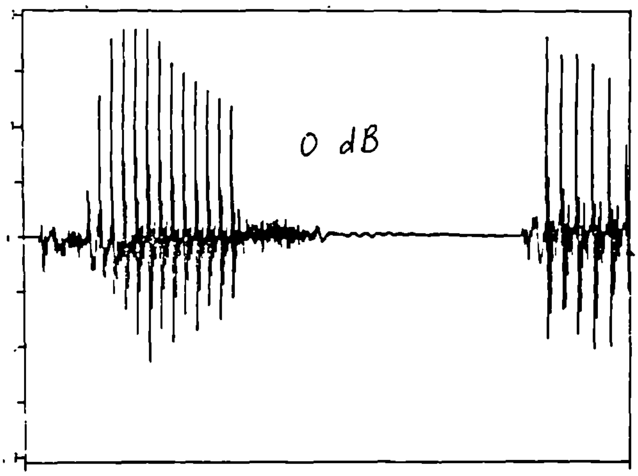


Figure 5.7
0 dB

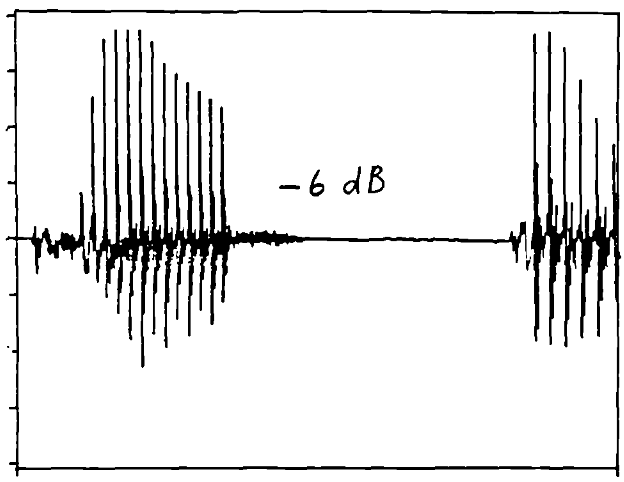


Figure 5.8
-6 dB

Figures showing non-breathy stimuli with +50ms voiceless aspiration at three amplitude levels

The stimuli number totalled 72. A tape was prepared where each stimulus (within the carrier phrase) was presented five times. These were randomised over the total number of 360. The interstimulus interval was 2 seconds long, and there was a pause between each group of twenty stimuli.

Procedure

Each listener heard the tape twice, so that for each listener, each stimulus was responded to ten times. In order to get used to the stimuli and to the task at hand, everyone taking the test did a dummy run on about 80 stimuli (from some part of the tape) before beginning. Listeners heard the tape, singly or in pairs, played on a Revox A 77 tape recorder and presented through Sennheiser HD414X earphones. In order to maintain the level constant at which the tape was heard a tone of 1000 Hz was recorded on to the beginning of the tape. Once a suitable listening level had been decided upon, the level of this tone was read on a voltmeter; each time the tape was presented, the level was set to give the same reading for the tone.

Icelandic listeners were instructed to place a tick in columns labelled "Yes" or "No" according to whether they heard a stop with or without preaspiration respectively. It was not thought suitable to phrase the question as one of deciding between the linguistic options available in Icelandic, the problem being that the contrasts in Icelandic involve additional parameters other than preaspiration. Medially these are the possible oppositions between:

1. [pa^hpa]
2. [pa:pa]
3. [pap:a]

It was felt that if speakers were asked to judge on whether a given token was one of the three above, they might be tempted to judge as preaspirated even those stimuli which did not have perceptible preaspiration, on the basis of the absence of vowel length or long stop closure. Therefore, not only was listeners' attention drawn to preaspiration itself, but they were in fact additionally instructed not to expect stimuli without preaspiration necessarily to sound like [pa:pa] or [pap:a]. Finally, they were told that in cases where they couldn't decide between Yes or No, this could be treated as No.

Eleven subjects in all listened to the test. The results for one of these were not included, since the test seemed to have been misunderstood (i.e. this subject seemed to have confused the Yes and No response columns). This subject's data were not included in the analysis of results. This left results for a total of 10 subjects.

5.1.1.3 Results

The Breathy Voiced Stimuli:

Figure 5.9 shows the results, averaged across all subjects, for the breathy voiced (henceforth BV) stimuli. From these results there is rather clear cut support for hypothesis A. The breathy voiced portion of preaspiration is not cancelled out

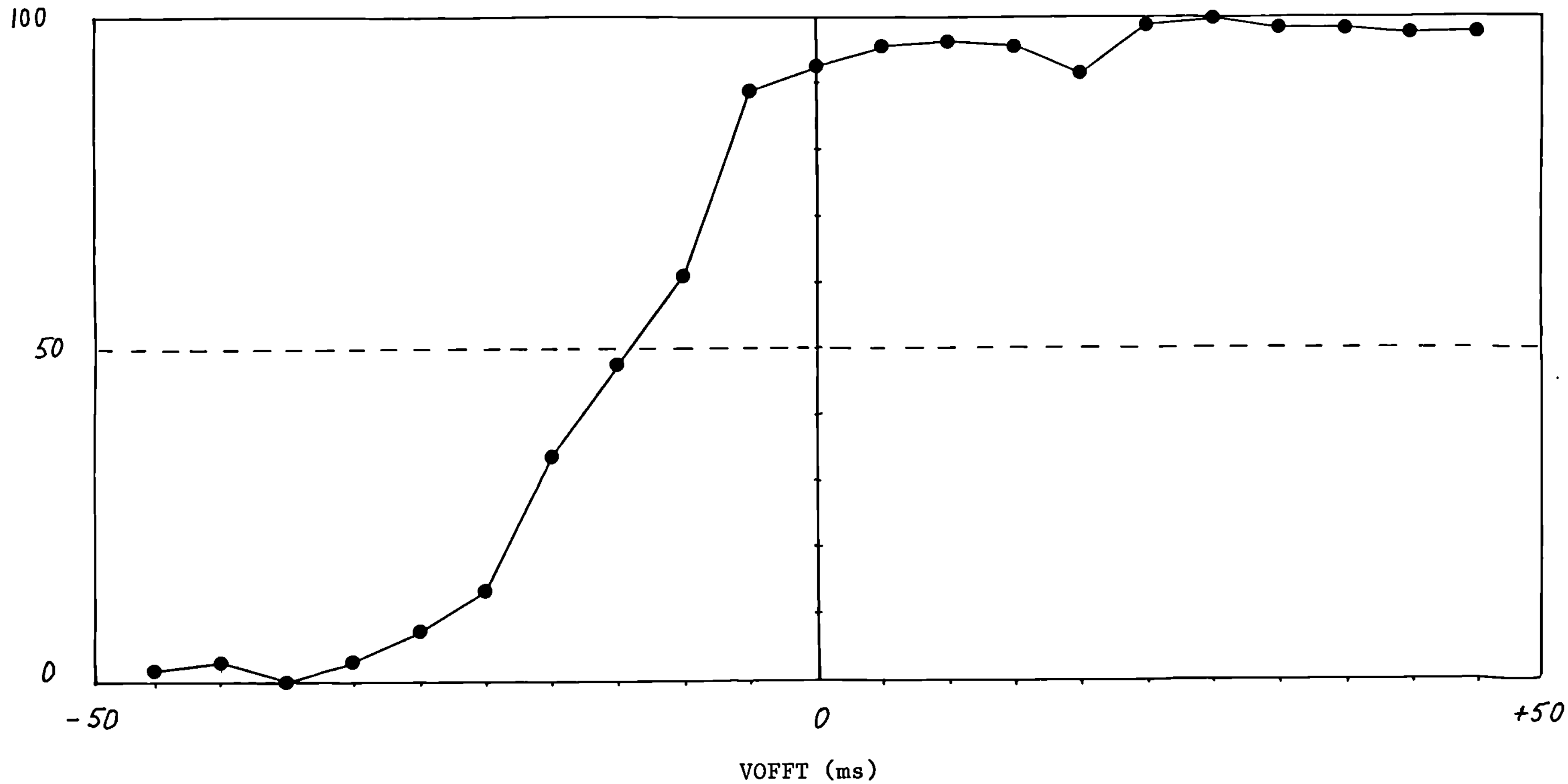


Figure 5.9 Results for BV stimuli averaged across subjects

perceptually. Even if the truly voiceless aspiration is entirely absent, preaspiration is unambiguously identified. The 50% crossover point is at -14ms showing that even if the end of the breathy voiced transition is absent preaspiration can still be identified reasonably well. One problem with the stimuli was that as the BV portion was more substantially excised, the syllables began to sound clipped. This may have contributed to the proportion of "No" responses. Conceivably, therefore, had the vowel (prior to the breathy voiced portion) been compensatorily lengthened to prevent the clipped impression, subjects might have been more willing to pass as preaspirated stimuli with even more of the breathy voiced transition missing. This of course is conjecture, but worth bearing in mind in any future replication of the test.

As even stimuli with no truly voiceless aspiration were overwhelmingly accepted as preaspirated, the manipulation of the levels of the voiceless aspiration did not show up anything relevant to hypothesis B. Indeed, as long as the breathy voiced transition is intact, neither the duration nor the amplitude of the truly voiceless aspiration affected listeners' judgments of preaspiration. This is supported by statistical analyses. Analysis of variance of the data show that the factors of duration and of amplitude have no significant effect on the percept of preaspiration (duration: $F(9,72) = 1.98$, $p < .06$; amplitude: $F(2,16) = 1.40$, $p < .3$). (See also Table 1a in Appendix 1).

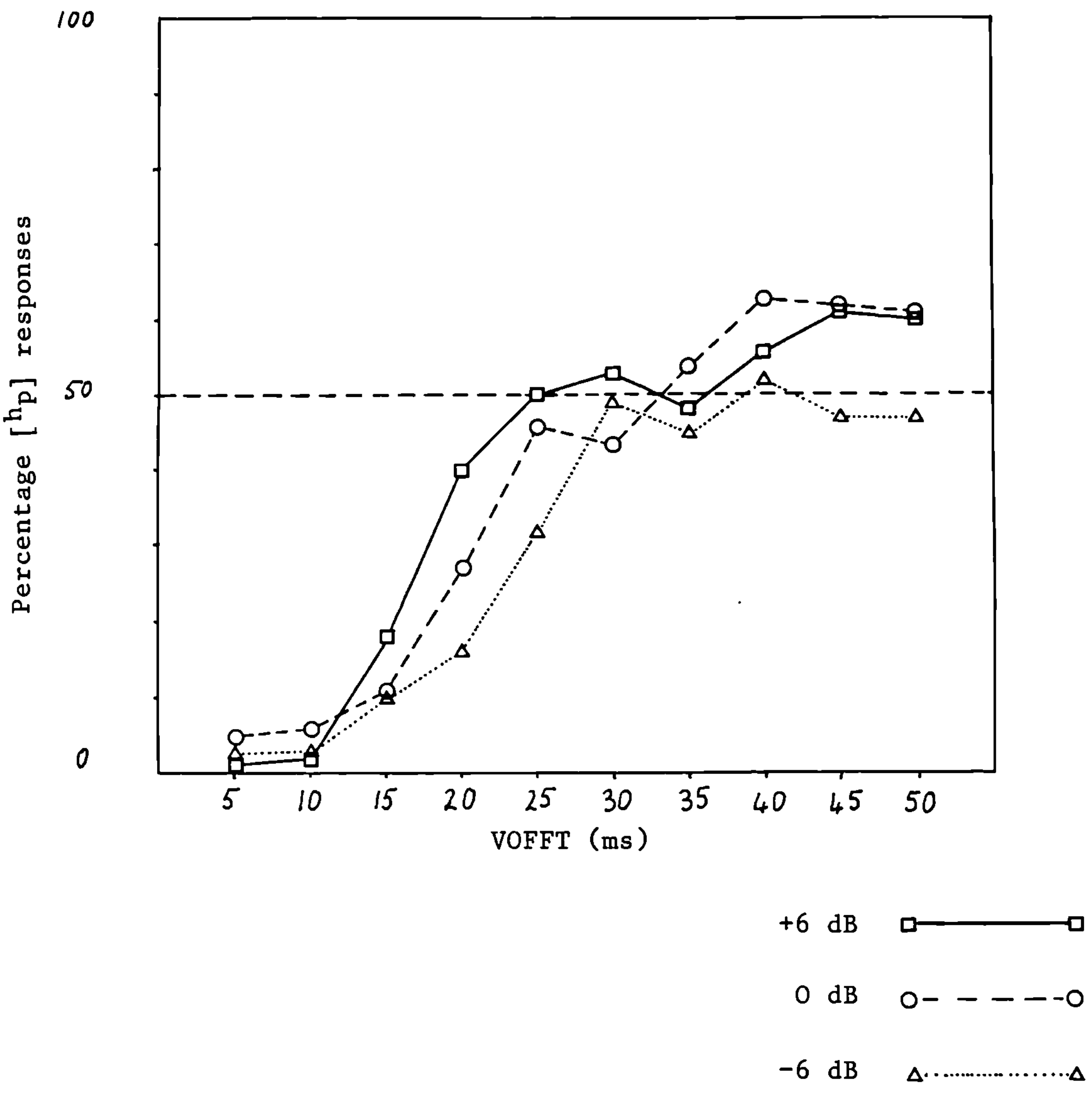


Figure 5.10 Results for Non-BV stimuli averaged across subjects

The Non Breathy Voiced Stimuli:

The results for the non breathy voiced stimuli (henceforth Non BV stimuli) averaged across all subjects are shown in Figure 5.10. The layout of this figure is the same as for Figure 5.9, except that now, as the breathy voiced transition is absent, there are no negative values to the right of time point 0. Only 36.5% of all these stimuli were heard as preaspirated, compared to 96.9% of the BV stimuli which contained the full breathy voiced transition (compare Figure 5.10 with Figure 5.9).

Analysis of variance of the Non BV stimuli, reveals that both duration and amplitude of the voiceless aspiration contributed significantly to the percept of preaspiration (see Table 1b in Appendix 1). The effect of aspiration duration was, not surprisingly perhaps, highly significant, with longer aspiraton yielding a greater number of "preaspirated" judgements ($F\ (9,72) = 72.45$, $p < .0001$). Aspiration amplitude also had a significant effect on listeners responses - the louder the aspiration, the greater the number of preaspirated judgments ($F\ (2,16) = 9.2$, p < p<.005. The interaction between the duration and amplitude of aspiration was also statistically significant ($F\ (18,144) = 2.73$, $p < .004$).

Examination by eye of the response patterns of the individual subjects show that they fall into two distinct groups: one containing four subjects (Group I) and another the remaining six (Group II). The results for these two groups are illustrated in

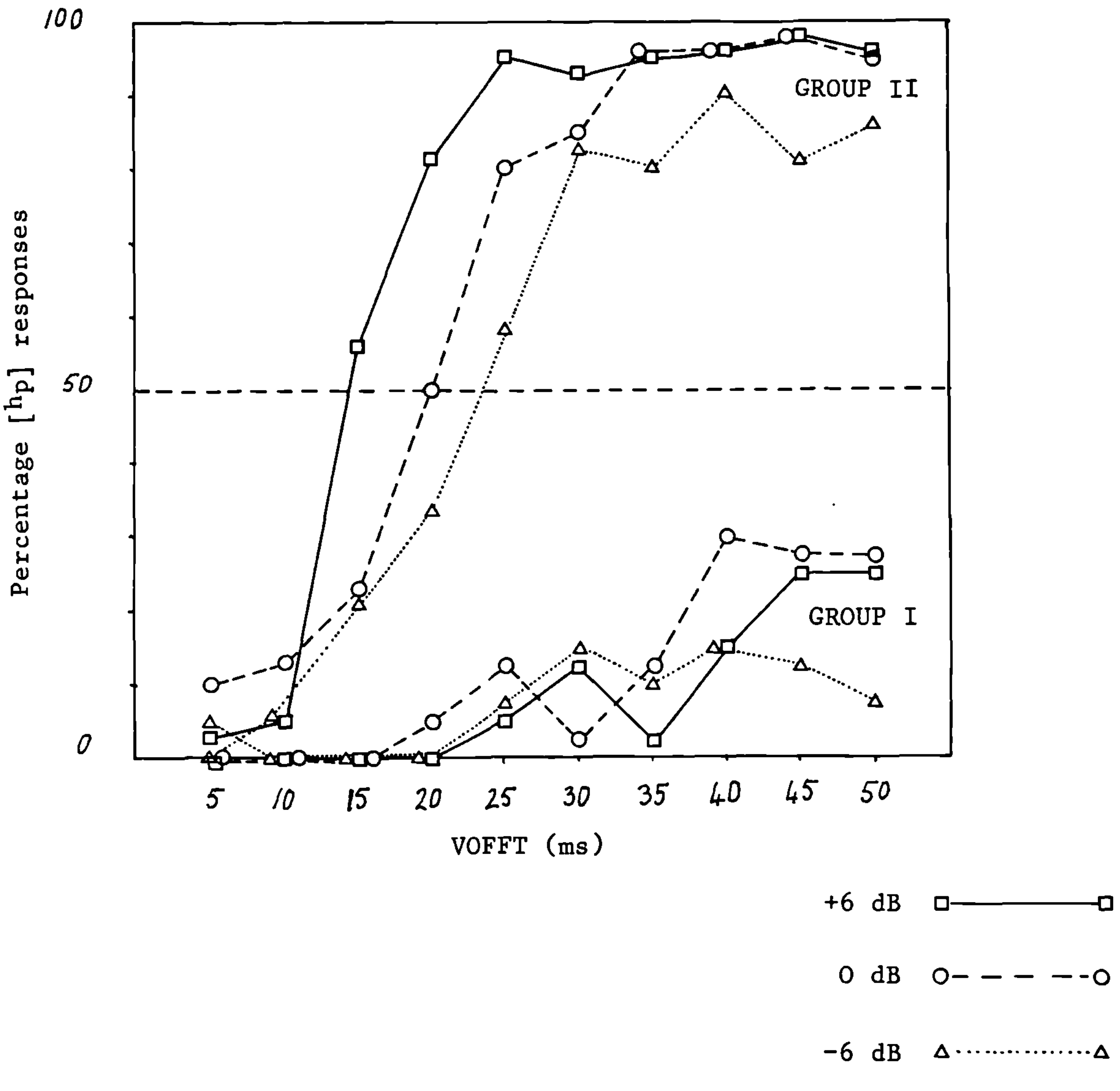


Figure 5.11 Results for non-BV stimuli for Groups I and II

Figure 5.11. An analysis of variance shows that the response patterns of the two groups are significantly different (see Table 1b of Appendix 1: $F(1,8) = 133.16$, $p < .0001$). For this reason, separate analyses were performed for the two groups. The results can be summarized as follows:

GROUP I (see Table 1c in Appendix 1)

This group had a very low preaspiration acceptance rate of stimuli where the breathy voiced portion of the preaspiration was missing. Only 9% of all the Non BV stimuli were judged to be preaspirated. There was a small but highly significant tendency for judgments of preaspiration to increase as the duration of the voiceless aspiration increased ($F(9,27) = 5.15$, $p < .001$). However, even when the duration of the voiceless aspiration is +50ms, the positive answers do not exceed 30%. Furthermore, the amplitude of aspiration did not affect listeners' judgments ($F(2,6) = 2.45$, $p < .2$).

GROUP II (see Table 1d in Appendix 1)

Group II responded in a different manner, seeming to accept stimuli without the breathy voiced transition as possible preaspirated stops. 64% of all the Non BV stimuli were judged to be preaspirated. The duration of the aspiration was highly significant ($F(9,45) = 120.3$, $p < .0001$). Listeners' judgments were also affected by the amplitude of the aspiration noise: as amplitude increased, so did the number of preaspirated responses. This effect is also highly significant ($F(2,10) = 13.10$,

$p < .005$). Furthermore, the effects of amplitude and duration of aspiration interact significantly for this group ($F\ (18,90) = 3.99$, $p < .0001$).

Between Group Differences

Not only is the difference between the two groups significant (mentioned above), but so are the interactions between the variable of group and all other main effects:

duration x group: $F\ (9,72) = 33.12$, $p < .0001$;

amplitude x group: $F\ (2,16) = 6.42$, $p < .01$

The interaction between duration and group arises from the fact that the difference between the two groups increases as the duration of aspiration increases. The interaction between amplitude and group arises because the effect of amplitude is significant for Group II, but not for Group I.

5.1.1.4 Summary and Discussion

Hypothesis A: the breathy voiced transition

Overall, the presence or absence of the breathy voiced transition exerts a highly significant effect on listeners' judgments of preaspiration ($F\ (1,8) = 351.12$, $p < .0001$: see Table 1g in Appendix 1). As long as the BV transition is present, subjects will almost invariably judge the stimulus to be preaspirated, irrespective of the duration or amplitude of the truly voiceless aspiration. Effectively, therefore, the BV transition alone suffices to cue the preaspirated stop.

This result lends positive support to Hypothesis A and suggests that the BV portion of preaspiration is not cancelled out by our perception. It also goes some way to answering the ancillary question posed earlier, of how long preaspiration must be (and specifically the voiceless portion) to be perceptible as such. It would appear that totally voiceless aspiration is not crucial, and therefore its very short duration in some languages or dialects and in given phonetic environments need not pose too much of a problem to our perception.

For the Non BV stimuli, there is some overall tendency for subjects not to accept these as preaspirated. Close examination of the data shows that subjects fall into two groups with respect to the ways in which they respond to stimuli which lack the BV transition: those (40%) who hear such stimuli as generally not preaspirated, and the remaining 60% for whom these stimuli will be heard as preaspirated, but only if the aspiration is long enough and loud enough.

As a possible explanation for the two distinct trends in subject responses to the non breathy voiced stimuli one could suggest that Group I were simply noting the oddity or unnaturalness of these stimuli, and were being more conservative in what they were allowing to "pass" as a token of a preaspirated stop. It will be recalled that the instruction to subjects was that cases of uncertainty should be treated as negative. In the experiments carried out by Pind (1982), where there was no breathy voiced transition in any of the stimuli, there is no mention of any subjects failing totally to accept these as tokens of preaspirated stops. It is therefore likely that, had the subjects been confronted with only non-breathy voiced stimuli, they would have had no difficulty in identifying as preaspirated stimuli with long durations of voiceless aspiration. However, given the presence of the two types of stimuli, the BV and the non BV, Group I were clearly differentiating between them and giving the latter a vote of no confidence. Even when judging on the breathy voiced stimuli, this group was slightly more "conservative" than the other in what they were allowing as preaspirated. This is illustrated in Figure 5.12 which is a restatement of the data of Figure 5.9, but with results given separately for each group. The 50% crossover points are at -11ms and -16.5ms for Groups I and II, respectively.

The slight difference between the two groups in judging on the BV stimuli is not however statistically significant, as is shown by an analysis of variance carried out on responses to the entire range of BV stimuli at 0dB, i.e. from -50ms to +50ms (see Table le in Appendix 1: $F(1,8) = 3.21$, $p < .2$). Even when comparison is restricted only to the negative range (from -50ms to 0) of the BV stimuli, the differences between the two groups' responses is still not significantly different ($F(1,8) = 1.56$, $p < .3$).

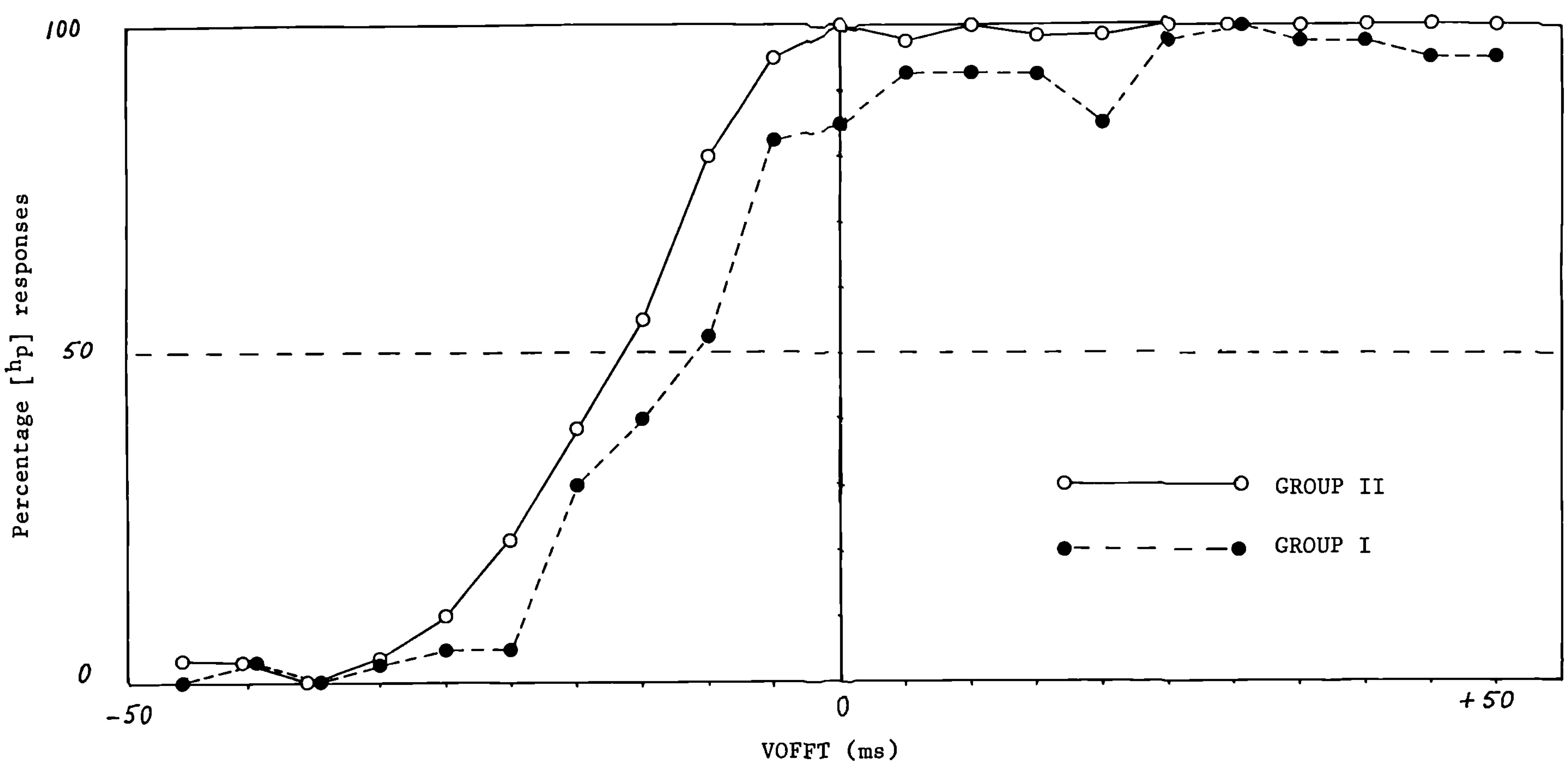


Figure 5.12 Results for BV stimuli for Groups I and II

The question was raised in Chapter 2 as to whether the breathy voiced transition belongs perceptually to the preaspiration or to the preceding vowel. First of all it is necessary to establish what approximate duration of breathy voiced transition is present in these stimuli, and what duration of such transition corresponds to the 50% crossover point for these subjects. The source recording from which these stimuli were constructed was a good quality audio signal, and precluded the simultanous recording of the airflow which would have allowed the breathy voiced transition to be measured. However, at the same recording session additional recordings were made of 20 repetitions of the same utterance using airflow equipment (set 12 in Table 1.1).[1] In these, the duration of the breathy voiced interval averaged 43ms. Using this figure to represent the approximate duration of the breathy voiced transition in the experimental stimuli, this means that the 50% crossover point occurred at 32ms for Group I and at 26.5ms for Group II.

The performance of these two groups with the non breathy voiced stimuli gave no crossover point at all for Group I and a crossover point at 20ms for Group II, as can be seen in Figure 5.11. (The 20ms crossover point represents results for the stimuli at 0dB, i.e. the source stimuli for which amplitude of aspiration had not been altered.)

Thus for Group II, who accepted both breathy and non breathy stimuli, 26.5ms of the breathy voiced transition can be equated

------

1 This data set simply involved repetitions of the word [pa^{h}pa].

with 20ms of truly voiceless aspiration. The 6.5ms difference here falls below the perceptual limen for duration given by Lehiste (1970:12-13), and can be probably considered perceptually irrelevant. It would therefore appear that the breathy voiced transition can be taken as roughly equivalent to voiceless aspiration, bearing in mind however that compared to the latter it yields a higher acceptability rate for preaspirated stops among the sample population at large. This may serve as a justification for the segmentation decision of the production data presented in Chapters 2 and 3.

Hypothesis B: aspiration level

The responses of Group II to the Non BV stimuli lend support to Hypothesis B. The level of the voiceless aspiration did seem to occasion substantial VOFFT boundary shifts in the predicted direction. The VOFFT boundaries (50% crossover points) were:

for -6dB at +23.5ms,
for 0dB at +20.0ms,
for +6dB at +14.5ms

This shows an overall boundary shift of 9ms or an average shift of 0.75ms per 1dB. Further evidence of the effect of aspiration level can be seen from the fact that at -6dB, the percentage of positive responses even at VOFFT of 30ms and over is lower than for the other two levels which are about 95%.

It is interesting to compare these results with those reported by Repp (1979) for a similar experiment on postaspirated stops in initial postpausal position. The results are directly comparable,

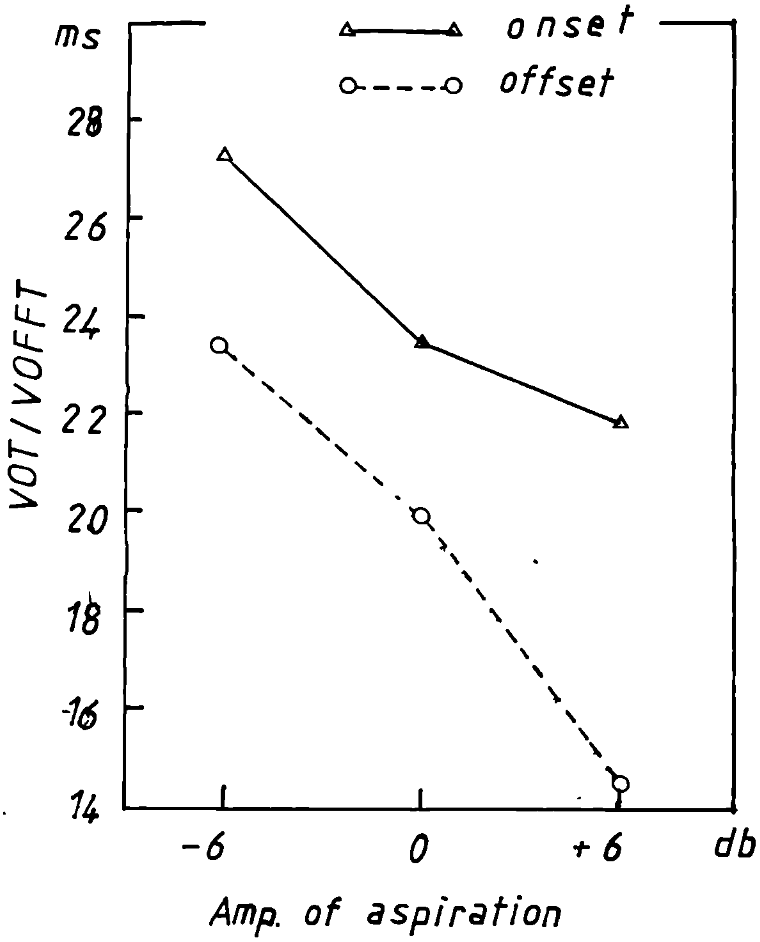


Figure 5.13 VOT/VOFFT boundary shifts as a function of changes in aspiration amplitude

as the manipulations of aspiration levels are the same. Figure 5.13 presents results of boundary shifts in Group II in Experiment 1 above, superimposed on those of Repp, showing the extent of VOT/VOFFT boundary shifts as a function of decreased and increased aspiration amplitude.

The boundary shifts are in a similar direction for post- and preaspirated stops; the higher the amplitude, the less aspiration duration is required to yield an aspirated percept. These findings are consistent with hypothesis B, which suggested that that a higher level of aspiration noise would contribute positively to the perception of the preaspirated stop.

Comparing the boundaries and boundary shifts for VOT and VOFFT, one can see that boundaries are shorter and the degree of boundary shifting is greater for VOFFT than for VOT. The VOT boundary at OdB is approximately 23.5ms and it shifts approximately 0.43ms per 1dB aspiration amplitude change. For VOFFT, the boundary is at 20ms, and the shifts 0.75ms per 1dB aspiration amplitude change.

The fact that boundaries do shift as a function of aspiration amplitude would seem to militate against an account of the perceptual task as involving the relative timing of two events. It suggests rather that aspiration is being positively detected as an integrated tradeoff of level and duration (and indeed, this suggestion is supported by the before-mentioned statistical interaction between these two factors. How this fits into the broader proposals regarding perception of 'voicing' contrasts will be made clear in Section 5.2.

5.1.2 Experiment 2

5.1.2.1 Motivation

Experiment 1 showed that the breathy voiced portion alone of the aspiration sufficed to cue the preaspirated member of the opposition. The question then arises of what exactly it is about the breathy voiced period that signals the preaspirated stop.

One suggestion, made by Chris Darwin (personal communication) is that the large drop in vowel amplitude may be what principally signals VOFFT. Work carried out by Darwin and Pearson (1982) reported that the moment of Voice Onset is best characterized as the moment where a certain critical level of intensity is attained in the vowel. So perhaps, in similar fashion, Voice Offset might also be characterized by the same feature in reverse, i.e., the lowering of the vowel amplitude levels beyond a given critical level.

It should be reiterated here that the underlying assumption in the work carried out and findings reported by Darwin and Pearson is that the task of VOT perception involves a judgment on the relative timing of two events, and their work was an attempt to characterize what the second event consisted of. One need not necessarily subscribe to the implied conceptualization of the task involved in the perception of a "voicing" contrast. An alternative hypothesis, termed the C-ness/V-ness hypothesis, is suggested in a later section of this chapter, and some of its predictions are tested in Experiments 3 and 1.

Even if the C-ness/V-ness hypothesis is wrong, and if VOT is in fact perceived as the relative timing of two events, this may not be generalisable to VOFFT. Voice offset and oral closure may not be (acoustically or auditorily) definable as "events" in the way that stop release and voice onset are. It is well established in the literature that in terms of auditory response offsets are much less salient than onsets (see Tyler et al., 1982). Thus, oral closure (effectively aspiration offset) probably does not constitute as well defined an event as the oral release burst. This would be even more true of voice offset as compared to voice onset, considering that the former is relatively a much more gradual matter even in production terms.

Regardless of these reservations, however, Darwin's hypothesis (which will henceforth be referred to as hypothesis D) remains a very interesting one, and it is hoped that the experiment below goes some way towards testing it.

To get back to the question posed in the opening to this section, there are other suggestions one might make as to what it is about the breathy voiced transition which signals the preaspirated stop. The transition has two components, voicing and aspiration, with the levels of the former decreasing as the level of the latter increases. Perhaps preaspiration is perceived to begin when the ratio of the two passes a critical level, so that aspiration perceptually dominates. This suggestion will be referred to as hypothesis E.

Alternatively, preaspiration might conceivably be perceived from the instant where aspiration noise itself attains a critical level, regardless of the presence of periodicity in the waveform: this will be called hypothesis F.

5.1.2.2 Experimental design

The experiment described here was an attempt to shed some light on the above three hypotheses. It involved the synthesis of a medial preaspirated stop which contained a breathy voiced portion, and a manipulation of the voicing and aspiration components in this breathy voiced portion. The synthesised stimuli were prepared in the Department of Experimental Psychology, Oxford University, with the assistance of Dr Bert Rosner. The technique used was Klatt's software synthesis described in Klatt (1980) with the addition of an executive system written by Diane Kewley-Port. The stimuli involved a sequence of the following segments, with the durations shown underneath:

a	ɦ	h	p	h	a	
100	65	55	80	10	60	ms

In all stimuli the manipulated portion was the breathy voiced portion, i.e. the first ɦ above. The voiceless aspiration portion (the second h above) was set rather low at 10dB for both Klatt's AF and AH parameters. This was probably too low, and it is possible that this voiceless aspiration may in fact have been integrated with the closure. But even if it was, it should not have a particularly detrimental effect on the experiment itself.

In Klatt's synthesis, there are four control parameters which are relevant to the construction of this breathy voiced portion, and these are the parameters manipulated in the experiment:

AV	Amplitude of Voicing
AVS	Amplitude of Sinusoidal Voicing (this involves a smoothed voicing waveform and results in strong attenuation above the second harmonic. Klatt (1980) recommends the addition of AVS to the normal voice source AV (in combination with aspiration noise) to produce a breathy voiced quality.
AH	Amplitude of Aspiration
AF	Amplitude of Frication

Three series of eleven stimuli each were prepared. The settings of the relevant parameters for the BV interval are shown in Table 5.1. In each series AV was reduced in eleven successive steps of 6dB from 60dB (which was the same level as that of the preceding vowel) to 0dB. Series I, where the levels of AF and AH were at 40dB and 60dB respectively, and AVS at 30dB, will for mnemonic purposes be referred to as the "StrongAsp + S" series (i.e. for strong aspiration with sinusoidal voicing). Series II, which differed from Series I only in that AVS was set at OdB, will be labelled "StrongAsp - S" (i.e. strong aspiration noise but no sinusoidal voicing). In Series III, AV and AVS were kept at the same levels as for the Series II, but the levels of AF and AH were lowered to 20dB and 40dB respectively. For this last series the label "WeakAsp - S" will be used (for weak aspiration noise and no sinusoidal voicing). The settings for other parameters for the construction of these stimuli are shown in Appendix 2.

Table 5.1 <u>The settings of the AV, AVS, AH and AF parameters (during the BV interval) for the three series of stimuli used in Experiment 2</u>

	SERIES I StrongAsp + S				SERIES II StrongAsp - S				SERIES III WeakAsp - S			
Stimulus	AV	AVS	AH	AF	AV	AVS	AH	AF	AV	AVS	AH	AF
1	60	30	60	40	60	0	60	40	60	0	40	20
2	54	"	"	"	54	"	"	"	54	"	"	"
3	48	"	"	"	48	"	"	"	48	"	"	"
4	42	"	"	"	42	"	"	"	42	"	"	"
5	36	"	"	"	36	"	"	"	36	"	"	"
6	30	"	"	"	30	"	"	"	30	"	"	"
7	24	"	"	"	24	"	"	"	24	"	"	"
8	18	"	"	"	18	"	"	"	18	"	"	"
9	12	"	"	"	12	"	"	"	12	"	"	"
10	6	"	"	"	6	"	"	"	6	"	"	"
11	0	"	"	"	0	"	"	"	0	"	"	"

A test tape was prepared where the stimuli were presented in two sets. In the first set there were ten repetitions each of the stimuli in "WeakAsp - S" and "StrongAsp - S", which had been randomized. In the second the randomized stimuli of "WeakAsp - S" and "StrongAsp + S" were presented (again ten tokens of each stimulus were used). So the total number of stimuli which listeners judged upon was 440.

It was not possible to assemble a large group of Icelanders or of Scottish Gaelic speakers at the time when this test had been constructed, and so the subjects used were not an optimal group. They were three Icelanders (being all the Icelanders that could be found at the time) and two phoneticians. The instruction given to subjects was to listen specifically for a preaspirated stop and to give yes or no judgments on whether they had heard one or not. It would obviously have been inappropriate to phrase the instruction in terms of distinguishing a linguistic contrast in a subject's language, given the spread of languages and also the problems mentioned in Experiment 1 regarding other factors besides preaspiration which play a role in contrasts in Icelandic. In fact the judgments by the two phoneticians turned out to be very similar to the judgments made by the Icelanders; an analysis of variance on the results showed no significant difference between the two groups ($F(1,3) = 1.4719$, $p < .4$; see Table 1a in Appendix 3). For this reason the results here are for the overall averages.

5.1.2.3 Expectations

At this point, it might be worth summing up briefly what the predictions should be of each of the hypotheses mentioned in the introduction to this section. If Hypothesis D is the correct one, one should expect high percentage responses of preaspirated stops to depend solely on the AV level, having dropped a sufficient amount from the level of the preceding vowel. The levels of AF and AH should not matter as such, and therefore the response graph for the WeakAsp and StrongAsp series should be very similar, showing positive identification of preaspiration once the AV level is at a sufficiently low setting.

If, on the other hand, Hypothesis E is correct and preaspiration identification depends on some ratio of the amplitudes of the voicing and the aspiration noise parameters during the breathy voiced interval, then one should expect quite a shift in the identification graph between the WeakAsp and the StrongAsp conditions. Positive identification of preaspiration should occur at a lower level of AV for the WeakAsp than for the StrongAsp series.

If, finally, Hypothesis F is correct, and identification of the preaspirated stop depends on aspiration noise attaining some critical loudness level in the BV interval irrespective of the voicing component, what we should expect from the response graph would depend on whether the AH and AF levels are above, below, or straddle that critical level. If, as was hoped, the two sets of levels chosen for the AH and AF parameters in the StrongAsp and the WeakAsp series do in fact straddle some critical level, then one should expect to find uniformly positive identificaton of preaspiration for the StrongAsp series (both I and II), but not for the WeakAsp series. If, the higher and lower settings for aspiration do not straddle a critical aspiration level, then the identification graphs for both the StrongAsp and WeakAsp series should both read positive or negative, depending on whether they lie above or below the critical aspiration level.

5.1.2.4 <u>Results</u> <u>and</u> <u>Discussion</u> (see Table 1a of Appendix 3)

The results are shown in Figure 5.14. The presence of two response curves for the WeakAsp series is due to the fact that this series was presented twice, once randomized with the StrongAsp - S stimuli, and once with the StrongAsp + S stimuli.

Of the three hypotheses, results tend to favour hypothesis F. At higher aspiration levels the StrongAsp series (both I and II) yield positive judgments of a preaspirated stop once the AV level is lower than about 45dB. The WeakAsp series never yields above 42% positive responses of a preaspirated stop, regardless of the AV level. This suggests that some critical level of aspiration noise must be attained to cue the preaspirated stop. The difference between the StrongAsp and the WeakAsp series is highly significant ($F(1,3) = 2634.84$, $p < .0001$).

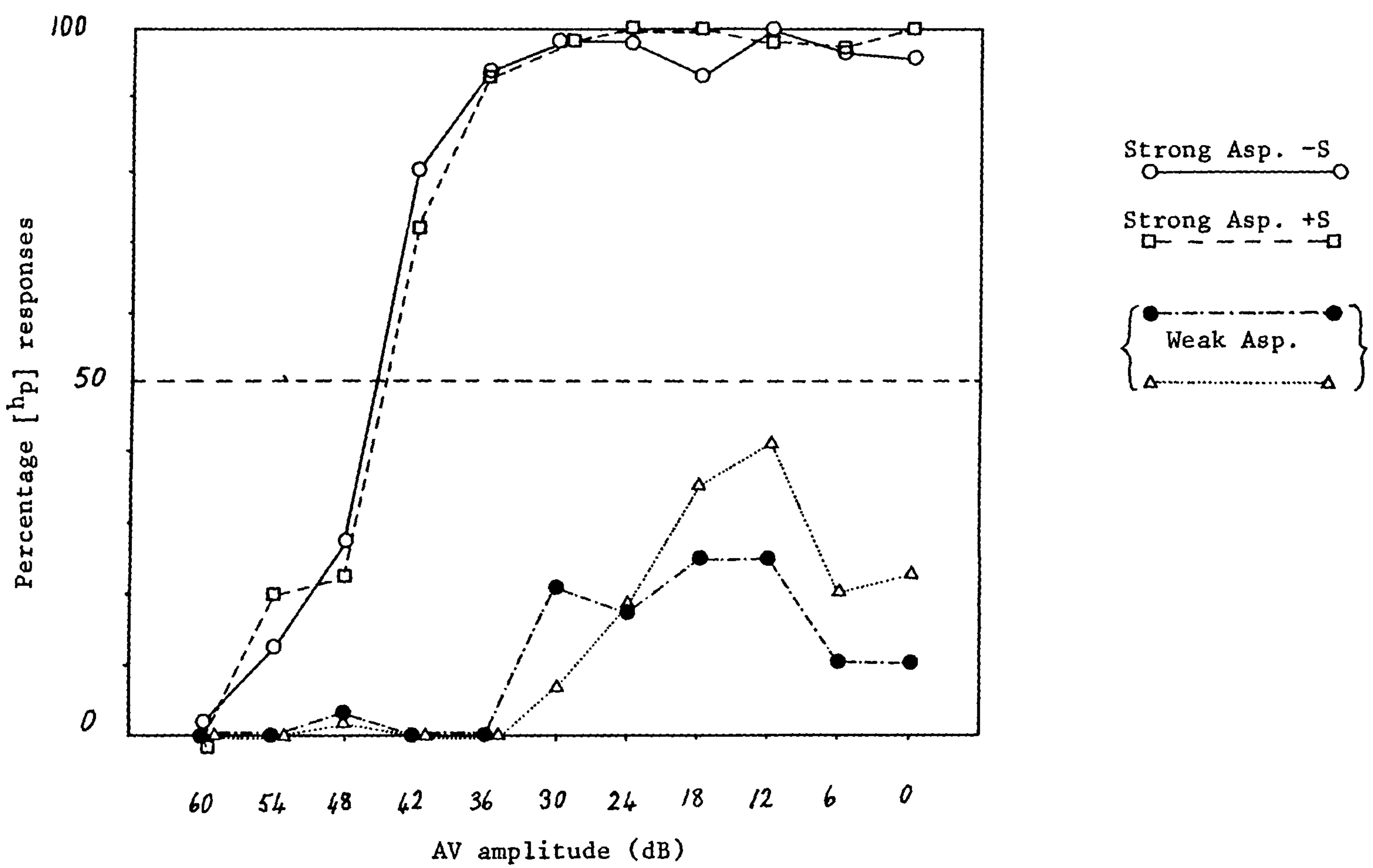


Figure 5.14 Averaged results for stimuli of Experiment 2

Hypothesis D, that the preaspirated stop is cued by the drop in vowel amplitude, does not seem a likely or sufficient explanation of the results in Figure 5.14. Contrary to the prediction of this hypothesis, positive judgments of preaspiration do not exceed 50% for the WeakAsp series, no matter how low the AV parameter. However, the AV parameter is important, as even with the StrongAsp series, some drop in AV level is also required for positive identification of preaspiration. The effect of the AV parameter on listeners' judgments was highly significant ($F_{(10,30)} = 102.835$, $p < .0001$). Thus, support for Hypothesis F is not unambiguous.

Hypothesis E, that the percept depends on the attainment of a given ratio between the "aspiration noise" and "voicing" components of the BV interval, is not supported either by the results. If it were simply a question of a ratio between the two components, one would not expect such low "preaspirated" scores for the WeakAsp series when the "voicing" component (AV) is very low or absent.[1]

The AVS parameter seems to matter little to listeners' responses, and the StrongAsp + S and StrongAsp - S reponse curves are very similar. The difference between these is also not statistically significant (for this see Table 1b in Appendix 3; $F_{(1,3)} = 0.0025$, $P < 1.0$).

------

[1] Yet, as pointed out in the preceding paragraph, this does not mean that the drop in AV is unimportant; stimuli of the StrongAsp series are not indenfifed as preaspirated until AV amplitude has dropped by about 15dB.

5.1.3 Conclusions on Experiments 1 and 2

The results of Experiment 2 illuminate to some extent the results of the first experiment reported above. It will be recalled that in Experiment 1, changes in the level of voiceless aspiration for the non breathy voiced stimuli (i.e. stimuli which did not contain the breathy voiced transition) occasioned shifts in the VOFFT boundary. Taken together, these two sets of results would suggest that:

- Aspiration noise is being positively detected.
- The level of aspiration noise must exceed some critical level in order that a preaspirated stop be detected. This critical level must lie, for our synthetic stimuli, somewhere between the StrongAsp and the WeakAsp series. Conceivably, what this critical level must be could be unearthed by constructing another set of test stimuli, where the AH and AF parameters would be varied more gradually between the two settings used in this test.
- Above this critical level there will be a trading relationship between the level of aspiration and its duration, as shown in Experiment 1. Either a longer duration or a higher amplitude of aspiration noise should enhance our perception of a preaspirated stop.

When talking of a critical level for aspiration noise, one question remains. Would this be a critical level in some absolute sense, or would it be a critical level in relation to the amplitude of the preceding vowel? Our experiment doesn't elucidate this point at all, but one can make certain inferences from the findings reported in Repp (1979) discussed earlier in relation to Experiment 1. For initial postaspirated stops, Repp found VOT boundary shifts could be occasioned by either the level of aspiration noise or the amplitude of the vowel. (Increases in aspiration level, or decreases in the amplitude of the vowel caused a reduction in the VOT boundary). So it would seem that aspiration level is detected as a ratio of the level of the adjacent vowel. This suggests, when it comes to interpreting our own results, that the critical level for aspiration is not some absolute level, but rather, a level which varies with the amplitude of the preceding vowel. So, in a rerun of this experiment, it would be interesting to manipulate both the level of the aspiration and the level of the preceding vowel.

One last point should be mentioned, which is however not central to the discussion here. It will be recalled that in Experiment 1 one group of subjects rejected stimuli without the breathy voiced transition. This was interpreted as indicating that, given the choice of the two types juxtaposed, subjects were simply detecting as unnatural, and therefore rejecting, the stimuli without the breathy voiced transition. One could have argued alternatively that the breathy voiced quality itself, or more precisely, the voicing component of the breathy voiced period, is in itself an important cue to the perception of a preaspirated stop. This would not seem to be the case. In the stimuli with stronger aspiration levels in this experiment (StrongAsp + S and StrongAsp - S) it only seems to be important that the voicing component be lower than a given level. Beyond that, further reduction of the voicing level or its complete absence seems to matter little. This must reinforce the conclusion arrived at earlier that the voicing component of the breathy voiced transition yields a more natural, acceptable, preaspirated stop, but is not in itself a critical cueing factor.

5.2 THE PERCEPTION OF VOICING CONTRASTS

5.2.0 Introduction

The main purpose of the rest of this chapter is to propose a hypothesis regarding the broader issue of the perception of voicing contrasts in general (sections 5.2.2 and 5.2.3) and to present a further experiment which was carried out to test aspects of the predictions which the hypothesis outlined below would make (section 5.2.4). The first subsection of the chapter (5.2.1) discusses briefly some current approaches to the perception of voicing contrasts, drawing attention to some of the main problems which the hypothesis attempts to address.

5.2.1 Multiplicity of Cues: A Problem in Perception?

Simple two way phonological voicing oppositions are characterized at a phonetic level by a number of different measurable correlates or subfeatures, as has been outlined in Chapter 1.1.0. The abundance of potential cues to the voicing contrast poses the problem of whether and how such cues are integrated to yield the simple binary percept, which we call voiced/voiceless. There are basically two ways of approaching this problem.

One way, exemplified by Stevens and Blumstein (1981) is to look for a single invariant integrated cue or property, which would be considered the primary one, and to regard all others as secondary cues which contribute to the primary one. The "integrated property" they propose is:

"Low frequency spectral energy or periodicity in the signal in a specified time window in the vicinity of the consonantal release. Detailed specification of this property requires that we define two events in time in the auditory representation of the signal; the time at which the consonantal release occurs, and the time at which the onset of low frequency spectral energy or periodicity occurs." (:31-32)

Essentially, their proposal amounts to a type of VOT detector. Other features, such as temporal adjustments in consonant or preceding vowel they consider to be "attributes that are not encompassed within this integrated property - attributes that might be labelled as secondary". (:33)

The other approach is epitomized in the title of a paper by Santerre and Suen (1981): "Why look for a single feature to distinguish stop cognates?". The perception of a voicing contrast would appear a much more complex and fragmented process according to this approach, which stresses that a number of apparently independent features may be operating to cue a single contrast.

One main motivation for this approach would be the apparent diversity of cues, depending on the environment. For example, stops in #CV are typically considered to be differentiated (in production and perception terms) by a VOT contrast; in VCV, stop closure duration may be the most important cue, and in VC#, the duration of a preceding vowel would appear to be the principal cue, at least for English (for discussion of these, see Chapter 1.1). The most reasonable and pervasive conclusion would therefore seem to be in the words of Stevens and Klatt (1974) that:

> "The voiced-voiceless distinction for a stop is not triggered by the same acoustic property (or properties) independent of the phonetic environment in which it appears" (:658).

Even for a single phonetic environment, a number of cues would seem to participate in the voiced-voiceless contrast. For example, in #CV, there has been much discussion on the extent to which F1 transitions or even Fo perturbations might complement the VOT cue. The study by Santerre and Suen mentioned above draws attention not only to the diversity of potential cues used in a single environment, but also the fact that individual cues are not always present in production. In their study, a number of parameters (potential cueing features) associated with the voicing contrast in English were measured in production. The features measured were: stop closure duration, the duration of a preceding vowel or sonorant, VOT duration, the frequencies and transitions of the first two formants in vowels preceding and following the stops. Using findings in the literature on thresholds of discrimination as decision criteria, they attempted to estimate which of the measured cues might be sufficient in enabling discrimination. Their main findings can be summarized as follows:

- A number of the above cues may potentially be involved in distinguishing a single contrast. See for example, Figure 5.15 which is reproduced from their paper. (In this figure, differences which are large enough to be considered

Speaker		am	F_1-TR_1	%	F_2-TR_2	%	SI	VOT
1	ample	$\boxed{120}$	920–880	4.35	2160–1640	24.07	$\boxed{139}$	34
	amble	$\boxed{222}$	860–800	6.98	2080–1300	37.50	$\boxed{36}$	21
2	ample	$\boxed{202}$	880–880	0	1920–1480	22.92	60	$\boxed{66}$
	amble	$\boxed{264}$	880–880	0	1800–1480	17.78	26	$\boxed{7}$
3	ample	$\boxed{200}$	640–640	0	1760–1360	22.73	$\boxed{88}$	$\boxed{52}$
	amble	$\boxed{301}$	800–700	12.50	2040–1260	38.24	$\boxed{23}$	$\boxed{11}$
4	ample	158	540–560	3.70	1690–1280	24.26	99	18
	amble	181	560–580	3.57	1680–1240	26.19	94	0
5	ample	$\boxed{173}$	720–700	2.78	1800–1100	38.89	$\boxed{115}$	$\boxed{71}$
	amble	$\boxed{278}$	720–680	5.56	1800–1240	31.11	$\boxed{57}$	$\boxed{12}$
6	ample	$\boxed{159}$	720–640	11.11	1600–1400	12.50	$\boxed{60}$	35
	amble	$\boxed{237}$	760–720	5.26	1600–1480	7.50	$\boxed{14}$	15

□ means that this difference alone is sufficient to differentiate the two words,
○ means that this difference alone is insufficient to differentiate the two words.

Figure 5.15 Table from Santerre and Suen showing potential cueing features measured in the production of the contrast 'ample/amble' sufficient on their own to cue the contrast are put in boxes. Differences which, though large, would not be considered sufficient are in circles). Therefore, for the pairs "amble/ample", the potentially sufficient cues would appear to be the following: the duration of the preceding vocalic element, the stop closure duration (which they label SI, or silent interval), and VOT duration.

- The same cues are not always used. It is also clear from Figure 5.15 that no one of these three cues is consistently always present to a "potentially sufficient" degree.

- There are interspeaker differences in the sets of "potentially sufficient" features used in production of a single contrast.

- Even individual speakers do not always use the same set of features in repetitions of the same pair of words.

The authors conclude, therefore, that the search for a "unique and privileged distinctive feature" is "premature in the present state of knowledge" (:170) and that a single contrast involves the use of various matrices of features. In production terms,

> "the quantity and the choice of features present could vary according to speakers, the phonemic environment, the syllabic structure, the suprasegmental features, the stylistic effects and finally everything which causes the variability which is observed in the language". (:172)

In perception terms,

> "...receptive competence includes the possibility of identifying the units by means of these varying matrices" (:172)

Returning to the first approach, one possible step in the direction of cue integration would be to regard specifically spectral cues (numbered 7 to 10 in Chapter 1.1.0) as secondary for the reason that they are unavoidable production byproducts of a voicing contrast and not independently controlled (for further details on this, see Chapter 1.1.0).

By far the strongest contender as a "primary" voicing cue has been VOT. Indeed it is not surprising that the integrated cue proposed by Stevens and Blumstein, mentioned above, effectively turns out to be a type of VOT detector. As pointed out in Chapter 1.1.3, the literature on voicing contrasts has been dominated by VOT, and it is very frequently assumed that the detection of voicing contrasts is a matter of VOT detection. Typically, the task of VOT detection has been conceptualized as one of judging on the relative timing of two events, voice onset and consonant release.

However, there are problems with VOT as a model for the perception of voicing. These have been already discussed in Chapter 1.1.3, but to recap briefly here on some of the main ones:

- VOT is most useful for initial postpausal prevocalic stops. For other positional variants it would seem to be of less importance than other cues.
- Factors such as tempo and stress affect VOT. When speech tempo increases, VOT values of voiced/voiceless stops overlap somewhat (Lisker and Abramson, 1967).

VOT perception, especially when conceptualized as a task involving the relative timing of two events, may not be generalized all that well to non stop manners of articulation. Fricative release, being more gradual than stop burst release, is less amenable to that explanation. Segments other than stops are not usually aspirated in languages; an explanation of the perception of the voicing contrast as a judgement on the "relative timing of two events" seems most suited to aspiration contrasts.

5.2.2 The C-ness/V-ness hypothesis

5.2.2.1 A preliminary formulation

The next sections are an attempt to outline a hypothesis regarding voicing perception. It favours the "invariant" approach, but the formulation is different from that of Stevens and Blumstein. As it is primarily prompted by production data, it seems worth digressing here in order to illustrate with some data from Irish,[1] already presented in Chapter 2. Later, sections 5.2.3 and 5.2.4 discuss experimental evidence which seems compatible with the hypothesis, and describe an experiment aimed at testing it.

Some production data (taken from Chapter 2)

On the face of it the voicing contrast in Irish would seem to present a classic example of the multiplicity of voicing cues.

------

1 This Irish data comes from set 1 (see Table 1.1).

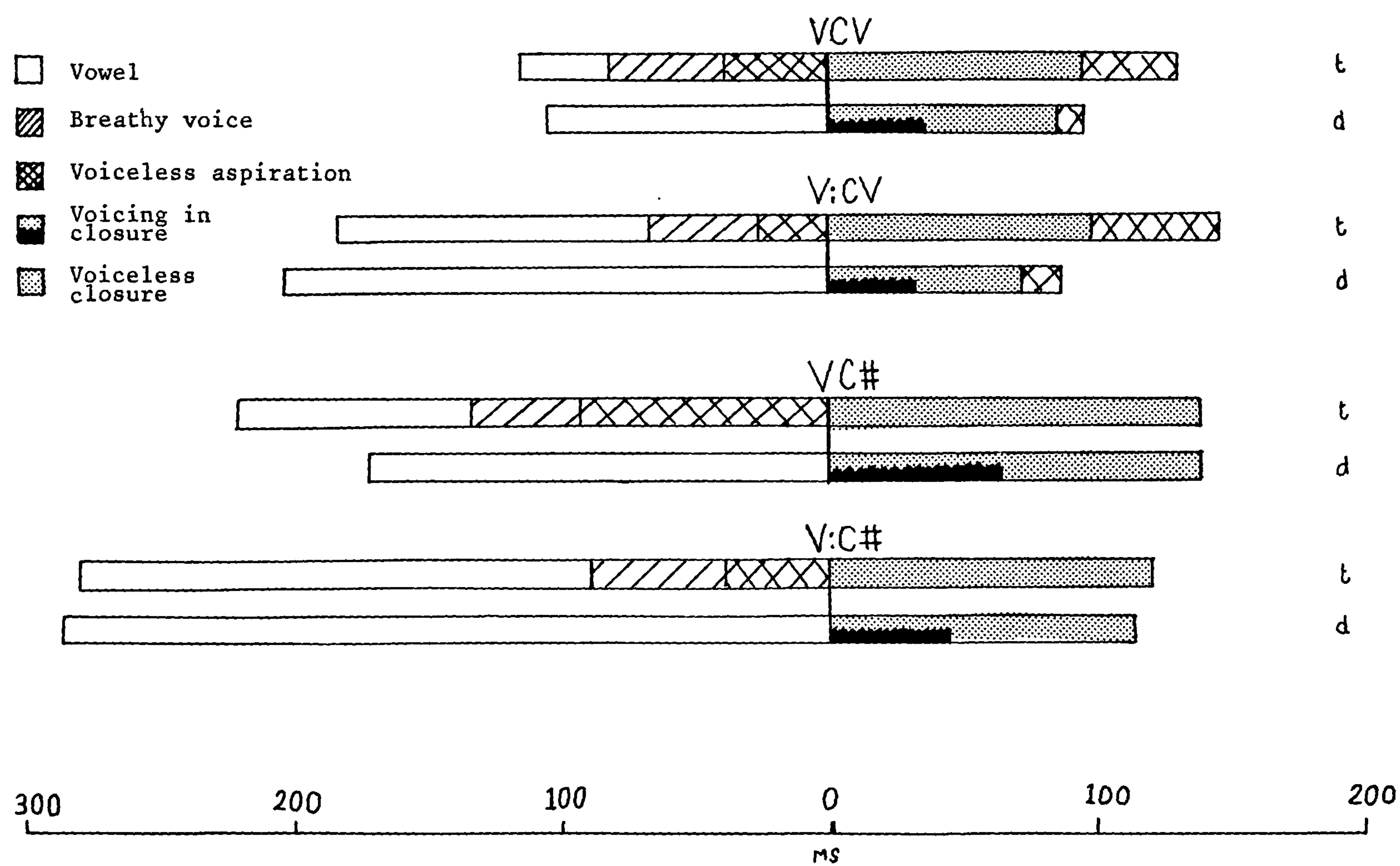


Figure 5.16 Features which contribute to the phonological voicing contrast in Irish

Each value shown represents an average for 12 tokens

As illustrated in Figure 5.16, which covers VCV and VC# positions, the following "features" or "sub-features" might be thought to be involved in the contrast:

Preaspiration, which characterizes the voiceless member.

Vocal fold vibration, which is present during the lenis (or voiced) stops, although never for more than half of the stop's duration.

Postaspiration, which contributes to the stop distinction in VCV.

Duration of preceding vowels would seem to be a differentiating factor for both final and medial positions.

Consonant closure durations may contribute something to the contrastin VCV, although the effect is not that great with long vowels.

The picture for Irish stops, therefore, would appear to be a rather similar but more complex version of the situation described earlier for English by Santerre and Suen (1981), where VOT, the duration of stop closure, and the duration of preceding vowel or vocalic element were found to be potential cues to the opposition (though not necessarily the only ones). And as in the data of Santerre and Suen, the extent to which a single individual subfeature is used, is not always very great.

Yet, to regard the above subfeatures as discrete separate events is clearly misleading, and perhaps the result of a too segmental perspective. Rather than a group of subfeatures independently varying, one could look at the change as involving the relative distribution of voicing and voicelessness in the V+C unit with all the subfeatures contributing to the overall picture. Figure 5.17 is a repetition of Figure 5.16 with, this time, the voiced

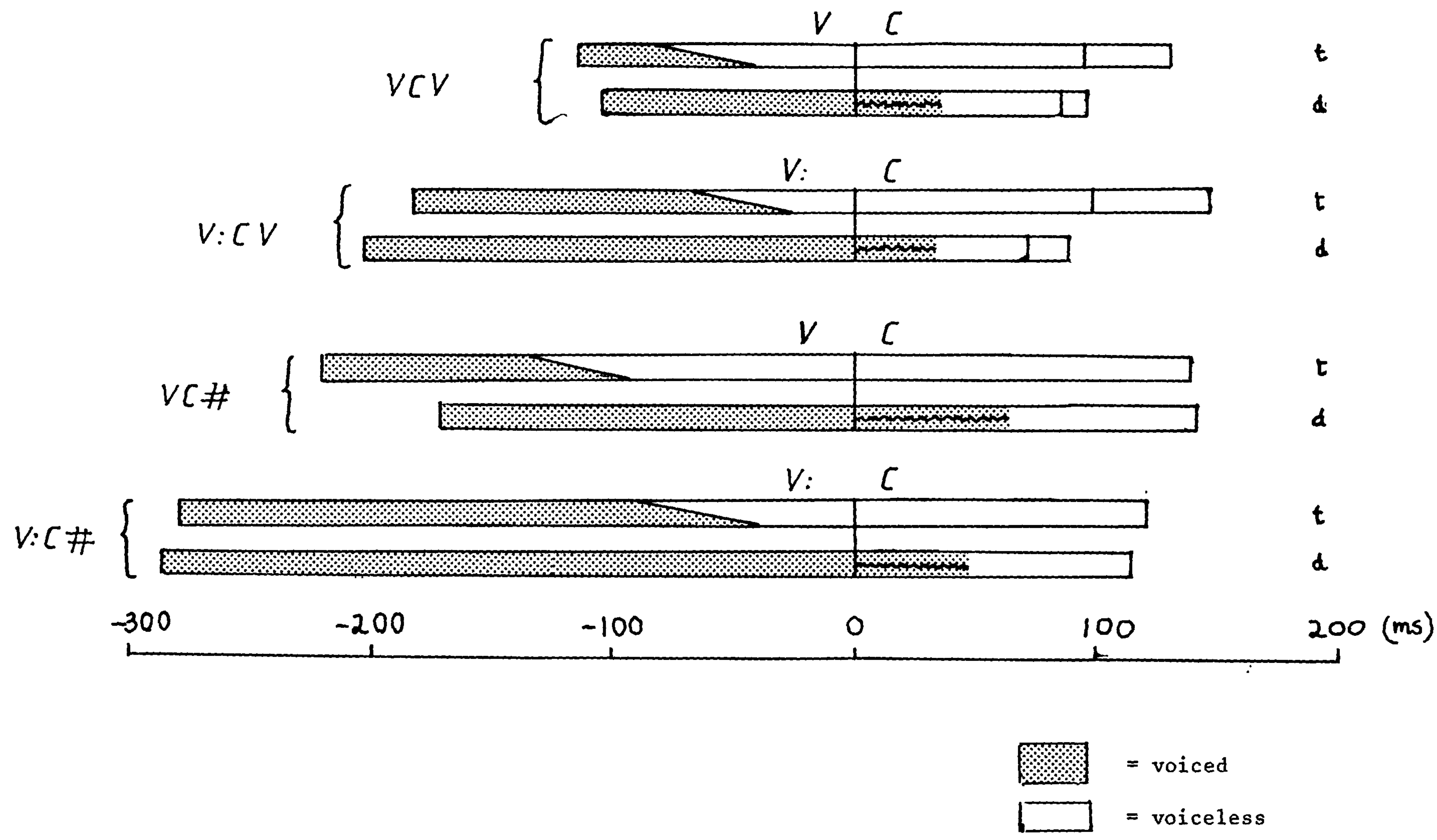


Figure 5.17 Distribution of voicing and voicelessness in the V+C sequence in Irish

Each value shown represents an average for 12 tokens

portions (shaded) and the voiceless portions (unshaded) distinguishable over the V+C unit. (The breathy voiced interval of preaspiration has simply been divided in two, although on the basis of the results of Experiments 1 and 2 it could probably be fully apportioned to the voiceless part of the V+C unit.) The hitherto named subfeatures affect the overall distributions in the following ways: a V+C unit is going to be weighted towards "voiced" if:

- the vowel is comparatively longer
- the consonant (closure in the case of stops) has vibration of the vocal folds

and more "voiceless" if the opposite applies, or if:

- VOT is longer
- there is VOFFT present (i.e. preaspiration).

Consonant closure duration will affect things in the following way: a shorter consonant closure will reduce the likelihood of devoicing (i.e. due to "passive" aerodynamic reasons), a longer consonant closure increases this likelihood and furthermore obviously increases the duration of the silent voiceless portion of a stop.

To return to perception, there is no need to presume that the brain is complicating the issue by making separate judgments on vowel durations, consonant durations, voicing during stop closure, VOT, etc. Voicing detection might simply be a matter of judging the relative extent of voicing and voicelessness in the V+C unit. This is what the hypothesis in its crudest form amounts to. A fuller elaboration of the hypothesis and its implications will be given later.

5.2.2.2 Some advantages of this perspective

This approach would seem to have the following advantages:

- It should be generalisable across word position, handling #CV (hitherto probably best regarded as a VOT contrast) equally well as VCV and VC#.

- It would cope with the main problem highlighted in the Santerre and Suen data, namely the variability in the extent to which, say, the cues of vowel duration, consonant duration or VOT, were used by different speakers, or even by a single speaker for a single contrast. The apparent freedom to choose among cues would seem to lend support to the above hypothesis, and not to the authors' own argument that each cue is being individually monitored.

- It would work across languages (which have a two-way voicing contrast) which might otherwise seem to use different sets of features. For example the task of perceiving the contrast in a particular environment in French, where voicing proper is utilized, need not appear greatly different from that of perceiving the contrast in another language, which would seem to use a different feature, e.g. aspiration. (VOT offered such a cross-language generalisation, but, as VOT turns out to be really useful only in the #CV environment (see Chapter 1.1.3) its generality is rather limited.) To illustrate the point being made here, Figure 5.18 shows data for one speaker of French (from data set 13 in Table 1.1 in Chapter 1.3)[1] measured and displayed in a fashion similar to Figure 5.17 for the Irish data. Here for example, the weighting of V+C syllables (and C+V for initial stops) would on the whole tend towards the "voiced" end of the scale compared to Irish (as indicated by the greater proportion of the "shaded" bar in Figure 5.18), but the contrast still shows as different relative durations of voicing to voicelessness. Therefore, although looked at from one point of view, French is making use of different subfeatures, e.g. voicing during stop closure in #CV or different degrees of the same subfeatures (e.g. voicing during stop closure, or vowel length differences in VCV), the contrasts can still be viewed as involving different weightings of voicing to voicelessness within the syllable.

- This approach should work for manners of articulation other than stops; or example it would handle the voicing opposition in fricatives just as well. Thus it escapes one of the drawbacks of an account in terms of VOT detection.

------

1 The words and carrier frames used are given in Appendix 5.

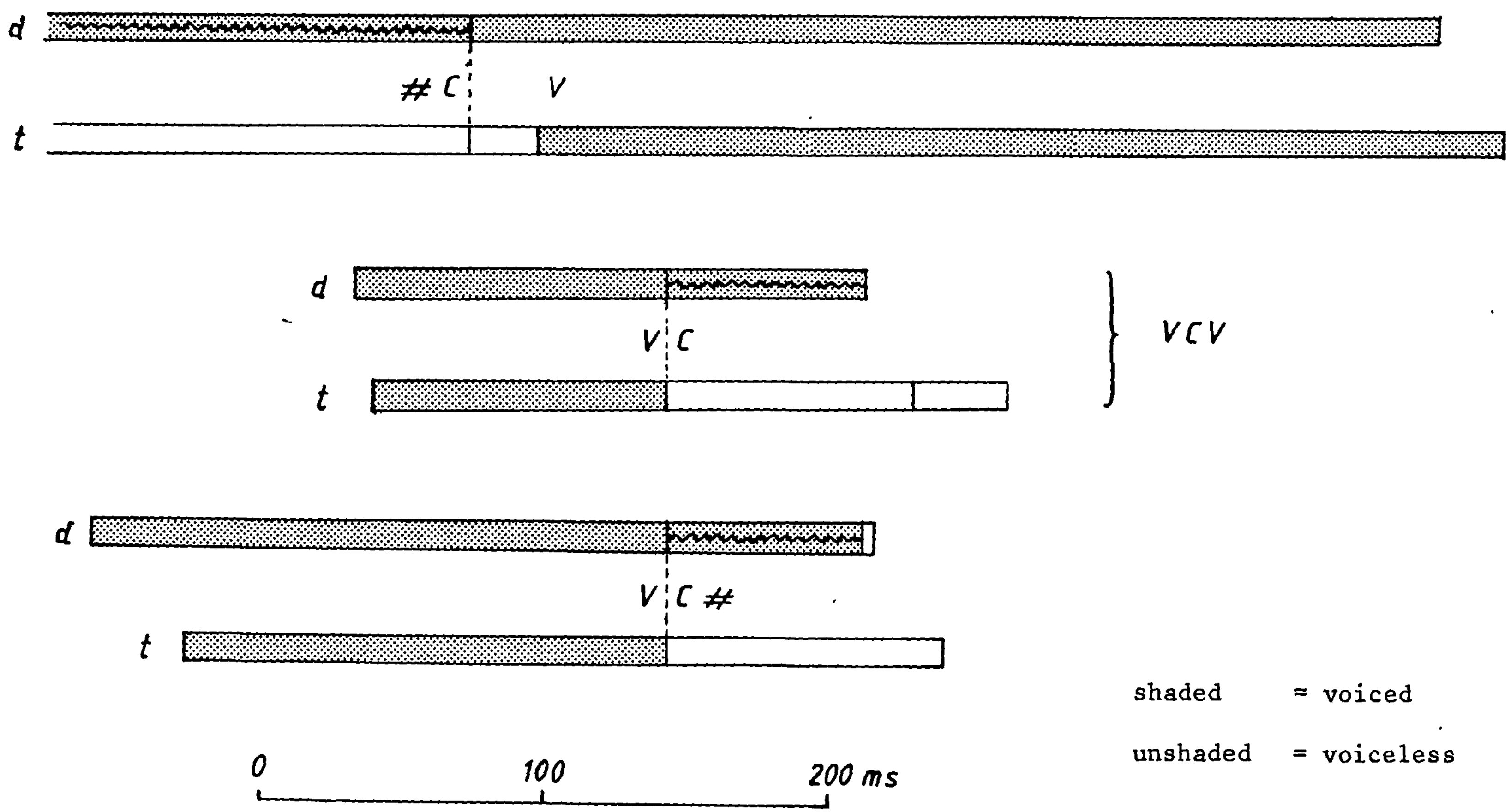


Figure 5.18 Voicing and voicelessness in vowel and stop sequences of French

Each value shown represents an average for 20 tokens

5.2.2.3 Summary of main points in hypothesis

Voicing contrasts are detected over a syllable type unit, V+C or C+V.

This process involves the extraction of two features and a judgment regarding their relative weighting within such units. These two features will be termed V-ness and C-ness - terms which, for the moment, can be understood as corresponding to the voiced and voiceless portions of the syllable respectively, but weighted according to the acoustic nature and amplitude of the sub-parts (some elaboration on this follows below). It is postulated that listeners do not manipulate a large number of independently operating cues, but rather two superordinate features of which the measured properties are components.

The detection of a voicing contrast involves essentially a temporal judgment, but very different from the type frequently implied in the literature, i.e. a judgment on the relative timing of two events.

The two superordinate features derive basically from the integration of cues within the voiced portions and within the voiceless portions of the syllable respectively. But the two features proposed are probably not best conceived of as the simple, measured durations of presence versus absence of vocal fold vibration hitherto implied, or in perceptual terms a simple detection of the durations of periodicity and aperiodicity. Although the discussion until now was presented in those terms

and Figures 5.17 and 5.18 (based on production data) show durations of voicing and voicelessness, the features are probably best conceived of more globally, as the composite entities V-ness and C-ness.
One reason for wishing to speak in terms of higher order features is to allow for differential weighting of the subparts of the signal which are periodic (or aperiodic), according to their acoustic nature and level. Of relevance here is the known psychoacoustic interaction between intensity and duration. It has been pointed out by Pastore (1981) that within an approximate range of 10ms to 200ms the auditory system integrates energy, and that, in measuring the absolute perceptual threshold for intensity, I x T is a constant for a specific range of T (I = intensity per unit time; T = duration of the stimulus). As the durations of VOT continua (and also frequently of adjacent vowels) fall within the limits for this temporal integration, it follows that changes in their durations should lead to proportionate changes in their effective intensity.

There are a number of experiments which suggest that the level of the periodic or aperiodic portions of the signal are highly relevant to our perception of voicing contrasts. Experiment 1, reported in section 5.1, and the similar experiment for initial stops by Repp (1979) suggest that a higher aspiration amplitude enhances the "voiceless" percept. The vowel amplitude also enhances the "voiced" percept, a fact also suggested by an experiment by Darwin and Pearson (1982), which showed that the attainment of a given intensity of the vowel was a more apt characterization of VOT than onset of periodicity per se.

Therefore, although the voiced (periodic) part of the V+C unit feeds into the V-ness percept, and the voiceless part into the C-ness percept, the sub-parts would not be equally weighted. For example, both silence (the unvoiced interval of a stop closure) and aspiration contribute to the 'voiceless' percept, but aspiration being acoustically more salient may proportionately contribute more.

There is a further reason why the V-ness/C-ness are best not envisaged as the simple periodic/aperiodic portions of the syllable, namely, that a simple 'chunk' of the physical signal could be simultaneously contributing to both C-ness and V-ness. In voiced fricatives, for example, simultaneous with periodicity which contributes to the V-ness percept, the frication noise presumably contributes to C-ness (although being typically weak, the contribution may not be very large).

The hypothesis is a broad, and in many ways necessarily (as yet) inexplicit, one; so it is difficult to envisage any one experiment which would test it in its entirety. However, it does permit certain predictions to be made, and these should be testable. The next section deals with these predictions, and with already existing experimental evidence which is relevant to them, before proceeding to Experiment 3, whose aim is to test one such specific prediction.

Before continuing, however, a brief aside may be in order here regarding the choice of the terms C-ness and V-ness. These have been borrowed from dependency phonology (see Anderson and Ewen 1980) and seem appropriate for the purpose at hand. However, it should be made clear that they are in fact being used to mean something rather different from what they signify within dependency phonology.

5.2.3 Predictions of the hypothesis and their validation

5.2.3.1 Predictions

According to the hypothesis the syllable is judged in terms of relative C-ness to V-ness. It postulates that an increase in one of these within a syllable will be evidenced by causing perceptual judgments to shift in the appropriate direction. Thus, for example, an increase in C-ness will lead to an increase in "voiceless" judgments, and alternatively an increase in V-ness will lead to an increase in "voiced" judgements. For this to be the case, it follows additionally that there must be perceptual integration of the sub-components of V-ness and C-ness. For instance, an increase in the duration or level of a sub-component which feeds into C-ness (such as aspiration) will, unless compensated for by a decrease in one or more of the other integrated sub-components, cause an increase in C-ness; this will be manifested as a shift in judgements towards "voiceless".

5.2.3.2 Experimental validation of these predictions in the literature

There are a number of experimental findings, some of which have already been mentioned briefly, which fall in with the above predictions and so seem to support the hypothesis.

V-ness

According to the prediction above, an increase in the level or duration of one of the components of V-ness should change the ratio and therefore lead to an increase in "voiced" judgments.

vowel amplitude

In one part of the experiment by Repp (1979) which was mentioned earlier, it was found that raising the vowel amplitude in #CV caused a shift in the VOT boundary. That is, for judgments to remain constant, a longer VOT was required; otherwise judgments shifted towards "voiced".

vowel duration - a following vowel in a C+V unit

A similar boundary shifting effect was reported by Summerfield (1981), as a consequence of increases in vowel duration in #CV syllables. In this study, aimed principally at determining the effects of speech rate on the VOT boundary, it was found that a longer duration of the vowel in a /bi-pi/ continuum (which had been medialized in a frame, "why are you -") led to an increase in "voiced" judgments.

This finding of Summerfield's may be related to the findings reported for production by Johnson and Nolan (1981) and by Weismer (1979) and to some extent in Chapter 2.1, for aspiration to be slightly longer with long vowels. These would be "explained" as a need to maintain the C-ness to V-ness balance of the syllable as a whole. If, by increasing the vowel duration or amplitude, the V-ness content is increased, the C-ness portion would also need to be enhanced or judgments of the consonant contrast will shift towards "voiced".

Vowel duration - a preceding vowel in the V+C unit

An effect is well attested in the literature is that of increased length in the preceding vowel increasing the likelihood of a voiced percept. This has been discussed as feature 6 in Chapters 1 and 2. This particular feature has been found relevant for final stops (Denes, 1955) and for intervocalic stops (Port, 1979). It would also appear to hold for word initial stops when "medialized" in a frame. In the experiment of Summerfield's, mentioned above, the duration of the immediately preceding element /ju/ had an effect similar to that of the preceding vowel duration in other environments.

The parts of the signal which contribute to V-ness are the vowel and the portion of the consonant for which the vocal folds are vibrating. An experiment by Javkin (1979) does suggest a perceptual equivalence between the above two components. This experiment (which has been already discussed in Chapter 1.1) was aimed at showing the perceptual basis of the universal tendency for vowels to be longer before voiced consonants. In the experiment, listeners heard synthesised V+C where C was sometimes voiced, sometimes not, and were asked to match the duration of a controllable tone to that of the vowel. Results showed that listeners consistently perceived the vowel as longer when the following C was voiced. It would thus appear that a degree of perceptual equivalence between the two does exist, and hence the possibility of interchangeability; they both contribute to a single percept - the one here termed V-ness.

One might argue here that the subjects in Javkin's experiment were not responding to the duration of the vowel, but rather to that of voicing in the syllable. But it is precisely this fuzziness of the distinction between the two which is interesting and indeed of relevance here.

C-ness

The components of the signal that feed into C-ness are silence (i.e. the portion of the consonant during which there is no vocal fold vibration) and aspiration noise. The latter would include the noise of the release burst of the stop.

According to the hypothesis an increase in the level or duration of one of the components of C-ness should change the C-ness to V-ness ratio in a way which would lead to an increase in "voiceless" judgements.

Aspiration amplitude

One facet of the experiment by Repp (1979) shows the counterpart of V-ness increase, i.e. C-ness increase. In syllables with initial prevocalic stops, an increase in aspiration amplitude causes a shift towards "voiceless" judgments. This effect was also shown to be clearly present for preaspiration in postvocalic position, judging by the results of Experiment 1, reported above. Therefore, an increase in aspiration amplitude has an effect similar to an increase in aspiration duration; within the present interpretation they both raise the proportion of C-ness in the syllable. And this leads to the shift towards "voiceless" judgments, just as an increase in vowel amplitude or duration increases the proportion of V-ness in the syllable, leading to more "voiced" judgments.

It is interesting to note in Repp's experiment that the effects of, say, increasing vowel amplitude, are cancelled out if aspiration level is also increased. This would go to show that, as both C-ness and V-ness have both been increased, their relative strengths remain more or less constant.

Aspiration duration

The effect of aspiration duration does not need commenting on; it is well known as a cue, particularly in #CV, but can also be of relevance in VCV (see for example the Irish data in Chapter 2.1.)

Stop closure duration

This is again a well attested cue in the literature for postvocalic stops, especially in VCV, and was dealt with as feature 5 in Chapters 1 and 2. It has not normally been thought relevant to the perception of stops in #CV. However, results from the experiment by Summerfield (1981), mentioned above, do suggest that it is relevant to the perception of word initial stops when they are medialized in a frame. Presumably, this is because the actual closure duration is available to our perception in this environment, as it wouldn't be for the postpausal position.

One could perhaps add here some suggestions of Summerfield (1981) which run along similar if not identical lines to the predictions made here. Having noted the effects mentioned above (i.e. of stop closure duration for "medialized" word initial stops, and of the duration of preceding and following vowels) he points out that these effects encompass little more than the timespan of acoustical events involved in the production of the stop (its constriction, occlusion and release). He proposes that a general rule for increasing the probability of a voiced stop percept might be to:

> "increase the proportion of the devoiced interval (i.e. the sum of the stop closure and the VOT) to the surrounding voiced interval encompassing the abutting vowels"

or in slightly different terms:

> "decreasing the ratio of aperiodic to periodic acoustical energy over the time course of supraglottal occlusion, constriction and release". (:1092)

According to the hypothesis there is a perceptual equivalence or integration between the elements of C-ness. One would therefore expect some kind of trading relationship between these two elements. For example, if for a voiceless stop the consonant closure duration were shortened, longer aspiration duration should be required to cue that member of the opposition. If, on the other hand, consonant closure were lengthened, one should expect shorter aspiration duration to be necessary.

This statement must be constrained by the necessity for both elements to be available to our perception. For instance, the duration of "silence" can hardly be relevant if it is not determinable. This may be the case in #CV, given that the moment of consonant closure is not acoustically marked as is the consonant release.

Our preaspirated stops provide an eminently suitable testing ground for the hypothesis. For these, one should expect an increase in consonant closure duration to allow a shorter preaspiration duration and vice versa.

This expectation runs directly counter to what one's expectations might otherwise be. For example, Pind (1982) asked a completely different question: namely, against which of the surrounding elements of preceding vowel or stop closure is preaspiration measured as a ratio? An underlying assumption would be that preaspiration is "extracted" as a separate element and its duration measured against adjacent elements. Therefore, as compared to the present approach, which is to regard the elements of C-ness (closure duration and preaspiration) as "integrated", Pind's underlying assumption is that preaspiration is either measured against stop closure duration or against vowel duration. If it is measured against stop closure duration, an increase there would be expected to necessitate a concomitant increase in preaspiration duration. If it is measured against vowel duration, changes in stop closure duration should have no effect on the perception of the preaspirated stop.

Of the two possibilities discussed, Pind's own preferred hypothesis is that preaspiration is measured more in relation to the preceding vowel. In some production measurements across different speaking rates he found that the measure h/V+h gave a reasonably constant ratio.

Pind conducted two tests where durations of the vowel and/or of stop closure were varied for a range of VOFFT continua. His results showed substantial boundary shifts (VOFFT <u>increases</u>) with increases in the vowel duration; when stop closure duration was increased there was a slight and not fully consistent <u>reduction</u> in the VOFFT boundary. From this he concluded that preaspiration perception depended much more on the vowel and took this as support of his proposed h/V+h ratio.

However, one problem with Pind's experiment lies within the phonology of the language he worked with, in the fact that vowel and consonant length is not free. The possible contrasts are as follows:

1. $a^{h}p$
2. a p:
3. a:p

The preaspirated stop (which is always preceded by a short vowel) contrasts with an unpreaspirated geminate stop (also preceded by a short vowel) and with an unpreaspirated single stop (preceded by a short vowel).

It is therefore difficult to interpret Pind's results and disambiguate whether and to what extent the results are consequent on the phonological factor. The phonology alone could lead one to expect that an increase in duration of either the vowel or stop closure would militate against the "preaspirated" percept as this would increase the likelihood of 2 or 3 above being perceived. In other words, on the basis of the phonological contrasts of Icelandic, increases in vowel or stop closure duration should lead to an increased VOFFT boundary.

The fact that this happens with the vowel could be explained by a number of factors - the phonological factor being one. This particular finding is not all that interesting, so it would be predicted no matter which model of preaspiration perception one adheres to.

And the fact that, in spite of the phonological factor mentioned, increases in stop closure duration did occasion a slight tendency towards VOFFT decrease could be construed as weak support for the C-ness V-ness hypothesis being presented here.

In any case it is clear that Icelandic is not the best testing ground to decide whether preaspiration is perceived as a ratio of the consonant closure duration, and hence in contrast to it, as Pind proposed could be the case, or in conjunction with the consonant closure (i.e. in an additive way, H + C, as is being proposed here; note, however, that this would not simply be the linear sum of the two, but, as described earlier,the elements would be acoustically weighted).

Scottish Gaelic does not have the same phonological constraints as Icelandic, and thus seemed a more interesting test language. In Scottish Gaelic both preaspirated and unpreaspirated stops occur after short and long vowels. Also the stop closure durations are similar (see Chapter 2.5). In fact, the unpreaspirated stop closure is fractionally longer, but if that is likely to affect matters, it would at least be in the direction opposite to that predicted (i.e. increase in closure duration could conceivably swing listeners towards the "unpreaspirated" judgment, rather than "add" to the percept of "preaspirated" as is suggested here).

5.2.4 EXPERIMENT 3

5.2.4.1 Aim of experiment

The purpose of the experiment was to investigate whether for preaspirated stops, the aspiration and stop closure (the elements of our proposed C-ness) might be perceived in some sort of additive integrated fashion, or aspiration perceived separately and in opposition/contrast to the stop closure.

If there is a degree of perceptual integration taking place, as the C-ness/V-ness hypothesis predicts, then one would expect a trading relationship between the aspiration and the stop closure, with an increase in either leading to an increase in "voiceless preaspirated" judgments. Changes in stop closure duration should cause a shift in the VOFFT boundary, with longer closures allowing a shift to the left (shorter preaspiration) and shorter closures necessitating a shift to the right (longer preaspiration).

If, on the other hand, preaspiration is separately perceived, one would expect the relationship between its duration and stop closure duration to be as Pind suggested could be the case, i.e. preaspiration duration is more likely to be, if anything, perceived as against stop closure duration. Therefore, one should expect any change to involve the opposite of a trading relationship; an increase in stop closure duration should reduce the perceptibility of preaspiration and hence cause a rightward shift in the VOFFT boundary.

The stimuli used were the same as those in Experiment 1, but with further manipulation of stop closure durations (see below). These stimuli were at three levels of aspiration, i.e. as described in connection with Experiment 1, besides stimuli with aspiration at the originally recorded level, there were two other series with aspiration amplitude either amplified or attenuated by 6db. As the three series of stimuli were used in Experiment 3, there was a further expectation that this experiment would also replicate the earlier findings of Experiment 1, and show VOFFT boundary reductions with increases in aspiration levels, thus yielding further confirmation of hypothesis B of Experiment 1 above.

5.2.4.2 Stimuli:

On the basis of the results of Experiment 1 it was thought that the hypothesis would best be tested by using stimuli which did not have the breathy voiced transition. Therefore the non-breathy voiced stimuli in Experiment 1 were used, modified in a few respects.

Firstly, as the subjects were to be speakers of Scottish Gaelic, the frame sentence was removed, so that the word could be presented in isolation.

Secondly for each of the non breathy stimuli used in Experiment 1, three new stimuli were made, so that stop closure durations were now 70ms, 100ms, and 130ms. This then left a total of 93 stimuli, which now differed in preaspiration duration, stop closure duration, and in intensity of preaspiration.

With each stimulus occurring four times, a tape was prepared where all stimuli were randomised over the total number of 93. The interstimulus interval was 1.5 seconds. The tape was presented to each subject twice, so that for each individual token, eight judgments were obtained from each listener. The tape was presented through headphones to participants singly or in pairs, in the Phonetics Laboratory in Edinburgh University. The same system as described for Experiment 1 was used to ensure that listeners heard the tape at the same level. In this experiment the subjects were asked to decide whether the stimuli they heard were instances of the word papa or paba. They were given a test run of 80 stimuli, and a short break between the two runs of the tape if they so desired.

5.2.4.3 Subjects:

The most suitable subjects, it was felt, would be speakers from the strongly preaspirating Cl dialect area (see Chapter 1.2.2.3) of which the Harris, Skye and North-Uist informants (used in Chapters 2 and 3), would be representative. The tape was therefore presented to 5 such subjects. Speakers of the Lewis dialect (area B) for whom voicing of the lenis stop might be as important a facet of the opposition as preaspiration, were thought to be less suitable candidates for the task, as their VOFFT boundary might well fall very close to 0 (i.e. the moment of oral closure) or conceivably even beyond (i.e. during the closure). If this were to be the case, one could expect no differentiation of stimuli, with all being perceived as [paʰpa].

However this result, although it would not illuminate our hypothesis one way or the other, would in itself be of descriptive interest in allowing a comparison of Lewis perception of VOFFT with that of the strongly preaspirating dialects. For that reason the test was carried out as well on three Lewis subjects.

5.2.4.4 Results

As expected, there were two distinct patterns in responses according to the dialect background of the subjects, and the data were averaged separately for the two groups. For simplicity of nomenclature in the following discussion, the Cl dialect area will be referred to as Harris, and area B as Lewis. Figures 5.19, 5.20 and 5.21 illustrate the results for the Harris group and Figures 5.22, 5.23 and 5.24 show results for the Lewis group. The basic presentation of these figures is the same as that used earlier in the figures relating to Experiment 1. Table 5.2 gives average VOFFT boundaries for the Harris and Lewis groups. For the Lewis subjects, it will be seen that there is not always a VOFFT boundary; when aspiration level was at 0dB or +6dB only those stimuli with the shortest closure duration yielded response curves which crossed the 50% line. Table 5.3 summarises for both groups the extent of the boundary shift (where measureable) as a

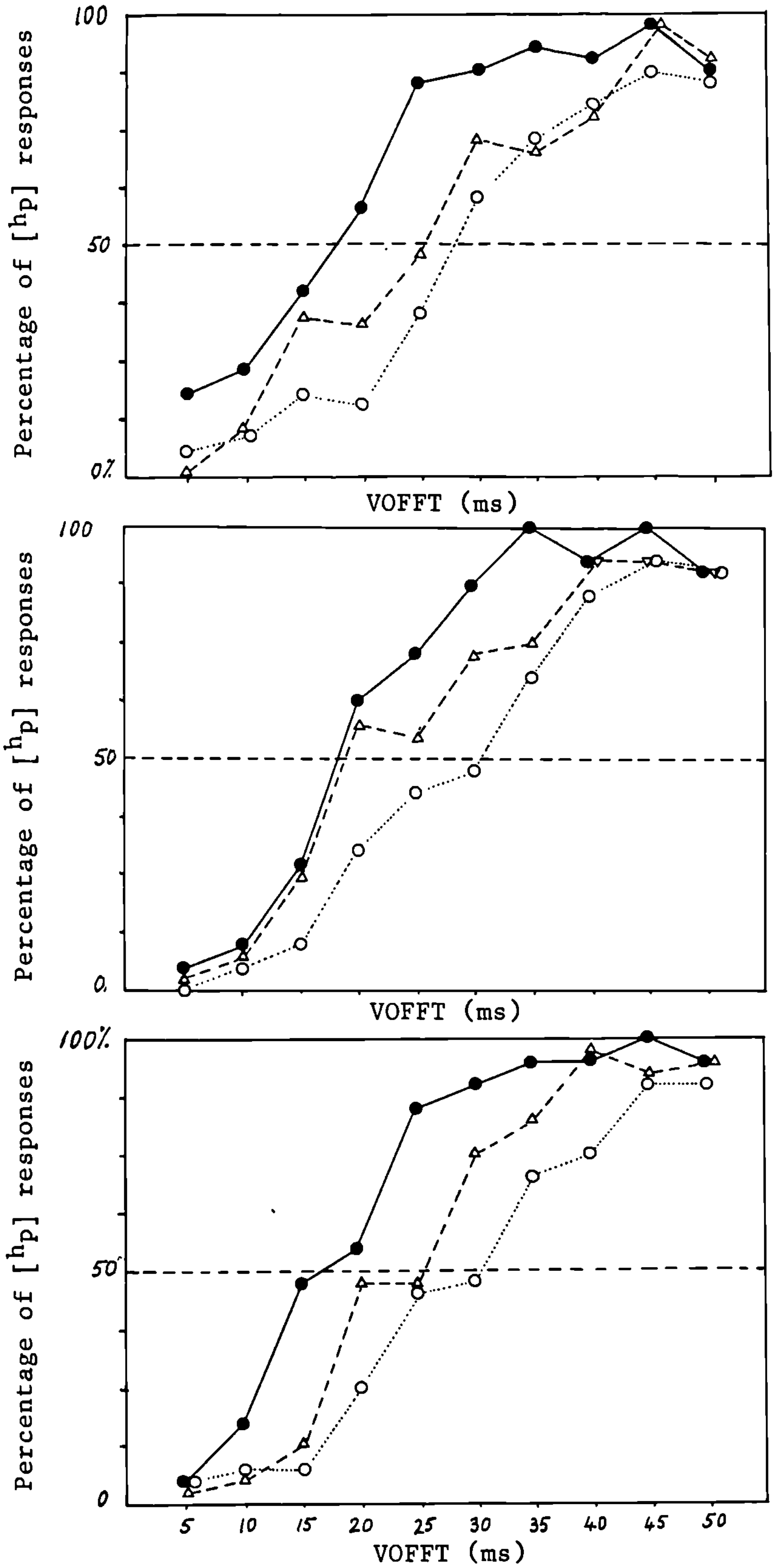


Figure 5.19
-6 dB

Figure 5.20
0 dB

Figure 5.21
+6 dB

Figures showing Harris responses for closure durations of
130ms 100ms 70ms

Table 5.2 VOFFT Boundaries (ms) (50% crossover points)

For closure durations (ms):		130	100	70
Harris	-6dB	17.9	25.5	28.0
	0dB	18.2	18.9	30.6
	+6dB	16.7	25.5	30.6
Lewis	-6dB	7.9	6.6	11.1
	0dB	do not cross 50%		
	+6dB	do not cross 50%		

function of closure duration. In this table a boundary shift in a direction opposite to that predicted is circled.

The Harris Group (Figures 5.19, 5.20 and 5.21 and Table 1a in Appendix 4)

The duration of stop closure did occasion rather substantial shifts in the VOFFT boundaries. The direction of the boundary shifts coincided in every case with the direction expected within the present hypothesis rather than in the direction one would expect if preaspiration were judged relative to stop closure, a possibility which was suggested by Pind. An increase in stop closure duration would seem to permit a negative shift (i.e. leftward in the figures) in VOFFT boundaries. The effect of stop closure duration was statistically highly significant ($F(2,8) = 24.3418$, $p < 0.001$). Thus, when stop closure durations are longer, less preaspiration duration is required to cue the preaspirated member of the opposition.

The total observed shift (occasioned by the overall 60ms change in closure duration) averages out at 12.1ms. Therefore, per 10ms of increase in stop closure duration an approximate boundary shift of 2ms is caused.

The Lewis Group (Figures 5.22, 5.23 and 5.24. See also Table 1b in Appendix 4)

The data for the Lewis group are presented using a similar format as for the Harris.

LEWIS

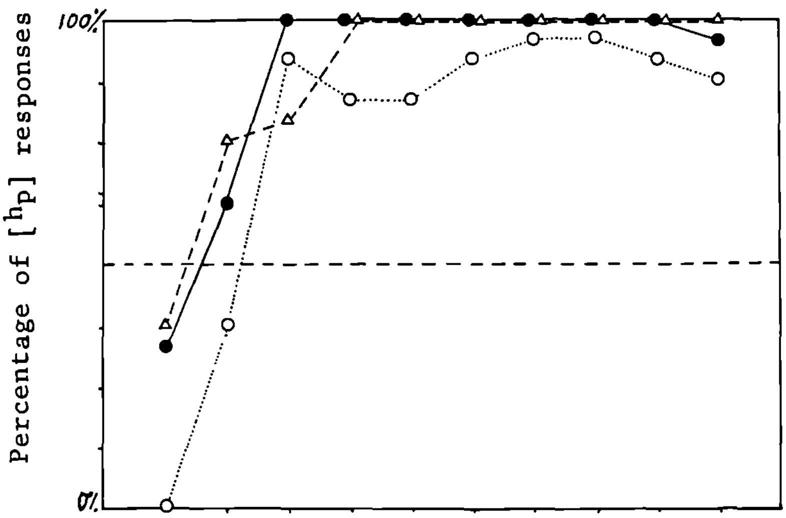


Figure 5.22
+6 dB

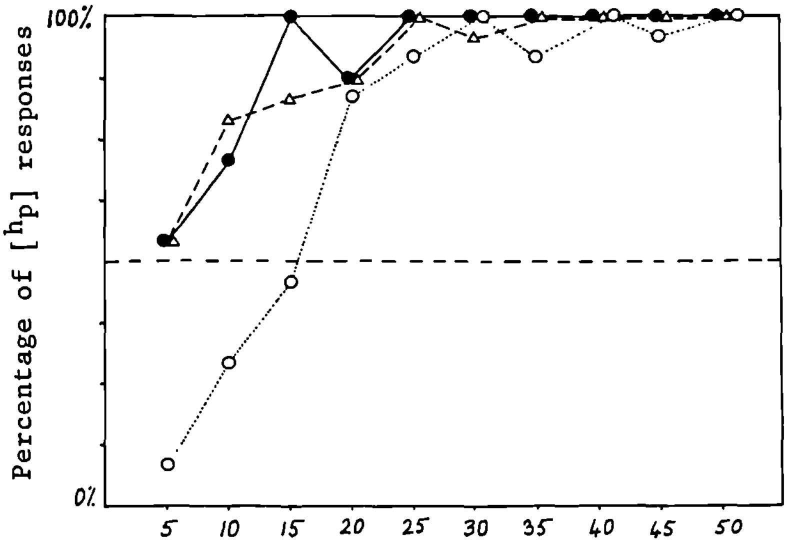


Figure 5.23
0 dB

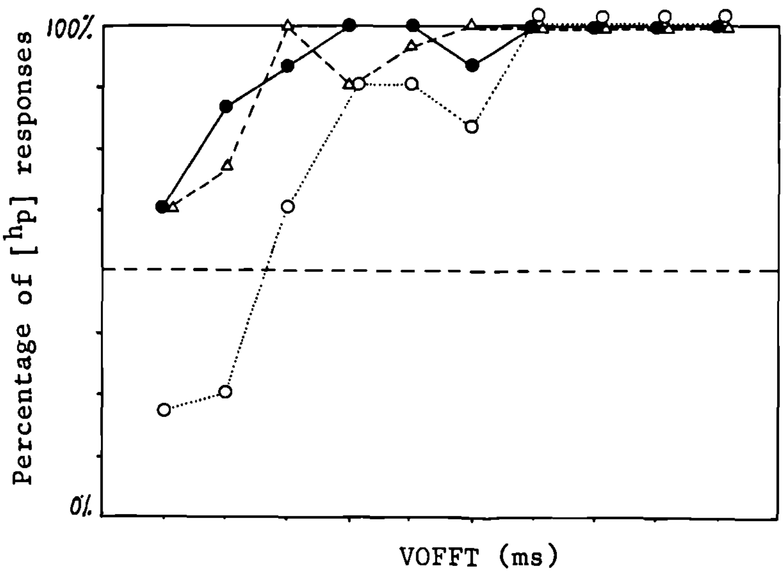


Figure 5.24
-6 dB

Figures showing Lewis responses for closure durations of

130ms ●——● 100ms △——△ 70ms ○——○

Table 5.3 VOFFT Boundary Shifts (ms) Occasioned by Differences in Closure Duration.

Closure Duration (ms)		130 → 100	100 → 70
Harris:	-6dB	+7.6	+2.5
	OdB	+0.7	+11.7
	+6dB	+8.8	+5.1
Lewis:	-6dB	-1.3	+4.5
	OdB, +6dB	-	-

Note: Encircled value denotes a shift which runs counter to the predicted direction.

Values in left and right columns are additive

As expected, the VOFFT boundaries were a good deal closer to zero for the Lewis than for the Harris group. This is evidenced not only in VOFFT boundaries at much shorter durations of aspiration, but also from the fact that response curves often do not cross the 50% line, especially at the higher levels of aspiration noise. The duration of stop closure also seems to be important for these subjects. This effect is statistically significant ($F_{(2,4)}$ 19.2921, $p < 0.01$).

The difference between responses to stimuli with 70ms and with 100ms stop closure is striking. Response curves for the former lie considerably to the right of the latter showing that with shorter closure durations, longer aspiration was required to cue a 'preaspirated' response. Only with the shorter stop closure (70ms) did listeners exhibit a full range of responses; as mentioned already, with longer stop closures response curves frequently did not cross the 50% line but were preponderantly judged as [pa^{h}pa]. At the lowest aspiration level where boundaries were measurable, the change in stop closure duration from 70ms to 100ms caused a boundary shift of 3.2ms which is a shift of 1ms per 10ms of closure duration. For the other aspiration levels the extent to which the response curve shifts with the 70/100ms closure duration change is considerably greater than this.

The change in closure duration from 100ms to 130ms does not occasion any great or consistent further boundary shifting. This however seems fairly likely to be a simple consequence of the fact that the boundary cannot shift much further. A more representative continuum of test stimuli for Lewis would probably need to include voicing during stop closure.

<u>Effects of aspiration level on VOFFT boundaries in experiment 3</u>

As three levels of aspiration noise were used in these stimuli, there was an expectation that results would provide further support for hypothesis B, outlined in connection with Experiment 1 in the early part of this chapter. This hypothesis proposes that an increase in aspiration level would lead to a decrease in the duration of aspiration required to cue the preaspirated stop, and was clearly supported by the results of Experiment 1. Contrary to expectations, however, there was no clear pattern of boundary shifting associated with the aspiration levels used in this experiment. Table 5.4 shows the boundary shifts as a function of aspiration level; shifts which run contrary to initial expectations are placed within circles. Tables 1a and 1b of Appendix 4 also indicate that the effect of aspiration level was not significant for either group of subjects; for Harris $F(2,8) = 0.1806$, $p < 1$; for the Lewis Group $F(2,4) = 1.008$, $p < 1$.

Table 5.4 VOFFT Boundary Shifts (ms) Occasioned by Changes in Aspiration Amplitude.

Aspiration amplitude		−6dB ⟶ 0dB	0dB ⟶ +6dB
Harris:			
Closure duration:	130ms	+0.3	-1.5
	100ms	−6.6	+6.6
	70ms	+2.6	0
Lewis:			
Closure duration:	130ms	not applicable.	
	100ms	not applicable.	
	70ms	+4.6	-2.2

Note: Positive values denote shifts which run counter to the predicted direction.
Values in left and right columns are additive

5.2.4.5 Discussion

Experiment 3 does seem to offer support for the prediction that the elements of C-ness, closure duration and aspiration noise, are perceived in an additive, integrated fashion. The alternative possibility, that preaspiration duration is measured against, or as a ratio of stop closure duration is not supported.

The extent of VOFFT boundary shift, as a function of stop closure duration is shown in Figure 5.25, for both the Harris and the Lewis subjects. For the latter group it was only possible to measure the shifting of the response curves at the 50% line when aspiration noise was at its lowest level. Therefore for the other aspiration levels (shown by dotted lines) a measure of the shift at the 75% line was taken. From this figure, the tendency of longer VOFFT with shorter closure duration is quite clear, except in the case of closure durations of 100ms and 130ms for the Lewis subjects. This last fact is not necessarily very surprising; as noted earlier, the boundary for stop closure of 100ms has already shifted almost as far as it can go.

A rather surprising finding, in view of the earlier experiments 1 & 2, was the lack of consistent boundary shifting with changes in aspiration amplitude level. It fails to offer the expected additional support for the findings which appeared rather clearcut in Experiments 1 and 2. In Experiment 1, it will be recalled, for Group 2 of subjects, who accepted the non-breathy-voiced stimuli as possible preaspiration stops, an increase in aspiration level occasioned a clear-cut and rather extensive reduction in the VOFFT boundary (see Figure 5.11). The latter figure may serve to remind the reader that the effects of aspiration amplitude were found by Repp (1979) to affect VOT boundaries in a similar way. Furthermore, the results of Experiment 2 seemed to point to aspiration noise level as being a highly significant determinant of the perception of preaspiration.

One can think of two kinds of explanation for the lack of boundary shifts in Experiment 3 as a consequence of differences in aspiration level. First of all, it may be that Scottish-Gaelic speakers perceive aspiration in a fashion which is different from their Icelandic counterparts. This line of explanation seems highly unlikely ; subjects in Experiment 2, which seemed to point unambiguously to the importance of aspiration level, were not all Icelanders, but were consistent, in their responses. The other, more likely, type of explanation would seem to lie in there being some interaction of the different variables of the stimuli, so that the results are skewed for aspiration level effects. However, it is not at all clear what kind of interaction might be going on here. This will obviously require some more investigation.

5.3 SUMMARY OF CONCLUSIONS

The first of these experiments demonstrated the perceptual importance of the breathy voiced transition.

The presence of completely voiceless aspiration as such is not required for a stop to be perceived as preaspirated. Furthermore, it seems likely that the breathy voiced transition is not only sufficient to cue preaspiration, but is considerably more natural than purely voiceless preaspiration and thus more acceptable to subjects.

The level of aspiration noise in both Experiments 1 and 2 was found to be very important in judgements on preaspiration. In Experiment 1, for Group 2 of subjects who "accepted" the stimuli with only voiceless aspiration as possible tokens of preaspiration, changes in aspiration amplitude induced rather sizeable boundary shifts. These shifts were similar to, but greater in extent than, those found for VOT in Repp (1979).

VOFFT boundaries for Icelandic and Harris Gaelic subjects were 20ms and 18.9ms respectively. These boundaries come from Experiment 1 and 3 and are estimated from the non breathy voiced stimuli at OdB ; (it will be recalled that by OdB is meant the level of the source stimulus which was manipulated to produce the other stimuli). Furthermore, the VOFFT boundary value cited there for Harris is that for the mid value for stop closure duration - 100ms.

The VOFFT boundary for the Lewis subjects falls at a much shorter preaspiration duration. For aspiration level at OdB Lewis responses only cross the 50% boundary mark when stop closure duration is at 70ms. Here the boundary falls at 15.7ms which would compare with 30.6ms for Harris in the same condition (compare Figures 5.23 and 5.20). Figure 5.25 also illustrates the considerable shorter VOFFT boundaries for the Lewis as compared to the Harris subjects. The continuum used is clearly asymmetric with respect to the voicing opposition in the Lewis dialect. According to the present model, all the stimuli would have too high a C-ness content.

Even for Icelandic and Harris Gaelic, the duration of preaspiration at which VOFFT boundaries fall is surprisingly short, in view of the very long durations found for preaspiration production in Chapter 2. Preaspiration durations are typically considerably longer than postaspiration durations (even if one excludes the breathy voiced transition from the total duration of the latter : see Chapter 2.4.2). Yet, VOFFT boundaries fall at aspiration durations which are as short as for VOT boundaries (Lisker and Abramson, 1970 give VOT boundaries for English speakers ranging from +25ms to 45ms depending on place of articulation). A similar observation to this is also made by Pind (1982). This suggests that the very long preaspiration durations found in production are not motivated by perceptual necessity.

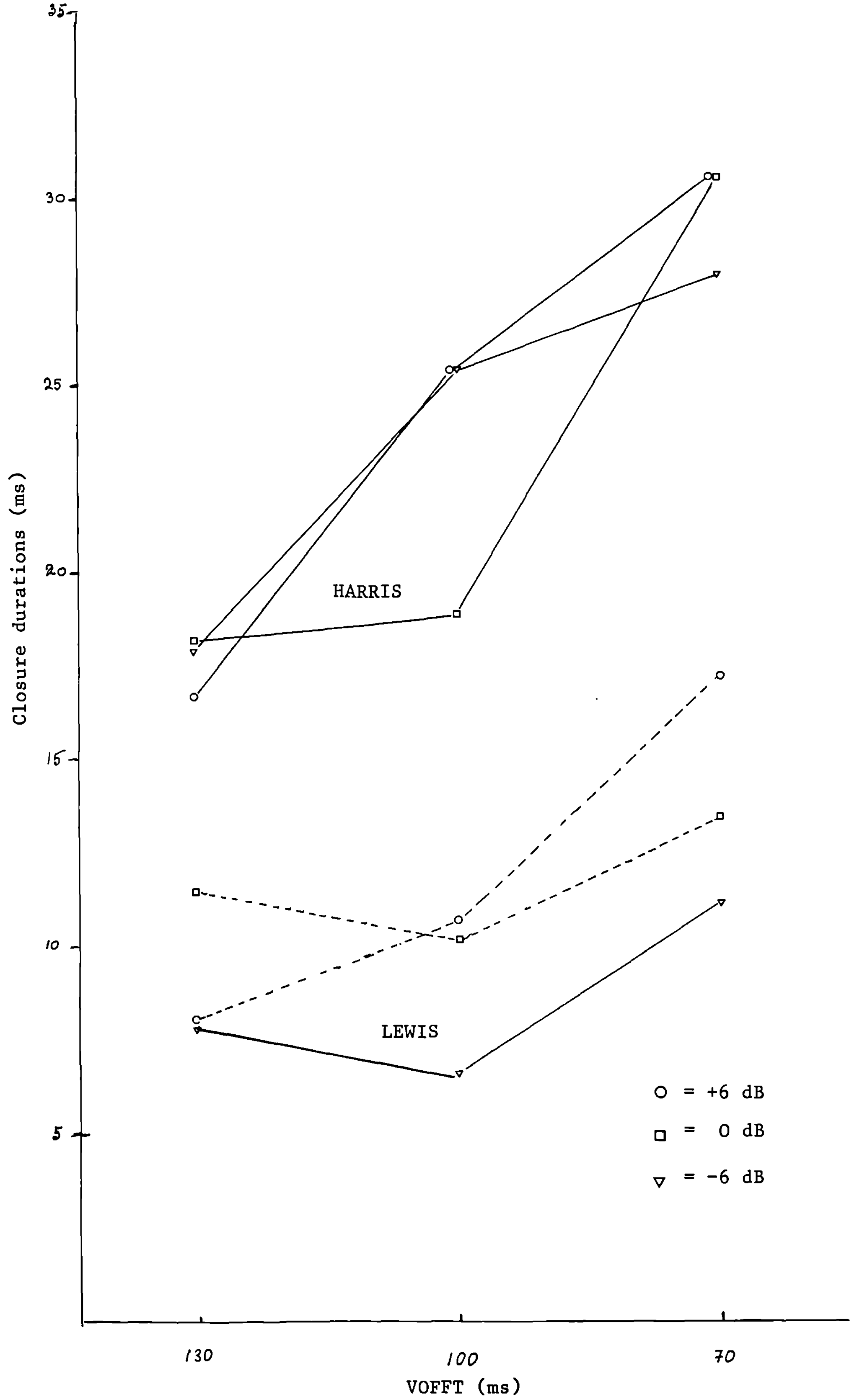


Figure 5.25 VOFFT boundary shifts as a function of closure durations (the dotted lines represent estimations at the 75% level)

The second part of this chapter discussed in some detail the hypothesis that the perception of a phonological "voicing" contrast may involve a judgement on the relative weightings of two components, C-ness and V-ness, in a syllable sized unit. The elements of C-ness and V-ness are the voiceless and voiced portions of the signal, and the hypothesis implies that the weighting of either depends on both the durations and the acoustic level of its subparts, and are perceptually integrated.

Various findings in the literature were discussed which seem compatible with the hypothesis. Some additional support for the hypothesis comes from the results of the experiments reported here. Experiment 3 lends support to the idea that the elements of C-ness, aspiration noise and silence, are perceived in an integrated additive way. Experiments 1 and 2 in showing the importance of aspiration noise level to the preaspiration percept further supports the contention that the acoustic level of an element of C-ness (or of V-ness) will contribute positively to its overall weighting. However, as regards the latter finding, the lack of consistent similar boundary shifts with the different levels of aspiration noise in Experiment 3 seems to point to some interaction of the variables in these stimuli which would need further investigation. Further experimentation on the C-ness/ V-ness hypothesis might attempt to quantify the relative contributions of the subcomponents to V-ness or C-ness. This could be done using an experimental procedure where subjects would be asked to manipulate a certain parameter over which they have control, to match stimuli which would vary along another parameter. For example, subjects might manipulate the duration of the vowel in a V + C unit, to match stimuli where the amplitude of V varied. This might yield a mapping of the correlation between vowel amplitude and duration. Similarly one could hope to quantify correlations between other sub elements of V-ness or C-ness, such as Aspiration amplitude and duration for example, or Vowel duration and voicing during the stop closure. This approach might also be one way of further investigating the relationship between Aspiration Amplitude and Closure Duration, and thus perhaps shed some light on the more puzzling aspects of the interaction of these two elements in the results of Experiment 3.

CONCLUSION

In this conclusion, some of the main findings of this study will be summarised, and areas indicated where future investigation might proceed.

The degree of preaspiration found in the languages looked at ranges on a kind of continuum. Icelandic and the Scottish-Gaelic dialects from the C1 area (e.g. Harris) have the longest preaspiration durations; Irish has the least. Lewis Gaelic falls somewhere in between these two.

Across languages, there is generally an inverse correlation between the extent to which vocal-fold vibration persists into the lenis stop, and the duration of preaspiration of the fortis. A number of other potential correlates of the phonological opposition were also looked at (durational features 1,2,4,5 and 6) ; here also it seems to be the case that languages or dialects with the least preaspiration (e.g. Irish) use the greatest degree of these other temporal features.

The characteristics of oppositions with preaspiration have been described, as well as the difference between pre- and postaspiration. Preaspiration durations are frequently considerably longer than postaspiration. Across languages, however, (if one restricts comparison to preaspiration in VC# and to postaspiration in #CV), there is greater variability in preaspiration values. Rather than the compact range described for postaspiration duration by Lisker and Abramson (1964), preaspiration values vary fairly continuously over a much wider range of values. Preaspiration values also show considerable conditioning from the phonological length of a preceding vowel, and are never very long with long vowels. Vowel length conditioning of postaspiration values is usually very slight and fairly inconsistent. Generally, separation of the fortis and lenis stop categories is better at voice offset than at voice onset.

Preaspiration, like postaspiration, shows considerable positional variation, with values being shorter in medial than in final position. Environments with relatively less stress yield rather a dramatic shortening of preaspiration duration.

One important difference between pre- and postaspiration would seem to be that voice offset is characterised by a slow, breathy-voiced transition from voice to voicelessness. Insofar as one can deduce from the production data, this transition is an unavoidable artefact, resulting from the fact that the elastic mass of the vocal-folds is in vibration, and that the supraglottal tract is open. It was found that in those environments where preaspiration was of short duration, the shortening was reflected in the voiceless portion of preaspiration rather than in the breathy voiced transition. Thus, for example, in relatively unstressed environments (as defined in Chapter 3) preaspiration may consist of little more than the breathy voiced transition.

The question of how voicelessness and aspiration (pre- and post-) are laryngeally controlled was also broached. Electroglottographic data for stops at different stress levels were considered in the light of two possible models of glottal control. One proposes that the degree of glottal opening is directly controlled during the stop, and specifically at oral release. The other proposes that control is exerted basically by means of the timing of the glottal gesture. The data presented suggest that although there are differences in the timing of the glottal gesture (as between preaspirated, unaspirated or postaspirated stops) the control of glottal amplitude (specifically at stop closure and release) may constitute a crucial articulatory target. Furthermore, it seems likely that the glottal gesture is finely tuned to the prevailing aerodynamic conditions.

Experiments were carried out on the perception of preaspiration. The duration of preaspiration required to cue a preaspirated stop is not in fact very long for the languages/dialects with long preaspiration values in production (e.g. Icelandic and Harris Gaelic). VOFFT boundaries (i.e. the 50% crossover point) are at very similar durations to those described in the literature for VOT boundaries. This may seem surprising given that in production, preaspiration values are considerably longer than postaspiration values. For Lewis, where preaspiration durations in production are of shorter duration, VOFFT boundaries are at even shorter durations of aspiration; for these dialects, it looks as if voicing of the lenis stop may be important to the distinction.

The perceptual importance of this breathy voiced transition was also investigated, and found to be highly relevant to the perception of the preaspirated stop. Stimuli which have all of the breathy-voiced transition intact were overwhelmingly accepted as preaspirated. Furthermore, the presence of the breathy-voiced transition seems to contribute greatly to the naturalness and acceptability of the stimuli. In an experiment where stimuli with the breathy-voiced transition were mixed with stimuli without the breathy-voiced transition, there was a rather high rejection rate for the latter.

These findings have a number of implications. As was mentioned above, the presence of any preaspiration in Irish is rather a surprise finding for anyone acquainted with traditional descriptions of the phonetics of Irish, where mention has always been of a contrast involving voicing and postaspiration. It is quite possible that similar amounts of preaspiration, or at the very least, a breathy voiced transition to a following voiceless consonant, may characterise other languages described as having an opposition involving voicing/postaspiration. Given the perceptual importance of even a very short interval of preaspiration, and given, indeed, the perceptual importance that attaches to the breathy voiced transition, it seems probable that the voice offset patterns of other languages would be worth similar investigation. This observation gains further support from recent experimental findings by O Kane (1978), which suggest that the very last portion of the offset of the vowel preceding a voiceless consonant may be perceptually very important.

Furthermore, subjects' responses to stimuli without the breathy voiced transition, as compared to stimuli with the breathy voiced transition, suggest that the naturalness and acceptability of synthetic speech might be enhanced by paying more attention to the transition from voice to voicelessness. This would be relevant, for example, to vowel offsets in V#; perhaps also to the transition from vowel to voiceless consonants such as fricatives; and, of course, to the transition from vowel to voiceless stop, where such breathy voiced transitions are found in production.

Diachronic aspects of preaspirating oppositions were looked at. In the languages of this study, the stops in question derive from a historical opposition of voiced and voiceless geminates. An account of the evolution of the contrasts in these languages is proposed. This account suggests that the old opposition of voiced and voiceless geminates was, in production terms, unstable, and that the voiced geminate would have been prone to devoicing. Devoicing of the voiced geminate would in time have triggered the development of preaspiration in the voiceless one, simply as a means of maintaining the opposition. Support for this account comes not only from what is known about the aerodynamic constraints on voicing, but also from the correlation observed in Chapter 2 between the degree to which voicing has been lost in the lenis series and the extent of preaspiration of the fortis for these languages.

The descriptive base of this study could be broadened in a way which would further elucidate the account proposed for the evolution of preaspiration. For example, in the dialects of Irish for which stops of long duration have been described, it would be interesting to assertain to what extent these stops might exhibit some of the tendencies suggested here to underlie the development of preaspiration. Similarly, research on the stop oppositions of Breton (which retains the geminates of Proto-Celtic) and of the "preaspirating" dialects of Norwegian should yield further insight into the development of preaspiration, and form an appropriate extension of this study.

The more general question of the direction of language change in relation to phonological "voicing" contrasts was discussed, and a preliminary schema proposed as to what the phonetic motivation for such change might be. One aspect of this schema suggests that rapidly spoken relatively unstressed syllables (in the sense defined in Chapter 3) may produce lenited variants which in time may become the dominant allophones.

The final part of the thesis is concerned with the perception of phonological "voicing" oppositions. The question is considered as to how the listener handles the multiplicity of seemingly relevant cues - a question which is pertinent to the perception of linguistic contrasts generally. An hypothesis is proposed to the effect that, rather than separate monitoring of disparate cues, detection of the opposition may involve the task of judging the relative ratios of two superordinate features in a syllable sized unit. The numerous, and seemingly disparate cues may, instead, be seen as forming part of these superordinate features; their status as "separate" cues may, to a large extent, be an artifact of an excessively segmental perspective.

The two superordinate features have been termed V-ness and C-ness, and correspond as a first approximation to the periodic and aperiodic portions of the syllable, but weighted in such a way as to take account of the acoustic nature and level of the signal. The hypothesis implies that the elements of V-ness or of C-ness function in an additive fashion. Thus, for example, an increase in the duration or level of an element of C-ness will enhance the "voiceless" percept. Empirical support for the hypothesis was obtained from Experiments 1 and 3.

Clearly future research would aim to model more explicitly the way in which the component cues of V-ness and of C-ness interact. For this to be possible, the perceptual data presented here would have to be refined and augmented. As suggested at the end of Chapter 5, a potentially useful approach here would involve the use of an interactive technique, where subjects would maintain perceptual equivalence by adjusting the acoustic value of one cue in response to changes in other cues.

This research was aimed at increasing our understanding of the functioning of contrasts involving preaspiration, and of voicing contrasts. But beyond that it may reasonably be hoped - along with future research along the lines suggested into this specific area of the phonological systems of languages - to contribute to the more adequate modelling within phonetic theory of the functioning of phonological contrasts generally.

Appendix 1

Analysis of variance of data from Experiment 1.

SU = subjects
VE = aspiration level (i.e. voiceless aspiration)
ST = stimuli (with different durations of voiceless aspiration or of breathy voiced transition)
BR = breathy vs. non-breathy
GR = two groups of subjects: 4 and 6 in number

Table 1a

Analysis of variance of responses to breathy stimuli for both groups of subjects.

SOURCE	DF1/ DF2	F	P VALUE	MEAN SQUARE	SUM OF SQ
GR	1/ 8	2.1006	0.1853	9.1013	9.1013
VE	2/ 16	1.4046	0.2741	0.6692	1.3383
GR VE	2/ 16	6.3862	0.0091	3.0423	6.0846
ST	9/ 72	1.9843	0.0535	0.4273	3.8460
GR ST	9/ 72	0.6350	0.7635	0.1368	1.2308
VE ST	18/ 144	1.3522	0.1648	0.3682	6.6278
GR VE ST	18/ 144	1.3633	0.1587	0.3712	6.6822
GR SU	8			4.3326	34.6611
GR SU VE	16			0.4764	7.6222
GR SU ST	72			0.2154	15.5056
GR SU VE ST	144			0.2723	39.2111

Table 1b

Analysis of variance of responses to non-breathy stimuli, both groups of subjects.

SOURCE	DF1/ DF2	F	P VALUE	MEAN SQUARE	SUM OF SQ
GR	1/ 8	133.1550	0.0000	2147.3094	2147.309[illegible]
VE	2/ 16	9.2015	0.0022	24.2338	[illegible]
GR VE	2/ 16	6.4246	0.0090	16.9202	[illegible]
ST	9/ 72	72.4474	0.0000	134.5978	[illegible]
GR ST	9/ 72	33.1191	0.0000	61 5310	[illegible]
VE ST	18/ 144	2.7333	0.0005	3.1746	[illegible]
GR VE ST	18/ 144	2.4253	0.0020	2.8169	[illegible]
GR SU	8			16.1264	[illegible]
GR SU VE	16			2.6337	[illegible]
GR SU ST	72			1.8579	133.7667
GR SU VE ST	144			1.1615	[illegible]

Table 1c

Analysis of variance for Group I (four subjects) responses to non-breathy stimuli.

SOURCE	DF1/ DF2	F	P VALUE	MEAN SQUARE	SUM OF SQ
VE	2/ 6	2.4511	0.1667	2.1583	4.3167
ST	9/ 27	5.1486	0.0004	8.9815	80.8333
VE ST	18/ 54	1.6510	0.0797	1.3620	24.5167
SU	3			19.5222	58.5667
SU VE	6			0.8806	5.2833
SU ST	27			1.7444	47.1000
SU VE ST	54			0.8250	44.5500

Table 1d

Analysis of variance for Group II (six subjects) responses to non-breathy stimuli.

SOURCE	DF1/ DF2	F	P VALUE	MEAN SQUARE	SUM OF SQ
VE	2/ 10	13.0796	0.0016	48.2056	96.4111
ST	9/ 45	120.3000	0.0000	231.6889	2085.2000
VE ST	18/ 90	3.9948	0.0000	5.4463	98.0333
SU	5			14.0889	70.4444
SU VE	10			3.6856	36.8556
SU ST	45			1.9259	86.6667
SU VE ST	90			1.3633	122.7000

Table 1e

Analysis of variance on Group I vs. Group II responses to breathy stimuli (note: entire range of positive and negative values).

SOURCE	DF1/ DF2	F	P VALUE	MEAN SQUARE	SUM OF SQ
GR	1/ 8	3.2089	0.1110	27.4572	27.4572
ST	20/ 160	104.9069	0.0000	166.6802	3333.6048
GR ST	20/ 160	0.7356	0.7848	1.1688	23.3759
GR SU	8			8.5565	68.4524
GR SU ST	160			1.5888	254.2143

Table 1f

Analysis of variance on Group I vs. Group II responses to negative range of breathy stimuli.

SOURCE	DF1/ DF2	F	P VALUE	MEAN SQUARE	SUM OF SQ
GR	1/ 8	1.5583	0.2472	19.4400	19.4400
ST	9/ 72	37.2606	0.0000	95.1526	856.3733
GR ST	9/ 72	0.7437	0.6678	1.8993	17.0933
GR SU	8			12.4750	99.8000
GR SU ST	72			2.5537	183.8667

Table 1g

Analysis of variance on breathy vs. non-breathy stimuli (for both Group I and Group II).

SOURCE	DF1/ DF2	F	P VALUE	MEAN SQUARE	SUM OF SQ
GR	1/ 8	223.0192	0.0000	1218.0099	1218.0099
VE	2/ 16	7.2919	0.0056	8.7085	17.4169
GR VE	2/ 16	13.5786	0.0004	16.2165	32.4331
ST	9/ 72	61.3323	0.0000	73.5917	662.3252
GR ST	9/ 72	24.0384	0.0000	28.8433	259.5895
VE ST	18/ 144	2.6144	0.0008	1.9240	34.6324
GR VE ST	18/ 144	1.9288	0.0177	1.4195	25.5506
BR	1/ 8	351.1184	0.0000	5265.9230	5265.9230
GR BR	1/ 8	62.5700	0.0000	938.3985	938.3985
VE BR	2/ 16	8.4526	0.0031	16.1934	32.3868
GR VE BR	2/ 16	1.9559	0.1738	3.7472	7.4943
ST BR	9/ 72	70.3427	0.0000	61.4332	552.8987
GR ST BR	9/ 72	37.5853	0.0000	32.8248	295.4230
VE ST BR	18/ 144	2.3200	0.0032	1.6189	29.1409
GR VE ST BR	18/ 144	2.5343	0.0012	1.7685	31.8333
GR SU	8			5.4615	43.6917
GR SU VE	16			1.1943	19.1083
GR SU ST	72			1.1999	86.3917
GR SU VE ST	144			0.7359	105.9750
GR SU BR	8			14.9976	119.9806
GR SU VE BR	16			1.9158	30.6528
GR SU ST BR	72			0.8733	62.8806
GR SU VE ST BR	144			0.6978	100.4861

Appendix 2

Settings of parameters for synthesis stimuli of Experiment 2.

APA48V PREASPIRATION SYNTHESIS FOR ALVA DATE: 19-MAR-85 SIGNAL MAX =

GLOBAL PARAMETERS

F4	C/P SW	F GLT RES	B GLT RES	F GLT ZRO	B GLT ZRO	B4	F5	B5	F6	B6	F NSL POL
3940	0	0	100	1500	6000	250	3850	200	4900	1000	250

B NSL POL	B NSL ZRO	F RAD ZRO	SAMP RATE	SAMP/LINE	SCAL AMP	BGLT RES2	NOT USED	NO. CAS FOR	COR SW	NOT USED
100	100	99	10000	50	48	200	0	4	1	0

MSEC	AV	AF	AH	AS	F0	F1	F2	F3	NZ	AN	A1	A2	A3	A4	A5	A6	AB	B1	B2	B3
0.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
5.	15	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
10.	30	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
15.	45	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
20.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
25.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
30.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
35.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
40.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
45.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
50.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
55.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
60.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
65.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
70.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
75.	60	0	0	0	119	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
80.	60	0	0	0	119	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
85.	60	0	0	0	118	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
90.	60	0	0	0	117	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
95.	60	0	0	0	116	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
100.	60	40	60	30	116	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
105.	48	40	60	30	115	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
110.	48	40	60	30	114	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
115.	48	40	60	30	113	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
120.	48	40	60	30	113	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
125.	48	40	60	30	112	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
130.	48	40	60	30	111	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
135.	48	40	60	30	110	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
140.	48	40	60	30	110	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
145.	48	40	60	30	109	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
150.	48	40	60	30	108	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
155.	48	40	60	30	107	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
160.	48	40	40	30	107	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
165.	48	40	20	30	106	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
170.	48	10	10	30	105	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
175.	0	10	10	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
180.	0	10	10	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
185.	0	10	10	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
190.	0	10	10	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
195.	0	10	10	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
200.	0	10	10	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
205.	0	10	10	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
210.	0	10	10	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
215.	0	10	10	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
220.	0	10	10	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
225.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
230.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
235.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
240.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
245.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
250.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
260.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
265.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
270.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	60	300	60	140
275.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
280.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
285.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
290.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
295.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
300.	0	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
305.	0	60	60	0	120	500	900	2200	250	0	0	0	0	0	0	0	60	150	60	140
310.	0	60	60	0	120	580	990	2308	250	0	0	0	0	0	0	0	60	150	60	140
315.	30	0	0	0	120	660	1080	2416	250	0	0	0	0	0	0	0	0	150	60	140
320.	40	0	0	0	120	740	1170	2524	250	0	0	0	0	0	0	0	0	150	60	140
325.	50	0	0	0	120	820	1260	2632	250	0	0	0	0	0	0	0	0	150	60	140
330.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
335.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
340.	60	0	0	0	120	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
345.	60	0	0	0	119	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
350.	60	0	0	0	118	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
355.	60	0	0	0	116	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
360.	60	0	0	0	115	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
365.	60	0	0	0	114	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
370.	60	0	0	0	113	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
375.	30	0	0	0	111	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140
380.	0	0	0	0	110	900	1350	2740	250	0	0	0	0	0	0	0	0	150	60	140

Appendix 3

Analysis of variance on data of Experiment 2.

SU = subjects
ST = stimuli (differing in amplitude of AV parameter)
VE = groupings of stimuli (1 = WeakAsp series; 2 = StrongAsp series)
TE = test run (there were two: one with StrongAsp - S and WeakAsp - S stimuli randomised, the second with StrongAsp + S and WeakAsp - S stimuli randomised)
GR = subject groups (Icelanders = 3; phoneticians = 2)

Table 1a
Analysis of variance on responses of the two subject groups to stimuli

SOURCE	DF1/	DF2	F	P VALUE	MEAN SQUARE	SUM OF SQ
GR	1/	3	1.4719	0.3119	6.8372	6.8372
ST	10/	30	102.8347	0.0000	108.6256	1086.2564
GR ST	10/	30	3.9796	0.0016	4.2038	42.0375
VE	1/	3	2634.8440	0.0000	1966.1525	1966.1525
GR VE	1/	3	25.6652	0.0148	19.1517	19.1517
ST VE	10/	30	41.8493	0.0000	49.5956	495.9559
GR ST VE	10/	30	2.6965	0.0173	3.1957	31.9566
TE	1/	3	0.5757	0.5032	1.4008	1.4008
GR TE	1/	3	14.6618	0.0314	35.6733	35.6733
ST TE	10/	30	0.4288	0.9208	1.3507	13.5074
GR ST TE	10/	30	1.9505	0.0769	6.1435	61.4351
VE TE	1/	3	0.1266	0.7455	1.0370	1.0370
GR VE TE	1/	3	6.7928	0.0799	55.6373	55.6373
ST VE TE	10/	30	0.4306	0.9198	0.8571	8.5713
GR ST VE TE	10/	30	2.2390	0.0431	4.4571	44.5709
GR SU	3				4.6452	13.9356
GR SU ST	30				1.0563	31.6894
GR SU VE	3				0.7462	2.2386
GR SU ST VE	30				1.1851	35.5530
GR SU TE	3				2.4331	7.2992
GR SU ST TE	30				3.1497	94.4924
GR SU VE TE	3				8.1907	24.5720
GR SU ST VE TE	30				1.9907	59.7197

Table 1b
Analysis of variance on responses to StrongAsp stimuli only
(i.e. StrongAsp - S vs. StrongAsp + S)

SOURCE	DF1/	DF2	F	P VALUE	MEAN SQUARE	SUM OF SQ
GR	1/	3	22.0440	0.0183	24.4376	24.4376
ST	10/	30	118.5210	0.0000	143.9013	1439.0126
GR ST	10/	30	5.1569	0.0002	6.2612	62.6120
TE	1/	3	0.0025	0.9632	0.0139	0.0139
GR TE	1/	3	0.1989	0.6859	1.1043	1.1043
ST TE	10/	30	0.1735	0.9970	0.5036	5.0359
GR ST TE	10/	30	0.1221	0.9993	0.3546	3.5457
GR SU	3				1.1086	3.3258
GR SU ST	30				1.2141	36.4242
GR SU TE	3				5.5530	16.6591
GR SU ST TE	30				2.9030	87.0909

Appendix 4

Analysis of variance on data of Experiment 3.

SU = subjects
ST = stimuli (VOFFT continua)
VE = closure durations
TE = aspiration levels
GR = groups (Harris = 5; Lewis = 3)

Table 1a
Analysis of variance on Harris responses.

SOURCE	DF1/	DF2	F	P VALUE	MEAN SQUARE	SUM OF SQ
TE	2/	8	Ø.18Ø6	Ø.8381	Ø.2822	Ø.5644
ST	9/	36	38.2424	Ø.ØØØØ	331.4479	2983.Ø311
TE ST	18/	72	1.Ø956	Ø.3744	1.3835	24.9Ø22
VE	2/	8	24.3418	Ø.ØØØ4	1ØØ.8Ø22	2Ø1.6Ø44
TE VE	4/	16	Ø.87Ø2	Ø.5Ø31	1.1822	4.7289
ST VE	18/	72	3.3519	Ø.ØØØ1	5.5257	99.4622
TE ST VE	36/	144	Ø.896Ø	Ø.6398	Ø.8946	32.2Ø44
SS	4				41.8Ø78	167.2311
SS TE	8				1.5628	12.5Ø22
SS ST	36				8.667Ø	312.Ø133
SS TE ST	72				1.2628	9Ø.92ØØ
SS VE	8				4.1411	33.1289
SS TE VE	16				1.3586	21.7378
SS ST VE	72				1.6485	118.6933
SS TE ST VE	144				Ø.9984	143.77[illegible]3

Table 1b
Analysis of variance on Lewis responses.

SOURCE	DF1/	DF2	F	P VALUE	MEAN SQUARE	SUM OF SQ
TE	2/	4	1.ØØ8Ø	Ø.4421	Ø.7ØØØ	1.4ØØ[illegible]
ST	9/	18	7Ø.Ø149	Ø.ØØØØ	75.23ØØ	677.Ø7[illegible]
TE ST	18/	36	3.6Ø4Ø	Ø.ØØØ5	1.[illegible]912	26[illegible]3
VE	2/	4	19.[illegible]921	Ø.ØØ[illegible]8	4[illegible].[illegible]ØØØ	86.[illegible]
TE VE	4/	8	Ø.8155	Ø.5496	Ø.2333	Ø.9[illegible]3[illegible]
ST VE	18/	36	7.6ØØ4	Ø.ØØØØ	4.7979	86.3[illegible]Ø
TE ST VE	36/	72	1.5631	Ø.Ø542	Ø.9844	35.4[illegible]7Ø
SS	2				14.1444	28.[illegible]89
SS TE	4				Ø.6944	2.7[illegible]7[illegible]
SS ST	18				1.Ø745	19.34[illegible]
SS TE ST	36				Ø.4146	14.925[illegible]
SS VE	4				2.2444	8.977[illegible]
SS TE VE	8				Ø.2861	2.[illegible]
SS ST VE	36				Ø.6313	22.[illegible]
SS TE ST VE	72				Ø.6297	45.[illegible]

BIBLIOGRAPHY

Abbs, J.H. & Sussman, H.M. (1971). Neurophysiological feature detectors and speech perception: a discussion of theoretical implications. Journal of Speech and Hearing Research 14, 23-36.

Abramson, A.S. & Lisker, L. (1970). Discriminibility along the voicing continuum: cross-language tests. Proceedings of the 6th International Congress of Phonetic Sciences,569-573. Prague: Academia.

Abramson, A.S. & Lisker, L. (1983). Relative power of cues: Fo shift versus voice onset time. In A. Cohen & M.P.R.v.d.Broeke (eds.), Abstracts of the Tenth International Congress of Phonetic Sciences, 505. Dordecht Holland: Foris Publications.

Al-Bamerni, A. (1983). Oral, Velic and Laryngeal Coarticulation Across Languages. Unpublished D.Phil thesis, University of Oxford.

Allen, W.S. (1973). Accent and rythm,prosodic features of Latin and Greek. Cambridge University Press.

Andersen, P. (1981). The effect of increased speaking rate and (intended) loudness on the glottal behaviour in stop consonant production as exemplified by Danish p. Annual Report of the Institute of Phonetics, University of Copenhagen 15, 103-146.

Anderson, J. & Ewen, C.J. (1980). Introduction; a sketch of dependency phonology. In J. Anderson and C.J. Ewen (eds.), Studies in Dependency Phonology. Ludwigsburg Studies in Language and Linguistics, 4.

Anthony, J.K.F. (1982). Breathing and Speaking: The Modification of Respiration for Speech. Unpublished Ph.D. thesis, University of Edinburgh.

Árnason, K. (1978) Preaspiration in modern Icelandic: phonetics and phonology. Sjötiu Ritgerðir.

Árnason, K. (1978). Palatalisation in Modern Icelandic: a case for historicism in synchronic linguistics. Lingua 46, 185-203.

Árnason, K. (1980). Quantity in historical phonology. Cambridge University Press.

Bauer, L. (1982). What is lenition? Manuscript.

Bell-Berti, F. (1973). The velopharyngeal mechanism: an electromygraphic study. Status Report on Speech Research, Haskins Laboratories, Supplement.

Bell-Berti, F. (1975). Control of pharyngeal cavity size for English voiced and voiceless stops. Journal of the Acoustical Society of America 57, 456-464.

Benediktsson, H. (1963).. The non-uniqueness of phonemic solutions: quantity and stress in Icelandic..Phonetica 10, 133-53.

Benediktsson, H. (1961-1962). Icelandic dialectology: methods and results. Islenzk Tunga III, Reykjavík.

Bergsveinsson S. (1941). Grundfragen der isländischen Satzphonetik. Berlin: Metten.

Bjarnason, O., Bjarnason, V., Edwards, J.H., Fridriksson, S., Magnusson, M., Mourant, A.. and Tiffs, D. (1973). The blood groups Icelanders, Annals of Human Genetics 36, 425-458, London: Cambridge University Press.

Bolinger, D. (1968). Aspects of Language New York: Harcourt, Brace & World Inc.

Borgstrøm, C.H. (1940). The Dialects of the Outer Hebrides: A Linguistic Survey of the Gaelic Dialects of Scotland 1. (Norsk Tidsskrift for Sprogvidenskap, Supplementary Vol. 1.)

Borgstrøm, C.H. (1941). The Dialects of Skye and Ross-shire: A Linguistic Survey of the Gaelic Dialects of Scotland 2. (Norsk Tidsskrift for Sprogvidenskap, Supplementary Vol. 2).

Borgstrøm, C.H. (1974). On the influence of Norse on Scottish Gaelic. Lochlann6,91-103. (Norsk Tidsskrift for Sprogvidenskap, Supplementary Vol. 11.)

Carminati, M.N., (1984). The Voicing Contrast in Italian Medial Single and Geminate Stops. Cambridge Papers in Phonetics and Experimental Linguistics 3.

Carramazza, A., Yeni-Komshian, G., Zurif, E. & Carbone, E. (1973). The acquisition of a new phonological contract: the case of stop consonants in French-English bilinguals. Journal of the Acoustical Society of America 54, 421-428.

Carramazza, A. & Yeni-Komshian, G. (1974). Voice onset time in two French dialects. Journal of Phonetics 2, 239-245.

Catford, J.C. (1977). Fundamental Problems in Phonetics. Edinburgh University Press.

Chapman, K.G. (1962). Icelandic-Norwegian Linguistic Relationships. (Norsk Tidsskrift for Sprogvidenskap, Supplementary Vol. 7), Universitetsforlaget: Oslo.

Chomsky, N. (1964). Current issues in linguistic theory. In Fodor and Katz (eds.), The Structure of Language, Readings in the Philosophy of Language. Eaglewood Cliffs, New Jersey : Prentice Hall.

Cole, R.A. & Cooper, W.E. (1975). Perception of voicing in English affricates and fricatives. Journal of the Acoustical Society of America 58, 1280-1287.

Daniloff, R.G. (1973). Normal articulation processes. In Minifie, Hixon and Williams (eds.), Normal Aspects of Speech, Hearing and Language. Eaglewood Cliffs, New Jersey : Prentice Hall.

Daniloff, R.G., Schuckers, G., and Feth, L. (1980). The Physiology of Speech and Hearing: an Introduction. Enylewood Cliffs, New Jersey: Prentice Hall, Inc.

Darwin, C.J. & Pearson, M. (1982). What tells us when voicing has started? Speech Communication 1, 29-44.

Denes, P. (1955). Effect of duration on the perception of voicing. Journal of the Acoustical Society of America 27, 761-764.

Dorian, N. (1978). East Sutherland Gaelic. Dublin: Dublin Institute for Advanced Studies.

Eilers, R.E., Gavin, W. & Wilson, W.R. (1979). Linguistic experience and phonemic perception in infancy: a cross-linguistic study. Child Development 50, 14-18.

Eimas, P.D. (1975). Speech perception in early infancy. In L.B. Cohen and P. Salapatek (eds.), Infant Perception. New York: Academic Press.

Eimas P.D. and Corbitt J.D. (1973). Selective adaption of linguistic feature detectors. Cognitive Psychology 4, 99-109.

Eimas, P.D. & Miller, J.L. (1978). Effects of selective adaption on the perception of speech and visual patterns: evidence for feature detectors. In R.D. Walk & H.L. Pick, Jr. (eds) Perception and Experience. New York: Plenum.

Einarsson, S. (1945). Icelandic: grammar, texts, glossary. Baltimore: Johns Hopkins Press.

Engstrand, O. and Nordstrand, L. (1984). A new phonetic interpretation of /h/ in Swedish. Journal of Phonetics 12/3, 195-207.

Fischer-Jørgensen, E. (1968). Voicing, tenseness and aspiration in stop consonants, with special reference to French and Danish. Annual Report of the Institute of Phonetics, University of Copenhagen 3, 63-114.

Fischer-Jørgensen, E., and Hutters, B. (1981). Unaspirated stop consonants before low vowels, a problem of delimitation - its causes and consequences. Annual Report of the Institute of Phonetics, University of Copenhagen 15, 77-103.

Foley, J. (1977). Foundations of Theoretical Phonology. Cambridge University Press.

Fowler, C. (1980). Coarticulation and theories of extrinsic timing. Journal of Phonetics 8, 113-133.

Fujimura, O. (1977). Physiological functions of the larynx in phonetic control . Paper presented at the International Congress of Phonetic Sciences, Miami.

Garnes, S. (1976). Quantity in Icelandic: production and perception. (Hamburger phonetische Beitrage, 18.) Hamburg: Buske Verlag.

Gay, T. (1978). Effective speaking rate on vowel formant movements. Journal of the Acoustical Society of America 63, 223-230.

Gay, T. & Hirose, H. (1973). Effective speaking rate on labial consonant production combined electromyographic / high speed motion picture study. Phonetica 27/1, 44-56.

Gay, T., Ushiyima T., Hirose, H. & Cooper, F.S. (1974). Effect of speaking rate on labial consonant-vowel articulation. Journal of Phonetics 2/1, 47-63.

Goodwin, H. B. (1905). Det moderna isländska ljudsystemet. Svenska Landsmal ock Svenskt Folklif, 99-113.

Goodwin, H. B. (1908). Utkast till systematisk framställning av det moderna isländska uttalet. Svenska Landsmal ock Svensk Folkliv, 77-115.

Greene, D. (1956). Gemination. Celtica 3, 284-289.

Grunwell, P. (1982). Clinical Phonology. Croom Helm Ltd., London.

Haggard, M.P., Ambler, S. & Callow M. (1970). Pitch as a voice cue. Journal of the Acoustical Society of America 47, 613-617.

Han, M.S. & Weitzman, R.S. (1970). Acoustic features of Korean /P,T,K/, /p,t,k,/ and /ph,th,kh/. Phonetica 22, 112-128.

Hardcastle, W.J. (1973). Some observations on the tense-lax distinction in initial stops in Korean. Journal of Phonetics 1, 263-272.

Haugen, E. (1958). The phonemics of Modern Icelandic. Language 34, 55-88.

Haugen, E. (1976). The Scandinavian Languages. London: Faber and Faber Limited.

Haugen, E. (1982). Scandinavian Language Structures: a comparative historical survey Tübingen: Max Niemeyer Verlag.

Healy, A.F. & Repp, B.F. (1982). Context-independence and phonetic mediation in categorical perception. Journal of Experimental Psychology: Human Perception and Performance 8/1, 68-80.

Holmer, N. (1957). The Gaelic of Arran. Dublin: Dublin Institute for Advanced Studies.

Hirose, H. & Gay, T. (1972). The activity of the intrinsic laryngeal muscles in voicing control. Phonetica 25, 140-164.

Hirose, H. & Ushijima, T. (1978). Laryngeal control for voicing distinction in Japanese consonant production. Phonetica 35, 1-10.

Hirsh, I.J. (1959). Auditory perception of temporal order. Journal of the Acoustical Society of America 31, 759-767.

Hombert, J.-M. (1978). Consonant types, vowel quality, and tone. In V.A. Fromkin (ed.), Tone: a linguistic survey. New York: Academic Press.

Hübel, D.H. & Wiesel, T.N. (1962). Receptive fields, binocular interaction and functional architecture in the cat's visual cortex. Journal of Physiology 160, 106-154.

Jackson, K. (1951). Common Gaelic: The evolution of the Goedelic languages. Proceedings of the British Academy 37, 71-97. Geoffrey Camberlege, London.

Javkin, H.J. (1979). The perceptual basis of vowel duration differences associated with the voiced/voiceless distinction. Report of the Phonological Laboratory, Berkeley 4, 52-66.

Johnson, I., and Nolan, F.N. (1981). VOT in German. Unpublished paper, Cambridge University Linguistics Department.

Keating, P. (1983 a). Physiological effects on stop consonant voicing. Paper presented at ASA meeting, May 1983, Cincinnati.

Keating, P. (1983 b). Universal phonetics and the organization of grammars. Unpublished paper.

Keating, P., Linker, W., and Huffman, M. (1983). Patterns in allophone distinction for voiced and voiceless stops. Journal of Phonetics 11, 277-290.

Kim, C. (1970). A Theory of Aspiration. Phonetica 21, 107-116.

Klatt, D.H. (1975). Vowel lengthening is syntactically determined in a connected discourse. Journal of Phonetics 3, 129-140.

Klatt, D. (1979). Segmental durations in English sentences. In B. Lindblom and S. Ohman, (eds.) Frontiers of Speech Communication Research. New York: Academic Press.

Klatt, D.H. (1980). Software for a cascade/parallel formant synthesizer. Journal of the Acoustical Society of America 67/3, 971-995.

Kohler, K.J. (1979). Dimensions in the perception of fortis and lenis plosives. Phonetica 36, 332-343.

Kohler, K.J. (1981). Contrastive phonology and the acquisition of phonetic skills. Phonetica 38, 213-226.

Kuehn D.P., and Moll K.L. (1976). A Cineradiographic study of VC and CV articulatory velocities. Journal of Phonetics 4, 303-320.

Kuhl, P.K. (1979). The perception of speech in early infancy. In N.J. Lass (ed.), Speech and Language, Vol. 1. New York: Academic Press.

Kuhl, P.K. (1982). Speech perception: an overview of current issues. In N.J. Lass, L.V. McReynolds, J.L. Northern and D.E. Yoder (eds.), Speech, Language and Hearing, Vol. 1. Philadelphia: W.B. Saunders.

Kuhl, P.K. & Miller, J. (1978). Speech perception by the chinchilla: identification functions for synthetic VOT stimuli. Journal of the Acoustical Society of America 63, 905-917.

Ladefoged, P. (1967). Three Areas of Experimental Phonetics. Oxford University Press.

Ladefoged, P. (1972). The features of the larynx. Journal of Phonetics 1, 74-83.

Ladefoged, P., Draper, M.H. & Whitteridge, D. (1958). Syllables and stress. Miscellanea Phonetica 3, 1-14.

Lass, R. (1984). Phonology. Cambridge: Cambridge University Press.

Lass, R. and Anderson, J.M. (1975). Old English Phonology. Cambridge University Press.

Lehiste, I. (1970). Suprasegmentals. Cambridge: MIT Press.

Lettvin, J.Y., Maturana, H.R., McCulloch, W.S. & Pitts, W.H. (1959). What the frog's eye tells the frog's brain. Proceedings of the IRE 47, 1940-1951.

Liberman, A. (1971) The voiceless vowel in Lapp again. Science in Iceland 2, 37-42.

Liberman, A. (1972). Sidelight on Icelandic and Scandanavian preaspiration. Travaux de l'Institut de Phonétique de Strasbourg 4, 1-17.

Liberman, A. (1982). The Scandinavian Languages. Minneapolis: University of Minnesota Press.

Liberman, A., Harris, K.S., Eimas, P., Lisker, L. & Bastian J. (1961). An effect of learning on speech perception: the discrimination of durations of silence with and without phonemic significance. Language and Speech 5, 175-195.

Lindblom, B. (1963). A spectrographic study of vowel reduction. Journal of the Acoustical Society of America 34, 1773-1781.

Lindblom, B. (1978). Phonetic aspects of linguistic explanation. Studia Linguistica 32, 1/2, 137-153.

Lindblom, B. (1983). Economy of speech gestures. In MacNeilage (ed.) The Production of Speech. New York: Springer Verlag.

Lisker, L. (1957). Closure duration and the intervocalic voiced-voiceless distinction in English. Language 33, 42-49.

Lisker, L. (1975). Is it VOT or a first formal detector? Journal of the Acoustical Society of America 57, 1547-1551.

Lisker, L. (1978). Rapid vs. Rabid: a catalogue of acoustic features that may cue the distinction. Haskins Laboratory Status Report 54, 127-132.

Lisker, L. and Abramson, A. (1964). A cross-language study of voicing in initial stops: acoustical measurements. Word 20, 384-422.

Lisker, L. and Abramson, A. (1967). Some effects of context on voice onset time in English stops. Language and Speech 10, 1-28.

Lisker, L. and Abramson, A. (1970). The voicing dimension: some experiments in comparative phonetics. Proceedings of the Sixth International Congress of Phonetic Sciences, 563-567. Prague: Academia, 563-567.

Löfqvist, A. (1976). Closure duration and aspiration for Swedish stops. Working Papers, Phonetics Lab, Department of General Linguistics, Lund University 13, 1-39.

Löfqvist, A. (1980). Interarticulator programming in stop production. Journal of Phonetics 8, 475-490.

Löfqvist, A., Baer, T., and Yoshioka, H. (1981). Scaling of glottal opening. Phonetica 38, 265-276.

Löfqvist, A. and Yoshioka, H. (1981a). Laryngeal activity in Icelandic obstruent production. Nordic Journal of Linguistics 4, 1-18.

Löfqvist, A., and Yoshioka, H. (1981b). Interarticulator programming in obstruent production. Phonetica 38, 21-34.

Maddieson, I. (1984). Patterns of Sounds. Cambridge: Cambridge University Press.

Malone, K. (1952). The phonemes of Modern Icelandic. In Studies in honour of Albert Morey Sturtevant. Lawrence: University of Kansas Press.

Marstrander, C. (1915). Bidrag Til det Norske Sprogs Historie i Irland. Oslo: Kristiania.

Marstrander, C. (1932). Okklusiver og substrater. Norsk Tidsskrift for Sprogvidenskap.

Massaro, D.M. & Cohen, M.M. (1976). The contribution of voice onset time and fundamental frequency as cues to the /zi/-/si/ distinction. Journal of the Acoustical Society of America 61:3, 704-717.

Miller, J.D., Weir, C.C., Pastore, R.E., Kelly, W.J. and Dooling, R.J. (1976). Discrimination and labeling of noise-buzz sequences with varying noise lead times. Journal of the Acoustical Society of America 60, 410-417.

Norwegian Archeological Review, vol.10 (1972) and vol.11 (1973).

Ní Chasaide, A. (1977). The Laterals of Donegal Irish and of Hiberno-English. Unpublished M.A. thesis. University College of North Wales, Bangor.

Ní Chasaide, A. (1979). Laterals in Gaoth-Dobhair Irish and Hiberno-English. Papers in Celtic Phonology. Occasional Papers in Linguistics and Language Learning 6, 54-79. Coleraine: N.U.U.

Ó Baoill, D. (1980). Preaspiration, epenthesis and vowel lengthening - interrelated and of similar origin? Celtica 13.

Ó Dochartaigh, C. (1979). Dialect differentiation in the Irish of Ulster. Unpublished Ph.D. thesis, University of Aberdeen.

Oftedal, M. (1947). Jaerske Okklusivar. Norsk Tidsskrift for Sprogvidenskap 14, 229-235.

Oftedal. (1956). The Gaelic of Leurbost, Isle of Lewis. Linguistic Survey of the Gaelic Dialects of Scotland 3. (Norsk Tidsskrift for Sprogvidenskap, Supplementary Vol. 4.)

Oftedal, M. (1947). On the frequency of Norse loanwords in Scottish Gaelic. Scottish Gaelic Studies 9, 116-127.

Ohala, J. (1974). Phonetic Explanation in Phonology. In A. Bruck, R.A. Fox, & M.W. La Galy (eds.), Papers from the parasession on Natural Phonology. Chicago Linguistic Society, Chicago.

Ohala, J. (1983). The origin of sound patterns in vocal tract constraints. In MacNeilage (ed.) The Production of Speech. New York: Springer Verlag.

Ó Kane, D. (1978). Manner of vowel termination as a perceptual cue to the voicing status of postvocalic stop consonants. Journal of Phonetics 6, 311-318.

Oller, D.K. (1973). The effect of position in utterance on speech segment duration in English. Journal of the Acoustical Society of America 54, 1235-1247.

Pastore, R.E. (1981). Possible psychoacoustic factors in speech. In P.D. Eimas and J.L. Miller (eds.), Perspectives on the Study of Speech. New Jersey: Lawrence Erlbaum Associates.

Pedersen, H. (1897). Aspirationen i Irsk, en Sproghistorisk Undersögelse. Leipzig.

Peterson, G. E. and Lehiste, I. (1969). Duration of syllable nuclei in English. Journal of the Acoustical Society of America 32, 693-703.

Pétursson, M. (1972). La préaspiration en islandais moderne. Examen de sa réalisation phonétique chez deux sujets. Studia Linguistica 26, 61-80.

Pétursson, M. (1974). Les articulations de l'islandais à la lumière de la radiocinématographic. Paris: Librairie C. Klincksieck.

Pickett, J.M. (1980). The Sounds of Speech Communication. Baltimore: University Park Press.

Pind, J.L. (1982). The Perception of Quantity and Preaspiration in Icelandic. Unpublished D.Phil thesis, University of Sussex.

Remez, R.E. (1980). Susceptibility of a stop consonant to adaptation on a speech-nonspeech continuum: further evidence against feature detectors in speech perception. Perception and Psychophysics 27:1, 17-23.

Pisoni, D.B. (1977). Identification and discrimination of the relative onset time of two component tones: implications for voicing perception in stops. Journal of the Acoustical Society of America 61, 1352-1361.

Port, R.F. (1979). Effects of word-internal vs. word-external tempo on the voicing boundary for medial stop closure. Status Report on Speech Research, SR-55/56. New Haven, Conn.:Haskins Laboratories.

Quiggin, E.C. (1906). A Dialect of Donegal. Cambridge University Press.

Raphael, L.J. (1972). Preceding vowel duration as a cue to the perception of the voicing characteristics of word-final consonants in American English. Journal of the Acoustical Society of America 51, 1296-1303.

Raphael, L.J. (1981). Durations and contexts as cues to word-final cognate opposition in English. Phonetica 38, 126-147.

Repp, B.H. (1979). Relative amplitude of aspiration noise as a voicing cue to syllable initial stop consonats. Language & Speech 22, 173-189.

Riordan, C.J. (1980). Larynx height during English stop consonants. Journal of Phonetics 8, 353-360.

Roach, P.J. (1978). Reaction time measurements of laryngeal closure. Phonetics Laboratory University of Reading Work in Progress 2, 1-23.

Rottenberg, M. (1968). The Breath-Stream Dynamics of Simple-Released Plosive Production. Basel: S. Karger.

Ruhlen, M. (1975). A guide to the languages of the world. Stanford.

Santerre, L. and Suen, C.Y. (1981). Why look for a single feature to distinguish stop cognates? Journal of Phonetics 9, 163-175.

Sawashima M, and Hirose H. (1983). Laryngeal gestures in speech production. In P.F. MacNeilage (ed.), The Production of Speech. New York: Springer Verlag.

Scully, C. (1969). Problems in the interpretation of pressure and airflow data in speech. University of Leeds Phonetics Department Report 2, 53-92.

Scully, C. (1974). A synthesiser study of aerodynamic factors in speech segment durations. In G. Fant (ed.), Speech Communication. Proceedings of the Speech Communication Seminar Volume 2, 227-234. Stockholm: Almqvist and Wiksell.

Shuken, C.R. (1980). An Instrumental Investigation of Some Scottish Gaelic Consonants. Unpublished Ph.D. thesis, University of Edinburgh.

Simon, C. & Fourcin, A.J. (1978). Cross-language study of speech pattern learning. Journal of the Acoustical Society of America 63: 925-935.

Simon, H. & Studdert-Kennedy (1978). Selective anchoring and adaptation of phonetic and nonphonetic continua. Journal of the Acoustical Society of America 64, 1338-1357.

Slis, I.H. & Cohen, A. (1969). On the complex regulation of the voiced-voiceless distinction. Language & Speech 12, 80-102 & 137-155.

Snedecor, G.W. and Cochran, W.G. (1971). Statistical Methods. Iowa State University Press.

Sommerfelt, A. (1922). The Dialect of Torr, Co. Donegal. Christiania : Jacob Dybwad.

Sommerfelt, A. (1965). The phonetic structure of the dialect of Torr, Co. Donegal. Lochlann III.

Stevens, K.N. and Blumstein, S.E. (1981). The search for invariant acoustic correlates. In P.D. Eimas and J.L. Miller (eds.) Perspectives on the Study of Speech. New Jersey: Lawrence Erlbaum Associates.

Stevens K.N. and Klatt D. (1974). Role of formant transitions in the voiced-voiceless distinction for stops. Journal of the Acoustical Society of America 55, 653-659.

Streeter, L.A. (1976). Language perception of two month old enfants shows effects of both innate mechanisms and experience. Nature 259, 39-41.

Studdert-Kennedy, M., Liberman, A.M., Harris, K.S., and Cooper, F.S. (1979). Motor theory of speech perception: a reply to Lane's critical review. Psychological Review 77, 234-249.

Summerfield, Q. (1981). Articulatory rate and perceptual constancy in phonetic perception. Journal of Experimental Psychology: Human Perception & Performance 7, 1074-1095.

Summerfield, Q. & Haggard, M. (1974). Perceptual processing of multiple cues and contexts: effects of following vowel upon stop consonant voicing. Journal of Phonetics 2, 279-295.

Sussman, H. (1979). Motor unit discharge patterns during speech: temporal reorganization due to coarticulatory and prosodic events. Proceedings of the 9th International Congress of Phonetic Sciences II, Copenhagen, 365-371.

Sussman, H. and MacNeilage, P. (1978). Motor unit correlates of stress: preliminary observations. Journal of Acoustical Society of America 64, 338-340.

Ternes, E. (1973). The Phonemic Analysis of Scottish Gaelic. (Forum Phoneticum, 1.) Hamburg: Helmut Buske.

Thrainsson, H. (1978). On the phonology of Icelandic preaspiation. Nordic Journal of Linguistics 1, 3-54.

Thurneysen, R. (1946). A Grammar of Old Irish. Dublin: Dublin Institute of Advanced Studies.

Tuller, B., Harris, K.S., and Scott Kelso, J.A. (1982). Stress and rate: differential transformations of articultion. Journal of the Acoustical Society of America 71, 1534-1543.

Tyler, R.S. , Summerfield, Q., Wood, E.J., & Fernnandes, M.A. (1982). Psychoacoustic and phonetic temporal processing in normal and hearing-impaired listeners. Journal of the Acoustical Society of America 72, 740-752.

Uldall, E.T. (1958). 'Vocal cord action in speech'. High-speed film, made at the Photographic Institute of the Federal Intitute of Technology, Zürich, for the Phonetics Department, Edinburgh University.

Umeda, N. (1975). Vowel duration in American English. Journal of the Acoustical Society of America 58, 434-445.

Van Dommelan, W.A. (1983). Parameter interaction in the perception of French plosives. Phonetica 40, 33-62.

Wagner, H. (1959). Gaelige Theilinn. Baile Átha Cliath: Institiúid Ard-Léinn.

Watson, I. (1983). Cues to the voicing conrast: a survey. Cambridge Papers in Phonetics & Experimental Linguistics 2, 1-34.

Weismer, G. (1979). Sensitivity of voice-onset time (VOT) measures to certain segmental features in speech production. Journal of Phonetics 7: 197-204.

Westbury, J.R. (1979). Aspects of the Temporal Control of Voicing in Consonant Clusters in English. Texas Linguistic Forum, Department of Linguistics, 14. Texas.

Westbury, J.F. and Keating, P. (1980). A model of stop consonant voicing and a theory of markedness. Paper presented at the Annual Meeting of the Linguistic Society of America In San Antonio, Texas.

Williams, B.J. (1982). Some problems in the description of stress in modern Welsh. Cambridge Papers in Phonetics and Experimental Linguistics 1.

Williams, L. (1977). The perception of stop-consonant voicing by Spanish-English bilinguals. Perception and Psychophysics 21: 289-297.

Wonnacott, T.H. and Wonnacott, R.J. (1972). Introductory Statistics. Wiley International.

Wyke, B. (1967). Recent advances in the neurology of phonation: phonatory reflex mechanisms in the larynx. British Journal of Communication Disorders 2, 2-14.

Zlatin, M. & Koenigsknecht, R. (1976). Development of the voicing contrast. A comparison of voice onset time values in stop perception and production. Journal of Speech and Hearing Research 19, 92-111.

Appendix 5

The words lists (with English glosses) are given below, on which data sets 1,2 and 13 are based. Details regarding all the other data sets (see Table 1.1, page 96a) are provided where relevant in the text.

Each list contains an inventory of items. Where necessary, individual items appeared a number of times in any recorded list to yield a balance for consonantal places of articulation and environment. Details regarding the total number of tokens obtained in each data set are contained in Table 1.1. The number of tokens represented by individual average values for particular environments are tabulated in the figures which present results.

The items in data sets 2 and 6 were uttered as citation forms. In all the other data sets each item was inserted into a carrier frame. The frames used for initial, medial and final stops in the three languages of this study can be found on page 97. The carier frames used for the additional French data set (13) are included below.

To safeguard against amplitude variations which tend to characterise the beginnings and ends of lists, additional dummy items/phrases were inserted into these positions and subsequently discarded.

DATA SET 1

Icelandic

(i) Initial Stops

pat	:	gesticulation
pár	:	scribble
par	:	couple
pex	:	quarrel
peð	:	pawn
patt	:	stalemate
pest	:	plague
pils	:	skirt
Páll	:	Paul
bál	:	flame
bað	:	bath
bak	:	back
bar	:	bar (unit of weight)
batt	:	to bind (past indicative)
tak	:	grasp
takk	:	thanks
dáð	:	deed
datt	:	to throw (past indicative)
gað	:	unmanly person
gas	:	gas
gekk	:	walk (past indicative)
kaf	:	plunge
kál	:	cabbage
karl	:	man
kann	:	to know (preterite)
kapp	:	zeal

(iii) Final Stops

labb	:	ramble
kvabb	:	begging
happ	:	luck
klapp	:	caress
stapp	:	stamping
hrap	:	fall
skap	:	mood
datt	:	to throw
fat	:	garment
odd	:	to put a point on (present indicative)
vegg	:	wall (oblique case)
egg	:	egg
sekk	:	sack (oblique case)
fékk	:	to take
hrekk	:	a practical joke (oblique case)
lek	:	to leak (present indicative)
drakk	:	to drink (past indicative)
sprakk	:	explode (past indicative)
krögg	:	pinch
lak	:	bed sheet

Icelandic

(ii) Medial Stops

pabba	:	daddy (oblique case)
krabba	:	crab (oblique case)
labba	:	to stroll
kappi	:	ardour (oblique case)
trappan	:	steps
lappa	:	Lapp (oblique case)

happa	:	luck (oblique case)
klappa	:	to chisel
stappa	:	to stamp
papa	:	Irish monk (oblique case)
krapa	:	to plunge
skapa	:	to create,
gaddar	:	spikes
Adda	:	Adda (proper noun)
patta	:	small boy (oblique case)
ata	:	to soil
fata	:	to clothe
skata	:	ray
eggi	:	egg (oblique case)
ekki	:	not
veki	:	to waken
bagga	:	bundle
baggan	:	the bundle
vagga	:	cradle
rakkan	:	the dog (oblique case)
bakka	:	bank (oblique case)
bakkan	:	the bank
vakka	:	to walk to & fro
staka	:	ditty
stakan	:	the ditty
raka	:	rake
haka	:	chin
vaka	:	to wake

Scottish Gaelic

(i) Initial Stops

còrr	:	surplus
pòg	:	kiss
tàmh	:	rest
tòrr	:	heap up
tè	:	slightly fermented
tìm	:	time
càrn	:	cairn
còr	:	music
cèard	:	tinker
gèarr	:	short
bàn	:	white
bòrd	:	table
daoine	:	people
dùinte	:	closed
dìleas	:	loyal
deo	:	breath
gaoth	:	wind
ceart	:	right
peann	:	pen
pailt	:	plentiful
poll	:	hole
taic	:	prop,support
tuil	:	torrent
teas	:	heat
cat	:	cat
cor	:	condition
geall	:	bet
bann	:	belt
boc	:	he goat
damh	:	deer
dean	:	do
gob	:	beak

Scottish Gaelic

(ii) Medial Stops

ròpan	:	rope
bàta	:	boat
còta	:	coat
àite	:	place
ràcan	:	rake
pòca	:	pocket
spìcean	:	spikes
nàbaidh	:	neighbour
Òban	:	Oban
gàdag	:	switch
làidir	:	strong
màgan	:	little paw
pògan	:	little kiss
còigear	:	five people
tapaidh	:	quick
cupan	:	cup
bata	:	stick
aiteas	:	joy
aca	:	at them
mucan	:	pigs
aice	:	at her
muice	:	of a pig
cabach	:	toothless
tobar	:	well
bradan	:	salmon
rodan	:	rat
maide	:	stick
luideach	:	ragged
magadh	:	mocking
aige	:	at him
ligeil	:	allowing
leabaidh	:	bed

(iii) Final Stops

pàp	:	rope
còt	:	cottage
rèit	:	concord
ràc	:	rake
bòc	:	he goat
cèic	:	cake
pìob	:	pipe
lùb	:	stitch
lùib	:	stitch (dative case)
gàd	:	twisted twig
Mòd	:	Mod
sràid	:	street
mhòid	:	Mod (genative)
pòg	:	kiss
pòig	:	kiss (dative)
ceap	:	last
cop	:	foam
slat	:	rod
brot	:	broth
cait	:	cats
poit	:	pot
glac	:	take
cnoc	:	hill
faic	:	see
breab	:	kick
gob	:	beak
ad	:	thou
creid	:	believe
beag	:	small
sluig	:	swallow

DATA SET 2

Scottish Gaelic

(i) Final Stops

ceap	:	(shoemaker's) last
muc	:	pig
mic	:	sons
cat	:	cat
cait	:	cats
pàp	:	pope
ràc	:	rake
cèic	:	cake
spùt	:	spout
rèit	:	agreement
cab	:	indent
mag	:	mock
sluig	:	swallow
gad	:	twisted twig
goid	:	steal
lùb	:	stitch
liùg	:	shout
còig	:	five
gàd	:	pull
rùid	:	rush

(ii) Medial Stops

cupa	:	cup
mucan	:	small pig
lice	:	flag-stone
bata	:	stick
lite	:	porridge
òpar	:	mark of travel
ràcan	:	rake
spìcean	:	spike
bàta	:	boat
àite	:	place
cabach	:	garrulous
magadh	:	mocking
ligeil	:	allow
gadaiche	:	robber
luideach	:	ragged
lùbadh	:	bending
liùgach	:	shouting
còigear	:	five people
gàdag	:	switch
làidir	:	strong

DATA SET 13

French

(i) Initial Stops : These were repeated in the following frame :
" - s'epelle comme ca."

paix	:	peace
baie	:	gulf
tais	:	pillow case
de	:	dice

(ii) Medial Stops : These were repeated in the following frame :
"Dis moi - donc."

pepe	:	granda
bebe	:	baby
peter	:	fart
pede	:	homosexual

(iii) Final Stops : These were repeated in the following frame :
"Dis moi - ."

tape	:	slap
rabe	:	leftovers (coll.)
rate	:	female rat
rade	:	to be left (en rade)

Irish

(i) Initial Stops

páigh	:	pay
báigh	:	rapport
tá	:	is
dá	:	two
cár	:	teeth
gá	:	need
péir	:	pair
b'fhearr	:	would prefer
téigh	:	warm
déa	:	good
carr	:	car
géarr	:	cut
geab	:	chatter
paist'	:	patch
baist	:	baptise
tais	:	damp
d'ais	:	beside you (le d'ais)
cas	:	turn
gas	:	stem
peat'	:	pet
b'ait	:	it was odd
teas	:	heat
deas	:	nice
ceap	:	(shoemaker's) last

(ii) Medial Stops

pápa	:	pope
lában	:	muck
préata	:	potato
bádaí	:	boats
ráca	:	rake
spága	:	big feet
scléipe	:	fun
láibe	:	mud (genitive case)
cráite	:	tormented
sráide	:	street (genitive case)
réice	:	rakish person
spáige	:	big feet (genitive case)
leapa	:	bed (genitive case)
leaba	:	bed
hata	:	hat
fada	:	long
leaca	:	flagstones
laga	:	weak (plural)
cnaipe	:	button
ribe	:	rib
raite	:	used up
faide	:	longer
aice	:	near
laige	:	faint

(iii) Final Stops

páp'	:	pope
cnáb	:	hemp
rát'	:	rate
spád	:	spade
bác	:	bake
spág	:	big foot
cáidhp	:	bonnet
cnáib	:	hemp (genitive case)
Cáit	:	Kate
spáid	:	spade (dative case)
béic	:	shout
spáig	:	big foot (dative case)
cnap	:	heap
geab	:	chatter
brat	:	flag
fad	:	length
cac	:	shit
snag	:	hiccup
cnaip'	:	button
rib'	:	rib
ait	:	peculiar
faid	:	length (dative case)
glaic	:	palm of hand (dative case)
ag	:	at