AN EXPERIMENTAL PHONETIC STUDY OF

SOME ASPECTS OF QATARI ARABIC

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To

the memory of my Father

who always encouraged me to seek knowledge

and

To

my   Mother

who gave me constant moral support

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support throughout my years of study.

Finally, I would like to express my deepest thanks to my family for their consistent support and for tolerating my absence from home.

ABSTRACT

This is an experimental study of some aspects of the phonetics of Qatari Arabic. Mainly, it examines the articulatory and acoustic characteristics of the pharyngealized and pharyngeal consonants and their coarticulatory effects and the factors that influence the temporal variations in vowel duration. The study falls into seven chapters:

Chapter One outlines the sound system of Qatari Arabic. It gives a phonetic description of the vowel and consonant phonemes and their allophones. It also deals with syllable structure and stress rules.

Chapter Two reviews some of the literature on labial, mandibular, linguo-palatal, linguo-pharyngeal, velopharyngeal and pharyngeal coarticulation.

Chapter Three is an electropalatographic investigation of the articulatory properties of the pharyngealized consonants and their coarticulatory effects.

Chapter Four is a spectrographic investigation of the acoustic properties of the pharyngealized consonants and their coarticulatory effects.

Chapter Five examines the articulatory and acoustic characteristics of the pharyngeal consonants and their effect on neighbouring vowels through xeroradiographic, aerodynamic and spectrographic techniques.

Chapter Six presents an electro-aerometric investigation of vowel duration in an attempt to delineate the factors that influence the variations in their timing patterns.

In Chapter Seven the findings of the previous four chapters are summarized and discussed. It also gives some suggestions for further research.

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INTRODUCTION

This study is an experimental investigation of some aspects of Qatari Arabic phonetics. I know of no other phonetic description of the dialect, thus this study is the first attempt to bring Qatari Arabic to the light so that it can take its rightful place in Arabic dialect studies and so that it can be compared or related to Standard Arabic and other varieties of Arabic.

The main concern of the study is to investigate the articulatory and acoustic properties of the emphatic and pharyngeal consonants and their coarticulatory effects, also to examine the temporal variations in vowel duration.

Although the study is primarily a phonetic one, the aspects are investigated within the framework of the synchronic phonology of the dialect.

The dialect investigated is that spoken by educated Qatari speakers in the capital, Doha. The speech of the author and two other male speakers, who were born and brought up in Doha, was the source of the data used in the experiments.

The thesis starts with the sound system of Qatari Arabic, its phonetics and phonology. A review of

some of the vast literature on coarticulation is then given. In particular, some of the literature on labial, mandibular, lingual, velopharyngeal and pharyngeal coarticulation is reviewed.

The articulatory and acoustic characteristics of the pharyngealized or emphatic consonants and their coarticulatory effects are investigated through electropalatography, pneumotachography, spectrography and xeroradiography. The effect of emphasis on neighbouring vowels and consonants and the scope of its anticipatory and perseverative effects are examined.

The articulatory and acoustic nature of the pharyngeal consonants and their effect on neighbouring segments are also examined through xeroradiography and spectrography techniques.

Electro-aerometric investigation of vowel duration is conducted to delineate the factors that cause systematic variations in the timing patterns of the vowels. The factors examined are vowel height, vowel length, voicing characteristics of the consonant following the vowel, its manner and place of articulation, pharyngealization, consonant length, stress, word length and place of the vowel in word structure.

In the last part of the thesis the results of the experiments are discussed and summarized.

It is hoped that this study would provide a further understanding of the complex articulatory and acoustic nature of the pharyngeal and pharyngealized consonants in Arabic. In addition it is hoped that it would shed a glimmer of light on the role of coarticulation in the general theory of speech production and in answering such questions as whether certain spatial and temporal coarticulatory effects are language-particular or language-universal phenomena and whether they are due to mechanical-inertial timing factors or deliberately programmed at a higher neural level.

The transcriptional symbols used are those of the International Phonetic Association. For typographical convenience transcriptional symbols are enclosed in slant brackets through out the study, except where ambiguity between phonological and phonetic interpretation can only be resolved by the explicit use of square brackets to indicate phonetic comment.

CHAPTER ONE

THE SOUND SYSTEM OF QATARI ARABIC

The following is a synchronic descriptive analysis of the phonology and phonetics of Qatari Arabic.

1.1   Syllable Structure

The following are the rules which operate in the phonological system of the dialect.

1.   The syllable nucleus is always composed of a vowel, either short or long.

2.   The syllable always begins with a consonant.

3.   The syllable can be closed or open.

4.   The vowel can be preceded by one, two or three consonants and followed by zero, one or two consonants.

Thus, the structure of the syllable in Qatari Arabic (henceforth throughout the study referred to as QA) can be represented by the following formula:

$$C_{1-3}V(:)C_{0-2}$$

where C represents a consonant phoneme, V a vowel phoneme and : length. The figures indicate the number of C elements that may precede or follow the vowel.

There are twelve different types of syllable patterns in QA. The following examples illustrate these different patterns:

1. CV   /ji/   ´he came´
2. CV: /la:/   ´no´
3. CCV   /´bgara/   ´a cow´
4. CCV: /´gɫa:wa/   ´cats´
5. CVC   /min/   ´from´
6. CV:C /be:t/   ´a house´
7. CVCC /bint/   ´a girl´
8. CCVC /ftal/   ´it became open´
9. CV:CC /ħa:rr/   ´it is hot´
10. CCV:C /flu:s/   ´money´
11. CCCV: /´stra:ħa/ ´a rest´
12. CCCV:C /stri:ħ/ ´have a rest!´

The eleventh and the twelfth types are very rare forms and restrictive as they only occur in word-initial position and the first consonant of the syllable has to be /s/ and the second consonant has to be /t/. See the following table (Figure 1.1) for the distribution of these syllable types in the word structure.

There is a tendency to elide the short unstressed vowel of the first syllable in disyllabic words merging the first and the second syllables into one syllable, e.g.

Syllable type	Free form	Word-inititial	Word-medial	Word-final
CV	ji	´wa-lad	´ma-θa-lan	´war-di
CV:	la:	´sa:-ʕa	ma-´la:-bis	Xal-´la:
CCV	-	´bga-ra	-	-
CCV:	-	´gɫa:-wa	-	-
CVC	min	´min-kum	mad-´ris-tik	´li-bas
CV:C	be:t	´be:t-kum	maɾ-ju:l-lij	mar-´ju:l
CVCC	bint	´bint-kum	-	-
CCVC	ftal	´ftal-law	-	-
CV:CC	ħa:rr	-	-	-
CCV:C	flu:s	´flu:s-ni	-	-
CCCV:	-	´stra:-ħa	-	-
CCCV:C	stri:ħ	-	-	-

Figure 1.1

The distribution of syllable types in the word structure

/ki´ta:b/   >   /kta:b/   ´a book´

/ba´ʕi:d/   >   /bʕi:d/   ´far away´

/ʃi´ʕa:r/   >   /ʃʕa:r/   ´a symbol´

Trisyllabic words are reduced to disyllabic words, e.g.

/´katabat/   >   /´kitbat/   ´she wrote´

/´saʔala/   >   /´siʔal/   ´he asked´

If the second member of a word-final cluster is a sonorant, i.e. /r/, /l/, /m/ or /n/ and the first member is not a sonorant a vowel is sometimes inserted between the two consonant and the cluster is broken, e.g.

/ʔakl/   >   /´ʔakil/   ´food´

/Xamr/   >   /´Xamur/   ´wine´

/laħn/   >.   /´laħin/   ´a melody´

/dʒism/   >   /´dʒisim/   ´a body´

There is a tendency to add an epenthetic short vowel before word-initial consonant clusters in citation forms thus, for example, /kta:b/ will be pronounced [ikta:b], /stʕ i:n/ will be pronounced [istʕi:n]. This epenthetic vowel is usually elided in normal discourse and is phonologically redundant.

In QA, and in Arabic in general, /X/, /ħ/ and /ʕ/ do not occur next to each other in the same root, so they

do not occur within the same word. However, they do
occur next to each other across word boundaries, e.g.

/faX ʕoːd/	´a big trap´
/tiːʕ Xaːɬik/	´obey your uncle´
/ruːħ ʕinda/	´go to him!´
/biːʕ ħaːlik/	´sell yourself!´
/raːħ Xaː ɬij/	´my uncle went´
/faX ħiliw/	´a nice trap´

Words may consist of up to seven syllables though
pentasyllabic, hexasyllabic and heptasyllabic words are
relatively rare, e.g.

monosyllabic	/dars/	´a lesson´
disyllabic	/´jadris/	´he studies´
trisyllabic	/ʔi´darris/	´he teaches´
titrasyllabic	/ʔidar´suːna/	´they teach him´
pentasyllabic	/ʔarustuq´raːɬij/	´aristocrat´
hexasyllabic	/ʔarustuqraː´ɬijji/	´aristocracy´
heptasyllabic	/ʔarustuqraːɬij´jatkum/	´your aristocracy´

1.2   Stress

QA, and Arabic in general, is hypothesized to be a
"stress-timed" language, thus, syllables can be stressed or
unstressed. The following are the rules for placing word

stress or accent in QA:

1. Stress falls on the ultimate syllable if it is long. By a long syllable we mean any syllable which contains a long vowel, a consonant cluster or a geminate, e.g.

/Xal´li:/	´leave it!´
/sa:´fart/	´I travelled´
/si´katt/	´I became silent´

2. If the penult and the antepenult are short (by short syllable we mean any syllable which has a short vowel and zero or one arresting consonant) open syllables of the form CVCVCV(C), stress falls on the antepenult syllable, e.g.

| /´maθalan/ | ´for example´ |
| /´ᵵalaba/ | ´students´ |

3. Otherwise stress falls on the penult syllable, e.g.

/´sikat/	´he became silent´
/mad´risi/	´school´
/tfa:´ragni/	´we became seperated´
/ʕa:r´fitak/	´I know you´
/mustaʃfa´ja:tkum/	´your hospitals´

Stress has no phonological, morphological or syntactical function in Arabic. In the above examples

/ˈsikat/ and /siˈkatt/ the shift of accent from the first to the second syllable is in agreement with the stress rules of the dialect as with the addition of the suffix /t/, indicating first or second person singular, the second syllable of the second word becomes long and thus carries the stress.

1.3 The Consonant System

The consonant system of QA incorporates twenty-nine consonant phonemes: /b, t, d, k, g, q,ʔ, m, n, l, r, f,θ,ð, s, z,ʃ, X, ħ, h, č, dʒ, w, j,ʕ, ṭ, ḷ,ẓ, ṣ/. They are in phonemic opposition in the language, as the following examples show:

/barr/	´desert´
/ṭarr/	´to beg´
/darr/	´to flow copiously´
/karr/	´to attack´
/garr/	´to settle down´
/qarr/	´to forcibly feed´
/marr/	´to pass´
/farr/	´to throw´
/ðarr/	´to sprinkle´
/ẓarr/	´to harm´
/sarr/	´to make happy´
/ṣarr/	´to tie up´

/ʃarr/	´evil´
/Xarr/	´to leak´
/ħarr/	´heat´
/warr/	´to put on the light´
/jarr/	´to pull´
/ti:n/	´figs´
/ƫi:n/	´clay´
/najj/	´raw´
/majj/	´proper name´
/θa:r/	´to rebel´
/ɣa:r/	´sprinkled´
/sa:r/	´to go´
/za:r/	´to visit´
/ra:s/	´a head´
/la:s/	´a type of material´
/Xaƚ/	´vinegar´
/Xal/	´to leave´
/ʔarꝺ/	´ground´
/ʕarꝺ/	´honour´
/habb/	´to blow´
/ħabb/	´to love´
/lak/	´for you´ mas.
/lač/	´for you´ fem.
/ħačči/	´itching´
/ħadʒdʒi/	´pilgrimage´

/p/ seems to have a phonemic status in QA as it contrasts with /b/ in the following minimal pair: /pa:n/ ´betel´ and /ba:n/ ´to appear´. But as it occurs only in few loan words from English as in /pe:p/ ´pipe´, from Persian as in /´pardi/ ´curtain´ and from Urdu as in /pa:n/ ´betel´, we are not going to consider it as a phoneme in the system.

The following chart (Figure 1.3) sets out the consonant phonemes of QA according to their place and manner of articulation. They comprise eight plosives, two nasals, two laterals, one trill, eleven fricatives, two affricates and three approximants. The phonetic symbols used are those of the International Phonetic Association.

1.3.1

The Phonetic Specification of the Consonant Phonemes

All consonant sounds of QA are produced by an egressive pulmonic air-stream. All consonant phonemes occur in all positions in the word, initially, medially and finally, except for the pharyngealized lateral /ɬ/ which does not occur in word-initial position and the glottal stop /ʔ/ which does not occur in word-final position.

1.3.1.a Plosives

	Bilabial	Labio-Dental	Dental	Alveolar	Palato-Alveolar	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosives	b			t d ṭ			k g	q		ʔ
Nasals	m			n						
Laterals				l ɫ						
Trill				r						
Fricatives		f	θ ð ðˤ	s z ṣ				x	ħ	h
Affricates					tʃ dʒ					
Approximants	w					j	w		ʕ	

Figure 1.3

The stop phonemes /b, t, ṭ, d, k, g, q, ʔ/ are realized as follows:

/b/ > [b]: is realized as a voiced bilabial plosive. It is partially or fully devoiced when it is next to a voiceless consonant:

/b/ > [b̥]/ voiceless consonant

Examples:

/sabt/ [sa̰b̥t] ´saturday´

/´bXała/ [´b̥X̰a̰ła̰] ´misers´

It is pharyngealized in the environment of a pharyngealized or an emphatic consonant:

/b/ > [ḅ]/ pharyngealized consonant

Examples:

/´bʕala/ [´ḅʕa̰ła̰] ´an onion´

/baṭ/ [ḅa̰ṭ] ´ducks´

/b/ occurs in all position in the word structure:

Initially /be:t/ ´a house´

Medially /´to:ba/ ´repentance´

/´sabbab/ ´he caused´

Finally /čalb/ ´a dog´

/t/ > [t]: is usually realized as a voiceless apico-laminal denti-alveolar aspirated plosive. It is realized as a dental when it is next to a dental consonant:

/t/ > [t̪]/ dental consonant

Examples:

 /tθu:r/   [ʈθu:r]   ´she rebels´

 /tᶻir/   [ʈᶻir]   ´she sprinkles´

And it is realized as a pharyngealized consonant when it occurs in a pharyngealized environment:

 /t/   >   [ṭ]/ pharyngealized consonant

Examples:

 /ṭᶻir/   [ṭᶻir]   ´she harms´

 /ṣo:t/   [ṣo:ṭ]   ´voice´

/t/ is usually nasally or laterally exploded when it is followed by a nasal or a lateral sound, as in:

 /tna:m/   ´she sleeps´

 /tla:l/   ´hills´

/t/ occurs in all positions in the word structure:

Initially   /ta:b/   ´to repent´

Medially   /mat´ru:s/   ´full´

             /´ñatta/   ´even´

Finally   /bint/   ´girl´

/ṭ/   >   [ṭ] is realized as a pharyngealized voiceless laminal unaspirated plosive. It is usually nasally or laterally exploded when it is followed by a nasal or a lateral consonant, thus:

 /´ṭna:zi/   ´object of ridicule´

/ƚlu:ʕ/   'sprouts of hair'

/t/ occurs in all positions in the word structure:

Initially   /ƚu:l/   'height'

Medially   /'muƚar/   'rain'

                /'baƚƚa/   'duck'

Finally   /Xe:ƚ/   'thread'

/d/   >   [d] is usually realized as a voiced apico-laminal denti-alveolar plosive. It is devoiced when next to a voiceless consonant:

                /d/   >   [d̥]/ voiceless consonant

e.g.   /dfa:f/   [d̥fa:f]   'cloaks'

/d/ is nasally or laterally exploded when followed by a nasal or a lateral consonant, thus:

                /'hudni/   'peace'

                /dla:l/   'coffee pots'

/d/ occurs in all positions in the word structure:

Initially   /dars/   'lesson'

Medially   /'Xadam/   'servants'

                /'baddal/   'he changed'

Finally   /ʕo:d/   'big'

/k/   >   [k] is usually realized as a voiceless aspirated velar plosive. It is laterally or nasally

released when followed by a lateral or nasal consonant, thus:

/ˈʃakli/   ´his shape´

/kna:r/   ´a kind of cherries´

/k/ occurs in all positions in the word structure:

Initially   /ˈku:ra/   ´a ball´

Medially   /makˈsu:r/   ´broken´

                 /ˈñakka/   ´itching´

Finally   /lak/   ´for you´ sing. mas.

/g/   >   [g] is usually realized as a voiced velar plosive. It is partially or fully devoiced when adjacent to a voiceless consonant:

/g/   >   [g̥]/ voicelss consonant

e.g.   /ˈgɬirij/   [ˈg̥ɜrei]   ´Qatari´ mas.

It is laterally or nasally released when followed by a lateral or a nasal consonant:

/gɬu:b/   ´hearts´

/ˈñagni/   ´our right´

/g/ occurs in all positions in the word structure:

Initially   /ga:l/   ´to say´

Medially   /ˈnagzi/   ´a jump´

                 /ˈɬigga/   ´hit him!´

Finally   /ñag/   ´right´

/q/ > [q] or [ʁ]: is realized as a voiceless unaspirated uvular stop or as a voiced uvular fricative as [q] and [ʁ] are in free variation, that is to say that each of them may replace the other in any position in the word or syllable without causing a change in meaning. It occurs in all positions in the word structure:

Initially	/qe:m/	´clouds´
Medially	/fu´qi:r/	´poor´ mas. sing.
	/´ħaqqaq/	´to investigate´
Finally	/ѕamq/	´gum´

/ʔ/ > [ʔ]: is realized as a glottal stop. It occurs only in word-initial and word-medial position but not word-final position:

Initially	/ʔams/	´yesterday´
Medially	/´siʔal/	´to ask´
	/´saʔʔal/	´he asked´ (too many questions)

1.3.b Nasals

The nasal phonemes /m/ and /n/ are realized as follows:

/m/ > [m]: is normally realized as a voiced bilabial nasal. But it is pharyngealized in the environment of a pharyngealized consonant:

/m/ > [m̴]/ pharyngealized consonant

e.g.   /ɫma:m/   [ɫma:m̥]   ´roof´

It is devoiced next to a voiceless consonant:

          /m/   >   [m̥]/ voiceless consonant

e.g.   /ʔam´θa:l/   [ʔam̥´θa:l]   ´examples´

And   it   becomes   a   labiodental   nasal   next   to   the labiodental fricative /f/:

          /m/   >   [ɱ]/ labiodental consonant

e.g.   /mfa:rig/   [ɱfa:rig]   ´leaver´

/m/ occurs in all positions in the word structure:

Initially   /mo:t/   ´death´

Medially   /´Xamur/   ´wine´

               /´Xammar/   ´to ferment´

Finally   /simm/   ´poison´

     /n/   >   [n]:   is   usually   realized   as   a   voiced apico-alveolar nasal.   But it is realized as a dental when adjacent to a dental consonant:

          /n/   >   [n̪]/ dental consonant

e.g.   /ʔin´ɣa:r/   [ʔin̪´ɣa:r]   ´warning´

And it is realized as a velar when adjacent to a velar consonant:

          /n/   >   [ŋ]/ velar consonant

e.g.   /ngu:m/   [ŋgu:m]   ´we get up´

       /´minkum/   [miŋkum]   ´from you´ pl.

It is devoiced when adjacent to a voiceless consonant:

        /n/   >   [n̥]/   voiceless   consonant   e.g

/nfa:X/   [n̥fa:X]   ʿswellʿ

It is pharyngealized in the neighbourhood of a pharyngealized consonant:

       /n/   >   [ɳ]/ pharyngealized consonant

e.g   /ˈṭna:zi/   [ˈṭṇạ:zʐ]   ʿobject of ridiculeʿ

     /naṭ/   [ṇạṭ]   ʿto jumpʿ

/n/ occurs in all positions in the word structure

Initially   /no:m/   ʿsleepʿ

Medially   /manˈθu:r/   ʿscatteredʿ

          /ˈXinni/   ʿperfumeʿ

Finally   /lo:n/   ʿcolourʿ

/n/ is assimilated to [m] when it is next to the bilabial stop /b/:

       /n/   >   [m]/ bilabial stop

e.g.   /janb/   [jamb]   ʿbodyʿ

     /ˈʕanbar/ [ˈʕambar] ʿambergrisʿ

Although the nasal consonants /n/ and /m/ are syllable marginal entities at the phonological level, phonetically they can be realized as syllabic consonants or as pre-nasals beginning to the following oral stops when preceding them, thus /ndu:r/ ʿwe turn aroundʿ can be realized as [ⁿdu:r] or [ṇdu:r].

1.3.1.c Laterals

The lateral phonemes /l/ and /ɫ/ are realized as follows:

/l/ > [l]: is usually realized as a voiced apico-alveolar lateral. It is partially or fully devoiced when adjacent to a voiceless consonant:

        /l/ > [l̥]/ voiceless consonant

e.g.   /tla:l/   [tl̥ɑːl]   ´hills´

It is realized as a dental when adjacent to a dental consonant:

        /l/ > [l̪]/ dental consonant

e.g.   /lθa:m/   [l̪θa:m]   ´veil´

And it is pharyngealized in the context of a pharyngealized consonant:

        /l/ > [ɫ]/ pharyngealized consonant

e.g.   /sˤalˤtˤ/   [sˤɑɫ]   ´pray!´

/l/ occurs in all positions in the word structure:

Initially   /le:n/   ´until´
Medially   /ʕalam/   ´flag´
              /ʕallam/   ´he taught´
Finally   /Xal/   ´leave!´

/ɫ/ > [ɫ]: is realized as a voiced pharyngealized alveolar lateral. It occurs in word-medial and word-final position but not in word-initial position, thus:

Medially	/ˈXa:ɬij/	´my uncle´
	/Xaɬ´ɬe:na:/	´we emptied it´
Finally	/Xaɬ/	´vinegar´

1.3.1.d Trill

/r/ is realized as a voiced apico-alveolar trill [r] or a voiced apico-alveolar tap [ɾ]. It is partially or fully devoiced when adjacent to a voiceless consonant:

/r/ > [r̥]/ voiceless consonant

e.g /tra:b/   [tr̥a:b]   ´earth´

/fra:ʃ/   [fr̥a:ʃ]   ´bed´

It is pharyngealized in the context of an emphatic consonant:

/r/ > [ɹ]/ emphatic consonant

e.g. /ɬra:g/   [ɬɹɑ̣:g]   ´a slap´

/ɬarr/   [ɬɑ̣ɹ]   ´to beg´

/r/ may occur in any position in the word structure:

Initially	/ri:l/	´foot´
Medially	/ˈmara/	´woman´
	/ˈmarra/	´once´
Finally	/marr/	´to pass´

1.3.1.e Fricatives

The fricative phonemes /f, θ, ɣ, ɣ̣, s, ṣ, z, ʃ, X, ħ, h,/

are phonetically realized as follows:

/f/ > [f]: is normally realized as a voiceless labio-dental fricative. It is pharyngealized in the neighbourhood of an emphatic consonant:

/f/ > [f̵]/ emphatic consonant e.g.

/fsu:ꞩ/   [f̵ꞩu:ꞩ]   ´gems´

/ʈaff/   [ʈɋf̵]   ´to put off´

/f/ can occur in all positions in the word structure:

Initially   /fi:l/   ´elephant´

Medially   /lifa/   ´to seek shelter´

            /liffa/   ´rap it!´ mas. sing.

Finally   /se:f/   ´sword´

/θ/ > [θ]: is realized as a voiceless apico-dental or interdental fricative. It can occur in all positions in the word structure:

Initially   /θalm/   ´notch´

Medially   /´miθil/   ´like´

            /´maθθal/ .   ´to act´

Finally   /θilθ/   ´one third

/ð/ > [ð]: is realized as a voiced apico-dental or interdental fricative. It is partially or fully devoiced next to a voiceless consonant:

/ð/ > [ð̥]/ voiceless consonant

e.g.　　　/tðir/　　　[t̪ðir]　　　´she scatters´

/ð/ occurs in word-initial, medial and final positions:

Initially　　　/ði:b/　　　　　´wolf´

Medially　　　/laˊði:ð/　.　´delicious´

　　　　　　　/ˊlaðði/　　　´joy´

Finally　　　/Xaðð/　　　　´to take´

　　　/ð̴/　　>　[ð̴]: is realized as a voiced pharyngealized apico-dental or interdental fricative. It can occur in all positions in the word structure:

Initially　　　/ð̴e:f/　　　　´guest´

Medially　　　/maˊð̴lu:m/　´unjustly treated´

　　　　　　　/ˊʕað̴ð̴a/　　´a bite´

Finally　　　/gað̴ð̴/　　　´a hole´

　　　/s/　　>　[s]: is realized as a voiceless lamino-alveolar fricative. It may occur in word-initial position:

　　　　　/se:f/　　　　　´sword´

in word-medial position:

　　　　　/ˊʕasal/　　　´honey´

　　　　　/ˊʕassal/　　´to become honey´

and in word-final position:

　　　　　/Xass/　　　　　´lettuce´

/ʂ/　　>　　[ʂ]　　:　is　realized　as　voiceless
lamino-alveolar pharyngealized fricative.

It occurs in word-initial position:

　　　　/ʂe:f/　　　　　　ˊsummerˊ

in word-medial position:

　　　　/ˊɦaʂa/　　　　　ˊstonesˊ

　　　　/ˊɦiʂʂa/　　　　ˊlessonˊ

and in word-final position:

　　　　/Xaʂʂ/　　　　　　ˊbelong toˊ

/z/　　>　　[z]: is normally realized as a voiced
lamino-alveolar fricative. It is partially or fully
devoiced when adjacent to a voiceless consonant:

　　　　/z/　　>　　[z̥]/ voiceless consonant

e.g.　　/ɦza:m/　　　[ɦz̥ɑ̣:m]　　　ˊbeltˊ

　　　　/zka:m/　　　[z̥kɑ̣:m]　　　ˊfluˊ

It occurs in word-initial position:

　　　　/zarʕ/　　　　ˊplantationˊ

in word-medial position:

　　　　/ˊɦizin/　　　ˊsadnessˊ

　　　　/ˊɦazzan/　　ˊto make someone sadˊ

in word-final position:

　　　　/mo:z/　　　　ˊbananasˊ

/ ʃ /　　>　　[ʃ] is realized as a voiceless

palato-alveolar fricative. It can occur in all positions in the word structure:

Initially	/ʃams/	´sun´
Medially	/´miʃa/	´he walked´
	/´miʃʃa/	´wipe it!´ sing. mas.
Finally	/ma:ʃ/	´mung beans´

/X/ > [X] is realized as a voiceless uvular fricative. It occurs in all positions of the word-structure:

Initially	/Xa:f/	´to get frightened´
Medially	/´baXat/	´luck´
	/´baXXar/	´to burn incense´
Finally	/faX/	´trap´

/ħ/ > [ħ] is realized as a voiceless pharyngeal fricative. It can occur in all positions of the word structure:

Initially	/ħa:r/	´hot´
Medially	/´siħar/	´to bewitch´
	/´siħħar/	´witches´
Finally	/milħ/	´salt´

/h/ > [h] is realized as a voiceless glottal fricative. It may occur in all positions in the word structure:

Initially	/he:l/	´cardamom´
Medially	/´sihar/	´he passed the night awake´
	/´sihhar/	´sleepless´ pl.
Finally	/wajh/	´face´

1.3.1.f Affricates

The affricates /č/ and /dʒ/ are realized as follows:

/č/ > [č] is realized as a voiceless palato-alveolar affricate. It occurs in all positions in the word structure:

Initially   /čalb/   'dog'

Medially   /mač´bu:s/   'carried rice'

              /´ħačči/   'itching'

Finally   /lač/   'for you' sing. fem.

/dʒ / > [dʒ] is realized as a voiced palato-alveolar affricate. It occurs in word-initial position:

              /dʒi:l/   'generation'

in word-medial position:

              /´na:dʒiħ/   'successful' sing. mas.

              /´ħadʒdʒi/   'pilgrimage'

in word-final position:

              /ħadʒ /   'to go in a pilgrimage'

1.3.1.g Approximants

The approximants phonemes /w/, /j/ and /ʕ/ are realized as follows:

/w/ > [w] is realized as a voiced labial-velar

approximant.

It can occur in all positions of the word structure:

Initially   /we:n/   'where'

Medially   /su´wa:d/   'blackness'

              /´sawwa/   'he made'

Finally   /saww/   'do!' sing. mas.

/j/   >   [j] is realized as a voiced palatal approximant.

It occurs in word-initial position:

              /jo:m/   'day'

in word-medial position:

              /´ħiji/   'he became alive'

              /´ħajji/   'a snake'

in word-final position:

              /ma:j/   'water'

/ʕ/   >   [ʕ] is realized as a voiced pharyngeal approximant.

It occurs in all positions of the word structure:

Initially   /ʕi:d/   'feast'

Medially   /´zaʕal/   'anger'

              /´zaʕʕal/   'he caused anger'

Finally   /be:ʕ/   'sale'

1.4   Consonant Combinations

In the following sections the distributional patterns of consonant combinations will be given. The term

'consonant combinations' is used to cover both consonant clusters and sequences. A series of consonants is called a 'cluster' if the consonants occur in the same syllable and a 'sequence' if they occur in two consecutive syllables (Pulgram 1965). Consonant combinations can occur in word-initial, word-medial and word-final positions. The word-initial and word-final consonant combinations are clusters and those which occur in word-medial positions are sequences as they are split by syllable boundaries.

1.4.1 Word-initial consonant clusters

The following table (Figure 1.4.1.a) and chart (Figure 1.4.1.b) display all possible word-initial two consonant clusters CC-. The vertical line of consonant symbols at the left represents the consonant which can be the first element of a cluster, referred to here as C1, and the symbols across represent the consonants which can be the second element of a cluster, referred to here as C2. As can be seen from the chart, there is quite a wide range of consonant combinations at C1 and C2. Appendix A shows a list of examples illustrating all possible word-initial CC clusters with a gloss in English.

Three-consonant clusters in word-initial position do occur, but their occurrence is very rare and

Figure 1.4.1.a

Word-Initial CC- combinating

C1	C2
b	d, k, g, m, n, l, r, f, θ, s, z, ʃ, x, ħ, h, w, j, ʕ, ƫ, ʂ
t	b, t, d, q, m, n, l, r, f, θ, ð, s, z, ʃ, X, ħ, h, w, j, ʕ, ẓ, ʂ
d	b, d, g, q, m, l, r, f, X, h, w, j
k	b, t, n, l, r, f, θ, s, w, j
g	b, d, n, m, l, r, f, z, ʃ, ħ, h, w, j, ʕ, ƫ, ⊦, ẓ, ʂ
q	t, r, z, w, j, ⊦, ʂ
m	b, t, d, k, g, q, ʔ, m, n, l, r, f, θ, ð, s, z, ʃ, X, ħ, h, č, dʒ, w, j, ʕ, ƫ, ẓ, ʂ
n	b, t, d, k, g, q, ʔ, m, n, l, r, f, θ, ð, s, z, ʃ, X, ħ, h, č, dʒ, w, j, ʕ, ƫ, ẓ, ʂ
l	b, t, k, g, m, l, θ, f, s, X, ħ, h, w, j, ʕ
r	b, t, g, m, r, f, s, ʃ, X, w, j, ʕ, ʂ
f	t, d, g, n, l, r, s, ʃ, X, ħ, w, j, ʂ
θ	g, n, dʒ, w, j
ð	b, k, n, l, r, j
s	b, ƫ, k, g, m, n, l, r, s, h, w, j, ʕ, ƫ
z	b, t, d, k, r, z, h, w, j, ʕ
ʃ	b, t, k, g, q, n, l, r, ħ, h, w, j, ʕ, ƫ, ṣ
X	b, t, d, m, l, r, f, ð, s, ʃ, w, j
ħ	b, t, g, q, m, n, l, r, ð, s, z, w, j, ƫ, ẓ, ṣ
h	b, t, m, n, l, w
č	t, m, l, f

dʒ	d, n, l, w, j
w	k, l, r, j
ʕ	t, d, g, m, n, l, r, θ, ð, s, č, w, j, ɫ, ɣ
ɫ	b, g, m, n, r, l, w, j, ɫ
ɣ	l, r, w, j, ʕ
s	b, d, g, q, m, n, l, r, f, X, ħ, w, j, ʕ, ṣ

C2

C1

Figure 1.4.1.b

word—initial   two consonant combinations

restrictive. The first element of the cluster has to be /s/, the second element has to be /t/ and the third element can be almost any consonant, e.g.

/stqi:l/	´resign!´
/stʃi:r/	´consult!´
/´stʕa:ra/	´borrowing´
/´stma:ra/	´a form´

1.4.2 Word-medial consonant sequences

The following table (Figure 1.4.2.a) and chart (Figure 1.4.2.b) list all possible word-medial two-consonant combinations -CC-. The vertical line of consonant symbols at the left represents the consonants which can be the first element of the sequence and referred to here as C3 and the symbols across the table represent the consonants which can be the second element of the sequence and referred to here as C4. Appendix B gives a list of examples illustrating each possible word-medial CC combination.

A sequence of three consonants -CCC- in the middle of the word is very rare, the only word, to my knowledge, is /qunť´ra:z/ (´contracting´), a loan word from English.

But sequences of three and four consonants across word boundaries are common, e.g.

Figure 1.4.2.a

Word-medial   -cc-combinations

C3	C4
b	b, t, d, k, g, q, n, l, r, θ, ӿ, s, z, ʃ, X, ħ, h, č, dӡ, w, j, ʕ, ŧ, ⱦ, ӿ, ɐ
t	b, t, d, k, g, q, ʔ, m, n, l, r, f, θ, ӿ, s, z, ʃ, X, ħ, h, č, dӡ, w, j, ʕ, ŧ, ӿ, ɐ
d	b, d, k, g, q, m, n, l, r, f, θ, s, z, ʃ, X, ħ, h, w, j, ʕ
k	b, t, d, k, m, n, l, r, f, θ, ӿ, s, ʃ, ħ, č, w, j, ӿ
g	b, g, m, n, r, f, s, z, ʃ, w, j, ʕ, ŧ, ⱦ, ӿ, ɐ
q	b, t, d, q, m, n, l, r, f, θ, s, z, ʃ, h, w, ŧ, ⱦ, ӿ, ɐ
ʔ	ʔ, m, l, θ, ӿ, w
m	b, t, d, k, g, q, m, n, l, r, s, z, ʃ, X, ħ, h, č, dӡ, j, ʕ, ŧ, ӿ, ɐ
n	b, t, d, k, g, q, m, n, l, r, f, θ, ӿ, s, z, ʃ, X, ħ, h, č, dӡ, w, j, ʕ, ŧ, ӿ, ɐ
l	b, t, d, k, g, q, m, n, l, f, θ, ӿ, s, z, ʃ, X, ħ, h, č, dӡ, w, j, ʕ, ŧ, ӿ, ɐ
r	b, t, d, k, g, q, m, n, r, f, θ, s, z, ʃ, X, ħ, h, č, dӡ, w, j, ʕ, ŧ, ӿ, ɐ
f	t, d, k, g, n, l, r, f, s, z, ʃ, X, ħ, h, č, dӡ, j, ʕ, ŧ, ӿ, ɐ
θ	b, g, n, l, r, θ, w
ӿ	b, k, m, n, l, r, f, ӿ, h, w, j, ʕ
s	b, t, d, k, g, ʔ, m, n, l, r, s, X, ħ, h, č, dӡ, w, j, ʕ, ŧ

cont. Figure 1.4.2.a

z	b, d, k, g, q, m, n, l, r, z, X, ħ, h, w, j, ʕ
ʃ	b, t, d, k, g, q, ʔ, m, n, l, r, f, ʃ, X, ħ, h, dʒ, w, j, ʕ, ⴾ
X	b, t, d, m, n, l, r, f, , s, z, ɣ, X, dʒ, w, ⴾ, ⵜ, ⵯ, ⵚ
ħ	b, t, d, k, g, q, m, n, l, r, f, ɣ, s, z, ʃ, ħ, č, dʒ, w, j, ⴾ, ⵯ, ⵚ
h	b, t, d, g, m, n, l, r, f, ɣ, z, ʃ, h, dʒ, w, j, ⴾ, ⵯ
č	b, q, n, l, r, f, θ, ɣ, s, č, w, j
dʒ	b, d, m, n, l, r, f, θ, ɣ, z, ħ, h
w	d, k, q, ʔ, m, l, r, f, s, z, ʃ, ħ, h, dʒ, w, j, ʕ, ⴾ, ⵯ, ⵚ
j	b, t, d, k, g, q, ʔ, m, n, l, r, f, θ, ɣ, s, z, ʃ, X, ħ, h, č, w, j, ʕ, ⴾ, ⵯ, ⵚ
ʕ	b, t, d, k, g, m, n, l, r, f, θ, ɣ, s, z, ʃ, č, d , w, j, ʕ, ⴾ, ⵯ, ⵚ
ⴾ	b, g, q, m, n, l, r, f, ʃ, ħ, h, w, j, ʕ, ⴾ
ⵜ	ⵜ
ⵯ	k, q, m, n, l, r, f, X, ħ, h, w, ⵯ
ⵚ	b, d, k, q, m, n, l, r, X, ħ, h, w, j, ʕ, ⵚ

C4

C3

Figure 1.4.2.b

word—medial   two consonant combinations

/ʔams tgu:l/ ´you said yesterday´

/čift gⱡa:wa/ ´I saw cats´

/ʔalñi:n tlu:m/ ´now you blame´

1.4.3 Word-final consonant clusters

There are not as many variations of word-final clusters as there are in word-initial clusters. Only two consonant clusters are permitted in word-final position. The following table (Figure 1.4.3.a) and chart (Figure 1.4.3.b) lay out all the possible word-final consonant clusters -CC. The vertical line of consonant symbols at the left represents the consonants which can be the first element of the cluster and referred to here as C5 and the symbols across the table represent the consonants which can be the second element of the cluster and referred to here as C6. Appendix C gives a full list of examples illustrating all types of word-final consonant clusters.

1.5. The Vowel System

1.5.1 Vowel Phonemes

The vowel system of QA contains eight monophthongs, three short vowels /i/, /a/, /u/ and five long vowels /i:/, /e:/, /a:/, /o:/ and /u:/. The examples given below show that these eight vowels are in

Figure 1.4.3.a

Word-Final -cc combinations

C5	C6
b	b, t, d, ʃ, ħ, ʁ
t	t, g, ħ
d	t, d
k	k
g	t, g, f
q	q, s
ʔ	d
m	t, d, q, m, n, s, ʃ, X, ʕ
n	b, t, d, g, n, z, č, dʒ
l	b, t, d, k, m, l, f, ħ, dʒ
r	b, t, d, g, q, r, s, dʒ, ʁ, ɐ
f	f
θ	θ
ʁ	ʁ
s	t, s, ɫ
z	t, z
ʃ	t, ʃ
X	t, X
ħ	t, ħ
h	d
č	č
dʒ	dʒ
w	w
j	h, j
ʕ	t, d, ʕ
ɫ	ʕ, ɫ
ɫ	b, ɫ
ʁ	ʁ
ɐ	d, f, ɐ

Figure 1.4.3.b

word-final two consonant combinations

phonemic opposition in the language:

/ħib/	´love!´
/ħab/	´he loved´
/ħub/	´love´
/æir/	´beg!´
/æi:r/	´fly!´
/æe:r/	´bird´
/sam/	´to poison´
/sa:m/	´poisoning´
/gum/	´get up!´
/go:m/	´people´
/ful/	´Arabian jasmine´
/fu:l/	´broad beans´
/lo:m/	´blame´
/lu:m/	´blame!´ sing. masc.
/ʃir´ba:/	´he drank it´
/ʃir´bi:/	´drink it!´ sing. fem.
/ʃir´bo:/	´they drank it´
/ʃir´bu:/	´drink it!´ plur.

1.5.2 The phonetic specification of the vowel phonemes
1.5.2.a The Short Vowels

The quality of the three short vowels /i/, /a/, /u/ and their allophones are specified on the cardinal vowel diagram given below (Figure 1.5.2.a). A cardinal vowel is a "fixed and unchanging reference point
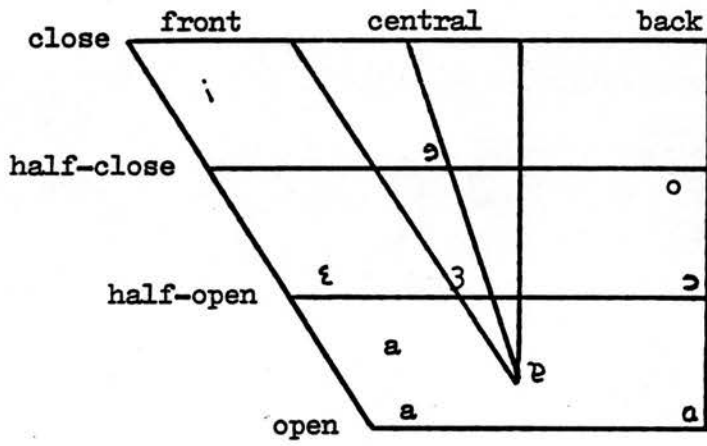
QA short vowels in relation to cardinal vowels

Figure 1.5.2.a

established within the total range of vowel quality, to which any other vowel sound can be directly related" (Abercrombie 1967, p.151). The description will be in three dimensions, the highest-point of the tongue on the vertical axis, the highest-point of the tongue on the horizontal axis and the lip posture.

/i/ has the phonetic exponents [ɛ̣], [ɵ], [ɜ̣], and [ị̈] under different conditions.

[ɛ̣] is a half-open front vowel, with the tongue is slightly more raised and retracted than cardinal [ɛ], and it occurs next to pharyngeal consonants:

    /i/   >   [ɛ̣]/ pharyngeal consonant

e.g.   /ʕiχir/   [ʕɛ̣χir]   ´excuse´

[ɵ] is a pharyngealized half-close central vowel which occurs next to emphatic consonants:

    /i/   >   [ɵ]/ emphatic consonant

e.g.   /ʈil/   [ʈɵɬ]   ´look!´ mas. sing.

[ɜ̣] is a half-open central vowel with the tongue is slightly raised from cardinal [ɜ]; it occurs in word-final position before a pause:

    /i/   >   [ɜ̣]/ -#

e.g   /´malli/   [´maḷḷɜ̣]   ´bowl´

[ị̈] the tongue position for this vowel is more open and retracted than cardinal [i]; it is half way between

cardinal [i] and [e], and it occurs elsewhere than the above environments:

/i/ > [i̞]/ elsewhere

/ˈʔikil/ [ˈʔi̞ki̞l] ʿeat!ʾ mas. sing.

/i/ may occur in word medial and final positions, in open and closed syllables, e.g.

/sit/ ʿsixʾ

/ˈtisiʕ/ ʿnineʾ

/ˈsalli/ ʿbasketʾ

/a/ has the phonetic exponents [a̱], [ɑ̝], [ɐ] and [a̱̝].

[a̱] is an open front vowel with the tongue more retracted than cardinal [a], and it occurs next to pharyngeal consonants:

/a/ > [a̱]/ pharyngeal consonant

e.g. /ħab/ [ħa̱b] ʿto loveʾ

[ɑ̝] is a pharyngealized open back vowel with the tongue slightly more advanced than cardinal [ɑ], and it occurs next to pharyngealized consonants:

/a/ > [ɑ̝]/ emphatic consonant

e.g. /ɬab/ [ɬɑ̝ɓ] ʿto jumpʾ

[ɐ] is a central vowel, between half-open and open, and it occurs in word-final position before a pause:

$$/a/ \quad > \quad [\mathfrak{p}]/ -\#$$

e.g   /´sikka/   [´sikkₚ]   ´street´

[a̰] is an open front vowel with the tongue   more raised and retracted than cardinal [a], and it occurs elsewhere than the above environments:

$$/a/ \quad > \quad [a̰]/ \text{ elsewhere}$$

e.g.   /damm/   [da̰m]   ´blood´

/a/ may occur in word-medial and final positions, in open and closed syllables, e.g.

      /lak/   ´for you´ mas. sing.

      /´Xaδa/   ´he took it´

/u/ has the phonetic exponents [ɔ], [ʒ] and [o̤] under the following conditions:

[ɔ] is a half-open back rounded vowel, and it occurs next to pharyngeal consonants:

$$/u/ \quad > \quad [ɔ]/ \text{ pharyngeal consonant}$$

e.g   /ħub/   [ħɔb]   ´love´

[ʒ] is a pharyngealized half-open rounded vowel which occurs next to emphatic consonants:

$$/u/ \quad > \quad [ʒ]/ \text{ emphatic consonant}$$

e.g   /ƫub/   [ƫʒɓ]   ´jump!´ mas. sing.

[o̞] is a half-close back rounded vowel, with the tongue position slightly more lowered and advanced than cardinal [o]. It occurs elsewhere than in the above contexts:

/u/ > [o̞]/ elsewhere

e.g. /dub/ [do̞b] ´fat´ mas. sing.

/u/ can occur in word-medial position only, in open and closed syllables:

/lub/ ´essence´

/´rubuʕ/ ´one fourth´

1.5.2.b Long Vowels

The quality of the five long vowels, /i:/, /e:/, /a:/, /o:/ /u:/, and their allophones are specified on the cardinal vowel diagram given below (Figure 1.5.2.b)

/i:/ has the following exponents: [ɨ̞:], [ɨ̞̃] and [i̞:] under the following conditions:

[ɨ̞:] is a close central vowel, with the tongue position slightly more lowered than cardinal [ɨ]. It occurs next to pharyngeal consonants:

/i:/ > [ɨ̞:]/ pharyngeal consonant

e.g. /ʕi:n/ [ʕɨ̞:n] ´help!´ mas. sing.

[ɨ̞:] is a pharyngealized close central vowel with the tongue slightly more lowered than cardinal [ɨ]. It occurs next to pharyngealized consonants:

QA long vowels in relation to cardinal vowels

Figure 1.5.2.b

/i:/   >   [ɨ̟:]/ emphatic consonant

e.g.   /ti:n/   [tɨ̟:n]   ´clay´

[ɨ̟:] is a long close front vowel with the tongue position being slightly more lowered and retracted than cardinal [i]. It occurs elsewhere than in the above contexts:

/i:/   >   [ɪ̟:]/ elsewhere

e.g   /ti:n/   [tɪ̟:n]   ´figs´

/i:/ may occur in word medial and final position, in open and closed syllables:

/fi:l/   ´elephant´

/ʃi:´li:/   ´pick it up´ fem. sing.

/e:/ has the allophones [ë̞:], [ë̞:] and [e̞:] under the following conditions:

[ë̞:] is a centralized half-close vowel with the tongue more lowered than cardinal [e]. It occurs next to pharyngeal consonants:

/e:/   >   [ë̞:]/ pharyngeal consonant

e.g   /ʕe:n/   [ʕë̞:n]   ´eye´

[ë̞:] is a pharyngealized centralized half-close vowel, with the tongue position being more lowered than cardinal [e]. It occurs next to pharyngealized consonants:

/e:/   >   [ë̞:]/ emphatic consonant

e.g.　　/be:ˀ/　　　[b̥ä:ˀ]　　　´eggs´

[e̯:] is a half-close front vowel, and has a tongue position slightly more retracted than cardinal [e] and it occurs elsewhere than in the above contexts:

　　　　/e:/　　>　[e̯:]/ elsewhere

e.g.　　/be:t/　　[be̯:t]　　　´house´

/e:/ may occur in word medial and final positions, in open and closed syllables, e.g.:

　　　　/be:´te:n/　　　　´two houses´

　　　　/lab´be:/　　　　´here I am!´

　　　　/a:/ has the following phonetic realizations [aː], [æː] and [ɑ̟ː] under the following conditions:

[aː] is an open back vowel which occurs next to pharyngeal consonants:

　　　　/a:/　　>　[aː]/ pharyngeal consonant

e.g.　　/ħa:r/　　[ħaːr]　　　´hot´

[æː] is a pharyngealized open back vowel. It occurs next to emphatic consonants:

　　　　/a:/　　>　[æː]/ emphatic consonant

e.g.　　/sa:m/　　[sæːm]　　´to fast´

[ɑ̟ː] is an open back vowel and has a tongue position

more advanced than cardinal [ɑ]. It occurs elsewhere than in the above contexts:

/a:/   >   [ɑ̈:]/ elsewhere

e.g.   /ja:r/   [jɑ̈:r]   ´neighbour´

/a:/ may occur in word-medial and final positions, in open and closed syllables, e.g.:

/ba:t/   ´he slept´

/muba:´ra:/   ´a match´

/o:/ has the following phonetic realizations: [o̞:], [õ̞:] and [o:] under the following conditions:

[o̞:] is a half-close back rounded vowel with a tongue position slightly more lowered than cardinal [o]. It occurs next to pharyngeal consonants:

/o:/   >   [o̞:]/ pharyngeal consonant

e.g.   /ħo:ʃ/   [ħo̞:ʃ]   ´courtyard´

[õ̞:] is a pharyngealized half-close back rounded vowel with a tongue position also slightly more lowered than cardinal [o] and it occurs next to emphatic consonants:

/o:/   >   [õ̞:]/ emphatic consonant

e.g.   /so:t/   [s̡õ̞:t̡]   ´voice´

[o:] is a half-close back rounded vowel which occurs elsewhere than in the above contexts:

	/o:/	>	[o:]/ elsewhere	
e.g.	/lo:n/	[l̥o:n]		´colour´

/o:/ can occur medially and finally in the word structure, and can occur in open and closed syllables, e.g.:

	/lo:m/	´blame´
	/lo:´ne:n/	´two colours´
	/ñab´bo:/	´they liked him´

/u:/ has the following phonetic exponents: [ʉ:], [ʉ̣:] and [u:] under the following conditions:

[ʉ:] is a close back rounded vowel with a tongue position slightly more lowered than cardinal [u]. It occurs next to pharyngeal consonants:

	/u:/	>	[ʉ:]/ pharyngeal consonant	
e.g.	/ʕu:d/	[ʕ̣ʉ:d]		´a stick´

[ʉ̣:] is a pharyngealized close back rounded vowel with a tongue position slightly more lowered than cardinal [u]. It occurs next to pharyngealized consonant:

	/u:/	>	[ʉ̣:]/ emphatic consonant	
e.g.	/ƫu:s/	[ƫʉ̣:ʂ]		´bowls´

[u:] is a close back rounded vowel which occurs elsewhere than in the above contexts:

	/u:/	>	[u:]/ elsewhere

e.g.   /du:r/   [d̪u:r̩]   ´rooms´

/u:/ may occur medially and finally in the word structure, and can occur in open and closed syllables, e.g.:

/ru:s/   ´heads´

/du:´ru:/   ´look for it´ pl.

The following table shows the first, second and third average formant values for each of the eight vowel phonemes when said in isolated words by two male speakers   in the non-emphatic context:

Vowel	F1	F2	F3
/i/	500	1750	2750
/i:/	300	2250	2750
/e:/	500	2000	2750
/a/	600	1500	2750
/a:/	600	1250	2600
/u/	400	1000	2600
/u:/	300	750	2500

Diphthongs are phonologically treated in this study as a complex made up of a vowel plus the consonantal element /j/ or /w/, and the following are some examples illustrating their occurrence in the

dialect:

/ˈ ħiliw/	´sweet´
/laww/	´if´
/ħleːw/	´kind´
/jaːw/	´they came´
/ʔumij/	´my mother´
/ħajj/	´alive´
/maːj/	´water´
/boːj/	´servant´
/ʔuˈXuːj/	´my brother´

1.5.3 Vowel-Consonant Combinations

The following chart (Figure 1.5.3) displays all the possible consonants that may follow each of the eight vowel phonemes. It can be seen that:

/i/ can precede all the consonants except /ʔ, ɫ/

/a/ can precede all the consonants except /ʔ/

/u/ can not precede /t, d, ʔ, θ, ɣ, s, z, ʃ, č, dʒ, w, j, ɫ/

/iː/ can precede all the consonants except /ʔ, w, j, ɫ/

/eː/ can not precede /g, q, ʔ, ɣ, j, ɫ, ө /

/aː/ can precede all the consonants

/oː/ can precede all the consonants except /ʔ, ɣ, w, ɫ/

/uː/ can precede all the consonants except /ʔ, ɫ/

Appendix D gives a list of words exemplifying all the possible VC combinations.

v \ c	b	t	d	k	g	b	ʔ	m	n	l	r	f	θ	χ	s	z	ʃ	x	ɦ	h	ð	dʒ	w	j	ʕ	ʈ	ƫ	ʁ	ɕ
i	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+
a	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
u	+			+	+	+		+	+	+	+	+						+		+					+	+		+	+
i:	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+			+	+		+	+
e:	+	+	+	+		+		+	+	+	+	+	+		+	+	+	+	+	+	+	+	+		+	+		+	
a:	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
o:	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+		+	+	+		+	+
u:	+	+	+	+	+	+		+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+

Figure 1.5.3

Vowel—consonant combinations

1.5.4 Consonant-Vowel Combinations

The chart below (Figure 1.5.4) shows all the possible consonants that may precede each of the eight vowel phonemes. It can be seen that:

/i/ can follow all the consonants.

/a/ can follow all the consonants.

/u/ can not follow /q, n, s, z, č, w, ł/.

/i:/ can follow all the consonants.

/e:/ can follow all the consonants except /ʔ, θ/.

/a:/ can follow all the consonants.

/o:/ can follow all the consonants.

/u:/ can follow all the consonants.

Appendix E gives a list of words illustrating all permissible CV combinations.

	v							
c	i	a	u	i:	e:	a:	o:	u:
b	+	+	+	+	+	+	+	+
t	+	+	+	+	+	+	+	+
d	+	+	+	+	+	+	+	+
k	+	+	+	+	+	+	+	+
g	+	+	+	+	+	+	+	+
q	+	+		+	+	+	+	+
ʔ	+	+	+	+		+	+	+
m	+	+	+	+	+	+	+	+
n	+	+		+	+	+	+	+
l	+	+	+	+	+	+	+	+
r	+	+	+	+	+	+	+	+
f	+	+	+	+	+	+	+	+
θ	+	+	+	+		+	+	+
ð	+	+	+	+	+	+	+	+
s	+	+		+	+	+	+	+
z	+	+		+	+	+	+	+
∫	+	+	+	+	+	+	+	+
X	+	+	+	+	+	+	+	+
ħ	+	+	+	+	+	+	+	+
h	+	+	+	+	+	+	+	+
č	+	+		+	+	+	+	+
dʒ	+	+	+	+	+	+	+	+
w	+	+		+	+	+	+	+
j	+	+	+	+	+	+	+	+
ʕ	+	+	+	+	+	+	+	+
ŧ	+	+	+	+	+	+	+	+
ƫ	+	+		+	+	+	+	+
ɤ	+	+	+	+	+	+	+	+
ɞ	+	+	+	+	+	+	+	+

Figure 1.5.4

Consonant-vowel combinations

CHAPTER TWO

COARTICULATION: REVIEW OF LITERATURE

2.   What is Coarticulation

At the articulatory physiological level and at the acoustic level speech is a continuum. There is not always one-to-one correspondence between the articulatory gesture/acoustic signal and linguistic units such as phonemes. This complexity and overlapping of the speech segments is expressed by Liberman et al. (1972) as follows "... the acoustic cues for successive phonemes are intermixed in the sound stream to such an extent that definable segments of sound do not correspond to segments at the phoneme level. Moreover, the same phoneme is most commonly represented in different phonemic environments by sounds that are vastly different. There is, in short, a marked lack of correspondence between sound and perceived phoneme" (p.14).

The wholeness and continuity of speech has been described vividly, but exaggeratedly by Hockett (1955), in his famous analogy, as a "row of Easter eggs carried along a moving belt; the eggs are of various sizes and variously colored, but not boiled. At a certain point, the belt carries the row of eggs between the two rollers of a wringer, which quite effectively smash them and rub them more or less into each other" (p.210). In this

imaginative process of speech production the Easter eggs correspond to discrete segments or phonemes and the mess of broken eggs corresponds to the speech output. The comparison shows that there are two levels which the investigator of speech production has to deal with: one is the abstract linguistic level, and the other is the physical articulatory level. And the phenomenon which captures the relation between these two levels is "coarticulation".

Though segments do not always exist physically in the speech signal nor in the flow of articulatory movements, cognitively or perceptually such units seem to be real. And the concept of coarticulation assumes the existence of these units as "canonical targets of articulation" (Daniloff & Hammarberg, 1973). As Hammarberg puts it "the concept of segment is brought to bear a priori on the study of the physical-physiological aspects of language" (1976, p.355).

Coarticulation is defined by Daniloff & Hammarberg (1973) as "the influence of one speech segment upon another; that is, the influence of a phonetic context upon a given segment" it involves "the spreading of a feature inherent to one canonical segment to another segment to which the feature is not inherent. The result of this process is a ´smoothing out´ of the transitions between segments and this turns a sequence of entities into a

continuum" (p.239). Here Daniloff & Hammarberg define coarticulation as a phonetic process. But three years later Hammarberg (1976) rejects this definition and regards coarticulation as a phonological process and not a phonetic one "the process yielding coarticulated allophones is not phonetic-physiological in nature, but rather a phonological assimilation process" (p.353).

Schouten & Pols (1979a) reject Hammarberg's definition as they assume that assimilation and coarticulation are two different things, the former governed by language specific phonological rules, and the latter is governed by universal physical constraints: "Coarticulation is due to the universal datum that one cannot move from one state to another state with infinite speed: when moving from one speech segment (extrinsic allophone) to, or in the direction of the next, a certain trajectory has to be covered" (p.2). They distinguish two forms of coarticulation, vowel reduction caused by stress and rate of speech and transitions from one extrinsic allophone area to another.

Fowler (1980) conceives coarticulation as a coproduction of consonants and vowels and of stressed and unstressed vowels "... instead of treating coarticulation as an adjustment of the canonical properties of a segment in acquiescence to its neighbors, it may be viewed as the overlapping production of successive, continuous, four dimensional segments" (p. 119).

Fujimura (1981) distinguishes two types of coarticulation: "hard coarticulation" and "soft coarticulation". He defines the two types as follows "hard coarticulation, defined as a direct mechanical smoothing effect, which may contain for example language-dependent and speaker-dependent time constraints, would account for only part of the so-called coarticulation phenomena. The Henke type look-ahead mechanism..., for example, goes beyond this notion, and should be described as a feature-copying (or agreement) process, i.e. soft coarticulation" (p. 109).

In 1982, Hammarberg refutes both Schouten's & Pols's definition and Fowler's definition. He also argues against the existence of phonemes, allophones and segments both as physical and mentalistic entities. And as coarticulation process presupposes the existence of segments, if they do not exist, coarticulation does not exist either, thus he concludes that "the only credible alternative seems to be to redefine coarticulation out of existence altogether" (p. 135).

We believe that coarticulation is a phonetic phenomenon and not a phonological one and that it involves two processes: an assimilation process, that is the interaction between two adjacent segments which involves accommodative and temporal displacement phenomena; and a "feature copying" process which involves the spreading of a feature across syllable or/and word

boundaries to other segments.

Coarticulation implies that a phonetic segment may have two kinds of features: inherent features and uninherent or ´derived´ features which are a result of the assimilation and feature copying processes. For example if we take the word ´whoosh´, /wuʃ/, in English we find that all the segments of the word are inherently rounded (Hammarberg, 1976). So there is no coarticulation of rounding in this word. But if we take a word like ´soon´, /sun/, on the other hand, we find that rounding is only property of the vowel /u/, while the rounding of the segments on either side are not inherent, but due to the influence of the rounded vowel /u/.

From the above example we notice that coarticulation is bidirectional, that is to say it affects both the preceding and the following segments. Thus giving us two types of coarticulatory effects: perseverative (´regressive´, ´carried-over´, ´retentive´, ´post-articulatory´, ´left-to-right´) coarticulation, in which the articulatory characteristics or features of a given segment are carried over to segment(s) which follow it in time. For example, in QA the word /sa:matla/ ´she fasted for him´, tongue retraction or backing associated with the pharyngealized /s/ is carried over to the six following segments. This can be presented schematically as follows:

sa:matla
⎯⎯⎯⎯→

The second type is anticipatory ('progressive', 'forward', 'prearticulatory', 'right-to-left') coarticulation in which the articulatory characteristics or features of a given segment are anticipated during segment(s) which precede it in time. For example, in the word /naʃi:ɮ/, 'active', in QA, tongue backing associated with the last segment /ɮ/ begins during the first segment /n/. This can be presented schematically as follows:

na ʃ i:ɮ

Menzerath and de Lacerda (1933) were the first to investigate and use the term 'coarticulation'. In their kymographic, oscillographic and labiographic investigation of German they found that speech consists of continuous acoustic signals and continuous articulatory movements and that it can not be separated into isolated consonants and vowels. During the production of /k/ in /kam/, for example, they found that the lips move apart to take a posture required for the following open vowel; this simultaneous motion of the articulatory organs they call 'synkinese' or 'koartikulation': "Wahrend des k-Verschluses ... bewegen sich die dabei unbeteiligten Lippen bereits auseinander-dies bezeichnen wir als 'Synkinese' oder 'Koartikulation' -, um das darauffolgende a vorzubereiten" (p.50).

As a result of such consonant-vowel coarticulation

we get so many allophones or variants of the same vowel: "Jeder Vokal ist in seiner Bewegungs_form abhangig von den angrenzenden Konsonanten: es gibt mithin so viele Varianten desselben Vokals wie es Kombinationen mit konsonanten gibt, praktisch also unzahlige" (p.58). Sounds, they state, are constantly dependent on the preceding segments and that coarticulation is dependent on the participating organs of speech, as the articulatory organs which are not involved or participating during the production of a particular segment prepare for the following or even further sounds, thus causing articulation to start as early as possible: "Das sprechen ist also ein Kompliziertes Bewegungsvielfaches, als synkinetischer Bewegungskomplex aufzufassen. Die Einzelbewegungen sind so verflochten, daf sie jeweils im geeigneten Moment eintreten, also stets vom folgenden (bzw. den folgenden) Laut(-en) abhangig bleiben. Diese Synkinese oder Koartikulation hangt inhrerseits von den beteiligten Organgruppen ab: die jeweils unbeteiligte Gruppe bereitet sich schon auf den nächsten, sogar den ubernächsten Laut vor. Die Artikulation setzt so früh wie moglich ein" (p.58).

Interest in coarticulation was renewed in the early 1960´s. In their research, investigators tried to answer such questions as: Is coarticulation deliberately programmed and necessary to the generation of speech, or is it a by-product of the mechanical inertial constraints?

Over how many segments do coarticulatory effects occur? Is there an asymmetry in terms of extent of anticipatory and perseverative coarticulation? Are coarticulatory effects more extensive in the forward or in the backward direction? Are some segments more or less resistant to coarticulation? Is coarticulation a language-specific or language-universal phenomenon? What are the effects of changes in speaking rate and stress on coarticulation? What are the effects of juncture boundaries (syllable, word, and phrase boundaries) on coarticulation?

In these studies coarticulation was examined by means of direct and indirect methods for observing the articulatory behaviour. High speed photography, cinefluorography and electropalatography provided direct measurements of the articulators' movements, shapes and place of contact. Electromyography and spectrography provided indirect evidence of the articulatory behaviour; in the former the articulatory behaviour is inferred from the electrical activity in the muscles and in the latter the articulatory behaviour is inferred from the acoustic variations in the speech wave. The following review of coarticulatory literature shows that each method or technique has contributed data which shed some light on our knowledge and understanding of the articulatory behaviour.

2.1   Labial and Mandibular Coarticulation

Some studies concerned with labial and mandibular coarticulation will be reviewed in this section. For the examples given in this survey, the transcription will be those of the authors concerned.

Fujimura (1961a) used high speed photography to assess articulatory movements of labial consonants. He found that jaw lowering for a following vowel was initiated prior to lip opening for the consonant. In 1961b, he used high speed stroboscopic photography to examine lip and jaw movements for intervocalic lingual consonants embedded in words. Different labial articulations accompanied different vowel environments and in some cases, lip configuration for a vowel began during or even before the production of the preceding consonant, thus giving evidence for anticipatory coarticulation.

Lindblom (1964) found that lip motion associated with /U/ in /e'dUd/ began immediately after the initial consonant closure and that this coarticulation occurred over different rates of production.

Kozhevnikov & Chistovich (1965) used several techniques in their investigation of coarticulation in Russian. They used electrical palatography, and mechanical levers to measure lip closure. Films to assess

the degree of lip opening and spreading were used extensively with measures of nasal-oral air flow and recording of the acoustic wave. They hypothesized that the basic articulatory program consists of the "syntagma" or "sense unit" which is a meaningful phrase consisting of a series of up to seven articulatory syllables. Lip protrusion was measured by placing electrodes below the vermilion border on either side of the central cleft of the lower lip. Protrusion was found to begin at the beginning of the initial consonants for syllables of the structure /CV/ and /CCV/ produced by a Russian speaker, where V was /u/. They examined meaningful and meaningless words of the following structures /CV1´C1V2/, /CV1´C2V2/ and /CV1´C1C2V2/ where V2=/u/. The delay of the start of lip rounding was measured from the beginning of V1 voicing. For all three word structures the delay was essentially the same, even if C1 belonged to the preceding syllable. Hence, they concluded that the articulatory syllable consists of any number of consonants followed by a vowel /CnV/, and that maximum coarticulation occurs within such syllables and minimum between them. They also found that coarticulation within their CnV syllables occurred when adjacent articulatory gestures were not contradictory: "... in syllables of the consonant-vowel type all the movements of a vowel which are not contradictory to the articulation of the consonant begin with the beginning of

the syllable" (p.122). The study also showed that the absolute durations of linguistic units and the extent of coarticulation are affected by stress patterns, phonetic structure and rate of speech production.

Daniloff & Moll (1968) performed a cinefluorographic study to extend the findings of the Kozhevnikov & Chistovich study of Russian to American English. In the study three speakers of American English produced meaningful sentences containing sequences of one to four consonants preceding the vowel /u/ with word and syllable boundaries falling within the sequences in various ways. It was found that for most utterances, the lip rounding gesture for the vowel /u/ started during the closure phase of the first consonant in the sequence. Thus lip rounding extended over as many as four segments preceding the rounded vowel. Furthermore, it was found that the starting point of lip protrusion was not affected by word and syllable boundaries within the sequence. Their results thus confirm Kozhevnikov & Chistovich's findings and support their hypothesized ´articulatory syllable´ /CnV/.

In his attempt to analyse open and close vowels in terms of their production, Lindblom (1968) constructed a dynamic model of lip and mandible interaction to predict the observed durational difference between open and close vowels. In the experiment, where high speed motion picture were used, three Swedish speakers produced the

following four nonsense sequences: /I′ba:bI/, /I′bi:bI/, /I′babbI/ and /I′bIbbI/ ten times. Analysis of these test words revealed extensive vowel-consonant anticipatory coarticulation of lip and jaw configurations. It was found that the mandible began its opening movement for the stressed open vowels /a/, /ɑ/ while the lips were still in position for /b/. Similarly it completed its closing movement for the second /b/ after the labial closure for this consonant had been attained.

Using high speed cinefluorography technique, Amerman, Daniloff and Moll (1970) investigated timing and coarticulation of jaw opening and lip retraction for the vowel /æ/. Meaningful sentences containing sequences of up to four consonants preceding the vowel /æ/ were constructed and read by four American subjects. It was found that jaw lowering extended over two, and in many cases, three consonants preceding /æ/ irrespective of word or syllable boundaries. Lip retraction showed similar results but was less consistent. Their data also showed that the voiceless fricative /s/ resisted jaw lowering and thus blocked the propagation of anticipatory coarticulation: "This result could have presumably been extended to four consonants, had the /s/ phoneme not shown itself unexpectedly to be contradictory to jaw lowering" (p.151). The fact that jaw displacement did begin immediately with the release of /s/ gesture agrees with Kozhevnikov & Chistovich's observation that coarticulation

of a vowel gesture may proceed only after the cessation of an opposing consonantal gesture.

Benguerel & Cowan (1974) investigated coarticulation of upper lip protrusion in French, particularly in long consonant clusters preceding a rounded vowel. Meaningful utterances containing the consonant clusters /strstr/, /rskr/, /rsfr/ and /kstr/ followed by either a rounded or unrounded vowel were recorded by six native speakers of French. A photocell was used to transduce upper lip movements into a recordable electrical signal. The result of the study showed that lip protrusion started as early as the first consonant of a cluster of four to six consonants preceding the rounded vowel /y/ as in the phrase ´une sinistre structure´ /ynsini<u>strstry</u>ktyr/. It was even observed, in some cases, that the lip rounding gesture began as early as the vowel preceding the consonant cluster.

Gay et al. (1974) studied the effect of speaking rate on the articulation of labial consonants. Two speakers of American English read a list of nonsense syllables containing the consonants /p/ and /w/ and the vowels /i/, /a/ and /u/ in all possible VCV combinations at both ´moderate´ and ´fast´ speaking rates. Electromyographic recordings from muscles that control movements of lips, tongue and jaw were obtained simultaneously with high speed lateral view x-ray films of the tongue and jaw, and high speed full-face motion pictures of the lips. The

result of the experiment showed that "for labial consonant production, an increase in speaking rate is accompanied by an increase in the activity level of the muscle (orbicularis oris) and slightly faster rates of lip movement (both closing and opening). Vowel production, however, shows an opposite effect: an increase in speaking rate is accompanied by a decrease in the activity level of the genioglossus muscle and as shown by the x-ray films, evidence of target undershoot. Jaw movement data show more variable, context-dependent effects of speaking rate" (p.47).

Lubker et al. (1974) investigated labial coarticulation in Swedish. Lip protrusion during the production of one-to-six consonants preceding the rounded vowel /y/, in /CV1C1-6y/ sequences embedded in meaningful disyllabic words, was examined through electromyographic recordings of the orbicularis oris muscle and high speed photography of the lips. The result showed that lip protrusion for /y/ began slightly before the onset of the first consonant in the consonant string preceding the rounded vowel; and that electromyographic activity from the orbicularis oris began prior to the onset of the test utterance. The findings support Benguerel & Cowan's results for French and also support the concept of the ´articulatory syllable´ proposed by Kozhevnikov and Chistovich.

Gay's (1975) electromyographic study and (1977)

cinefluorographic study showed that the intervocalic consonant in V1CV2 constructions affected the onset of lip rounding for the rounded second vowel /u/. The rounding gesture for the post consonantal rounded vowel did not begin until the closure for the intervocalic consonant was completed even though the preconsonantal vowel was a rounded vowel as in the sequence /kutup/. Thus the result of this study contradicts the results of the above studies for Swedish and French. Gay concludes that both anticipatory and perseverative labial coarticulation do not spread further than the immediately neighbouring segment.

Bell-Berti & Harris (1979, 1982) investigated both anticipatory and perseverative coarticulation of lip rounding electromyographically, using both nonsense and meaningful words and phrases in American English. The results of both studies showed that lip protrusion or rounding occurs at a fixed time interval before and after the onset of the rounded vowel /u/ regardless of the number of consonant segments preceding or following it. Thus, they suggest that coarticulation is a time-locked process. This result contradicts Henke's 'look-ahead' scanning model, and also disagrees with the data of the following study by Sussman & Westbury.

In their electromyographic experiment, Sussman & Westbury (1981) examined anticipatory labial coarticulation associated with the rounded vowel /u/, to

establish whether the preceding neutral vowel /a/ and the antagonistic spread vowel /i/ facilitate or inhibit lip protrusion. Their data consisted of the five disyllabic nonsense words: /kikstu/, /kakstu/, /tiku/, /taku/ and /tuki/ which were repeated 20 times by 3 speakers of American English. Their results showed that EMG activity of the orbicularis oris superior began earlier and with greater force when the preceding vowel was /i/ than when it was /a/. Their finding contradicts both the articulatory-syllable model and the time-locked model; also it "contradicts the compatibility notion of the look-ahead scan model for right-to-left coarticulation" (p.23). They conclude by proposing an alternative operation for the look-ahead scan model to accommodate their findings for labial coarticulation: "The look-ahead scanner exhibits variable time programming depending on the unique queue of segments adjacent for production. The number of intervening consonantal segments should, in most cases, pose no special problem as rounding per se is not antagonistic to most consonants. Word boundaries are also no problem as the anticipatory rounding can span such linguistic units … The presence of prior vowels, however, creates a need for idiosyncratic programming adjustments. If a prior vowel is biomechanically antagonistic to rounding, then temporal and amplitude adjustments are incorporated into the anticipatory rounding gesture. If the initial vowel is itself a rounded

vowel an anticipated rounding command is initiated followed, perhaps, by a resetting of the scanner." (pp.22-23).

Lubker (1981) conducted a similar experiment on Swedish using nonsense utterances of the form /...V1CnV2.../. His results support those of Sussman and Westbury as it was found that lip protrusion for a rounded vowel is anticipated during the production of the preceding unrounded segments by a maximum temporal distance of about 600 msec before the onset of the rounded vowel; it was even found that rounding starts during the unrounded vowel preceding the consonants, but "the precise location of the onset of EMG activity within the nonround vowel appears to be somehow related to the stress of that vowel" (p.64). His data, he claims, provide evidence against the ´articulatory-syllable´ model and support the ´look-ahead´ model.

In 1982 Lubker & Gay conducted an experiment similar to the previous one to investigate anticipatory labial coarticulation in Swedish and American English. Their data revealed that there are language-specific differences in the production of rounded vowels as the speakers of Swedish "exhibit more extensive movement toward protrusion, produce more accurate target or goal positions, and either begin movement toward those positions earlier or in relation to the time available to them than do the speakers of American English" (p.445).

This suggests that anticipatory labial coarticulation is a "learned behavior, important to some languages such as Swedish, but not to other languages such as American English" (p.443).

In summary, labial coarticulation has been studied in relation to lip protrusion or rounding associated with rounded vowels, mainly through the use of electromyography. The results of the studies fall into two categories: The first category is represented by the results reported by Kozhevnikov & Chestovich (1965) for Russian, Daniloff & Moll (1968) for American English, Benguerel and Cowan (1974) for French, Lubker et al. (1974), McAllister (1974, 1978, 1980), Lubker (1981) for Swedish, and Sussman & Westbury (1981) for American English, where it was found that lip rounding for a phonologically rounded vowel was initiated during the non labial segments preceding it by about 600 msec or by as many as six segments preceding its onset including the unrounded vowel of the preceding syllable. In general the findings of those studies seem to support either the ´articulatory-syllable´ or the ´look-ahead´ model. The second category is represented by the results reported by Gay (1977, 1979) and Bell-Berti & Harris (1979, 1982) for American English, where it was found that anticipatory and perseverative labial coarticulation are not as extensive and that they occur at a fixed time

before and after the rounded vowel, thus, labial coarticulation, they claim, is "temporally locked to the onset of the rounded vowel or limited to a relatively small temporal window ... and therefore is not related to the duration of the consonant context in which coarticulation may occur" (Lubker & Gay 1982, p.437).

2.2   Linguo-Palatal Coarticulation

A number of acoustic studies have demonstrated that phonetic context, rate of production, stress, etc. influence the vowel spectra in connected speech. Lindblom's 1963 study of vowel reduction postulated ideal vowel "target" formant frequencies. Vowel production was assumed to be controlled by invariant neural commands. Increase in the rate of production resulted in failure of the articulators to reach the vowel "target" producing perseverative coarticulation or "undershoot". Lindblom also found that decrease in stress resulted in vowel reduction or "undershoot".

Stevens & House (1963) and Stevens et al. (1966) investigated the variability of vowel formants in /C1VC2/ constructions acoustically. Both anticipatory and perseverative coarticulatory variations of the vowel were observed and attributed to the phonetic context of C1 and C2. It was also found that formant frequencies of

tense vowels approached their hypothetical target values more closely than those of lax vowels.

Lehiste (1962) found that word boundaries influenced coarticulation. In her spectrographic study she examined /l/ spectra in various word and intra-syllabic positions. The analysis revealed that the spectra of /l/ differed according to its position within a morpheme and its position in relation to syllable and word boundaries.

Ohman (1966) examined the influence of vowel context on intervocalic consonants by means of spectrography. Nonsense vowel+voiced stop+ vowel, /V1CV2/, utterances were constructed and produced by Swedish, American and Russian speakers. The result revealed systematic coarticulatory variations of VC and CV transitions, and the transition variations were influenced by the vowel as well as the stop consonant involved. Anticipation of V2 began during the closure phase of the plosive, and V1 influenced the final VC opening phase. This demonstrates coarticulation over at least two segments on either side of a given segment. This finding led Ohman to propose a physiological model in which "the VCV articulations are represented by a basic diphthongal gesture with an independent stop-consonant gesture superimposed on its transitional portion" (p.151).

In his cinefluorographic study, Houde (968) investigated tongue movements during speech production. Radiopaque markers were attached to the surface of the

tongue of one speaker in order to observe the simultaneous motions of five small segments of the tongue. The subject produced 18 symmetrical trisyllablic utterances of the form /VCVCV/ constructed from the vowels /i/, /ɑ/ and /u/ and the consonants /b/ and /g/ at four conditions of rate and stress. It was found that in most cases the velocity of tongue movements toward and away from vowel targets was not affected by stress and that the rate at which articulatory components moved toward their target positions was independent of speaking rate. In the utterance involving the bilabial /b/, lip closure occurred simultaneously with tongue movement toward the vowel. In the sequence involving the velar /g/, the vowel to consonant transitions were generally shifted in the direction of the first vowel. Thus the tongue closure for the consonant is coarticulated with the preceding and the following vowels. This finding agrees with Ohman's model of speech production.

Perkell (1969) carried out a cinefluorographic study of the articulatory movements during the production of 13 nonsense utterances. His data showed that during the unstressed syllables in /hə'tɛ/ and /hə'zɛ/ sequences, the tongue tip began a rapid motion toward the dento-alveolar ridge and the target configuration of the following vowel, giving evidence that the tip of the tongue does perform anticipatory coarticulation across a

/VC/ sequence. Tongue body displacement for the vowels /u/ and /U/ during the utterances /h ə'tU/ and /h ə'tu/ began during the consonants preceding them, demonstrating anticipatory coarticulation effects of the following vowel for a /CV/ sequence.

MacNeilage & DeClerk (1969) performed a cinefluorographic and electromyographic study in which one subject read 36 CVC syllables. The syllables were constructed from all possible combinations of the consonants /b, d, g/ and the vowels /i, u, æ,ɔ/. Analysis of these syllables showed extensive allophonic variations. Anticipatory coarticulations were observed in nearly every case, either for the electromyographic voltage pattern or articulatory movements or both. Right-to-left coarticulation was found to be more frequent and of greater magnitude and complexity than left-to-right coarticulation. They claim that coarticulation results from the inherent mechanical characteristics and limitations of the articulatory mechanism and from deliberate overlapping of articulatory gestures. They also propose three control mechanisms to account for the observed contextual variations: an "anticipatory" mechanism for right-to-left coarticulation, a "compatibility" mechanism and a "gamma-loop" mechanism to account for left-to-right coarticulation.

Amerman (1970) investigated the coarticulatory behaviour of the apex and body of the tongue

cinefluorographically. Two subjects read specially constructed nonsense sequences of the form /C1C2V/, /C1C2C3V/ and /VC1C2/. The data indicated extensive anticipatory coarticulation by tongue apex and body, both in anticipation of consonant /VCC/ and vowel /CCV/ configurations respectively. This gives evidence for two distinct coarticulatory units /CV/ and /VC/.

Kent (1970, 1972) examined the dynamic properties of lingual articulation by using cinefluorography and spectrography. He performed two experiments, one for examining consonant articulation and the other for examining vowel and diphthong articulation. The data consisted of VCV and CV/CVCV utterances. It was found that the velocity of the closure and release of the intervocalic consonant in a symmetric vowel context depends on the distance between the vowel and consonant configurations; the larger the distance, the greater is the articulatory velocity. The closure and release of the intervocalic consonant was not accelerated with increase in speaking rate. Increase in speaking rate resulted in an undershoot in the production of diphthongs. The effects of speaking rate seemed to vary according to the particular vowel involved, for example, it was found that tongue body movements proceeding from an /o/ configuration were faster than movements proceeding from an /ɑ/ configuration.

In their cinefluorographic study, Carney & Moll (1971)

extended Ohman's (1966) study of coarticulation in /VCV/ constructions by using fricative intervocalic consonants instead of plosives. They found that when the fricative /f/ or /v/ was used, coarticulatory effects in the form of a basic vowel-to-vowel movement was observed in the entire tongue and in lip rounding. While, when the fricative /s/ or /z/ was used, where the tongue tip and blade are crucial for its production and therefore not free to coarticulate, the major coarticulatory effects were observed in the tongue body, tongue root and lip rounding only. It was also found that the vocal tract configuration during the production of a fricative is more affected by the postconsonantal vowel than by the preconsonantal vowel.

Kent & Moll (1972a), using cinefluorography, to study tongue body movements during vowel and diphthong gestures for two speakers of American English. Most of the speech samples consisted of meaningful sentences containing sequences of the form vowel+X+vowel or diphthong+ X+vowel, where X= null, a word boundary, a non-lingual consonant or a word boundary followed by a non-lingual consonant. Anticipatory coarticulation was observed, and the effects of V2 on V1 in V1V2, V1 V2 and V1CV2 sequences were noticed regardless of word boundary and intervening non-lingual consonant. Furthermore, the articulatory gestures of V1 and V2 interacted even when they had opposing gestures. For

example, a front vowel tended to be less front when followed by a back vowel, and close vowel tended to be less close when followed by an open vowel. The data demonstrated that anticipatory vowel-to-vowel coarticulation may traverse phoneme, syllable, morpheme and word boundaries.

In 1972b, Kent & Moll investigated mandibular position and tongue apex and body articulation for certain lingual consonants by means of cinefluorography. Two American subjects produced 12 VCV utterances made of the four consonants /g, j, d, z/ and the three vowels /i, u, ɑ/ at two speaking rates "moderate" and "rapid". They found that for the articulations of /j, d, z/ (but not for /g/), the individual points on the tongue assumed relatively invariant positions in the oral cavity for the production of these sounds. The small range of tongue positions found for /d/ and /z/ indicated that "at least part of the tongue body does not coarticulate freely with the surrounding vowel context" (p.472). This was ascribed to a strong physical coupling existing between tongue and apex and tongue body, preventing the body of the tongue from freely accommodating features of the vowel context during tongue apex articulations. As for /g/ it was found that the place of articulatory constriction varied according to the vowel context. Thus the effect of vowel context on consonant articulation can only take place in dorsal articulations and not in

apical articulations.

Gay (1974) performed a cinefluorographic/acoustic study to investigate the effects of changes in both phonetic context and speaking rate on the tongue and jaw movements in attaining target positions for the vowels /i, a, u/. Two American subjects produced nonsense utterances of the form /pV1CV2p /, where V1 and V2 were all possible combinations of /i, a, u/ with the consonants /p, t, k/ at both slow and fast speaking rates. He found that target positions of V1 and V2 were affected by both anticipatory and perseverative effects as a function of the intervocalic consonant. Least displacement of the vowel target occurred when C was /t/ and greatest when it was /p/. However, target positions of V1 were found to be stable across changes in V2, and this led him to conclude that anticipatory effects do not extend across the consonant to the preceding vowel. Perseverative vowel effects were observed and found to be of a fairly complicated nature and linked to the consonant separating the two vowels. The acoustic study did not reflect these coarticulatory effects. The fast production of the vowels resulted in an undershoot and an upward shift in the frequencies of the first and second formants.

Gay then designed an electromyographic experiment (1975) and a cinefluorographic experiment (1977) to explore whether tongue body and lip movements from one

vowel to another in V1CV2 sequences were constrained by the intervocalic consonant or not. Results from both studies showed that the intervocalic consonant affected the timing of movements of tongue body from V1 to V2. Movements of tongue body from the first vowel to the second vowel did not begin until the closure for the intervocalic consonant was completed. Thus Gay concluded that carryover and anticipatory effects for a given segment do not extend beyond the immediately neighbouring segment. Results from both studies argue against Ohman's (1966) model, which proposes that vowel-to-vowel movements in VCV is essentially diphthongal with the consonant simply superimposed on the basic gesture.

Barry & Kuenzel (1975) investigated coarticulatory airflow characteristics of intervocalic voiceless plosives by means of pneumotachography. Four subjects with three different language backgrounds (French, English, German) read nonsense utterances of the form V1CV2. From observing the filtered airflow curve patterns it was found that airflow during /k/ closure phase was the most sensitive to variations in the vowel context and /p/ was the least sensitive.

In their acoustic investigation of lingual coarticulation between the nasal /m/ and a following vowel and the effect of some juncture boundaries

between them, Su et al. (1975) found, in American English, that when there was no boundary, or only a low level juncture boundary (syllable or word boundary) between /m/ and the vowel coarticulation took place; but when there was a higher level juncture boundary (sentence boundary, intervening pause) between them a little or no coarticulation took place.

Butcher & Weiher (1976) studied tongue-palate contact during the production of VCV nonsense words by means of electropalatography. Both anticipatory and perseverative coarticulations were observed, with the anticipatory effect being more extensive. /i/ was found to exert the greatest effect and /a/ the least. Furthermore, coarticulation across closures from one vowel to the other was observed more frequently with alveolars than with velars.

Bladon & Al Bamerni (1976) investigated the extent to which the lateral /l/ in RP coarticulates with a neighbouring vowel, a second lateral and a voiceless consonant acoustically. They observed extensive coarticulation in both rightward and leftward directions. Their results were found to be consistent with Kozhevnikov & Chistovich's 'articulatory syllable' in which coarticulation is found to be maximum between a vowel and any number of consonants preceding it; this was found to be true not only for anticipatory coarticulation but also for perseverative coarticulation. Hence, they

conclude that the same mechanism of articulatory control is responsible for both right-to-left and left-to-right coarticulation. They also found that the syllabic dark [ɬ̩] is highly resistant to coarticulation while the non-syllabic dark [ɫ] is somewhat less resistant, and the non-syllabic clear [l] coarticulates more freely than the dark [ɫ]. Also it was found that /l/ coarticulates more with an adjacent voiceless plosive than with a voiceless fricative, but it does not coarticulate at all with a voiceless plosive if it is preceded by the voiceless fricative /s/. Thus they propose the notion of "coarticulation resistance": "Coarticulation on RP /l/ takes place freely from either direction, but the direction itself in unimportant. Antagonistic vocal tract adjustments apart, coarticulation is inhibited only by coarticulation resistance (CR) at some point in the succession of speech events. Each extrinsic allophone (and indeed each boundary condition) is assigned a value for CR by rules which may in some instances be language-particular or in others quasi-universal. The CR value could be represented as a numerical coefficient attaching to a phonetic feature, say [3 CR], along the lines proposed by Chomsky & Halle (1968) for all other phonetic specifications in the phonological system" (p.149).

Bladon & Nolan (1977) conducted a cinefluorographic investigation of tongue tip and blade alveolars in English. They found that while the apical alveolars /l/, /n/, /t/

and /d/ coarticulate with the laminal alveolars /s/ and /z/ by becoming laminals next to them in both directions, left-to-right and right-to-left, the laminal fricatives /s/ and /z/ resist coarticulation with the apical alveolars as they remain laminal next to the apical sounds. Thus they propose the notion of ´coarticulation resistance´ to interpret their data.

Amerman & Daniloff (1977) examined anticipatory coarticulation of tongue apex and tongue dorsum by means of cinefluorography. Two American speakers produced nonsense C1C2V and VC1C2 sequences. The voiced lax clusters /bd, bz, db, zb/ and the voiceless tense clusters /pt, ps, tp, sp/ were combined with the vowels /a,i, u, a, I/ in all possible combinations. It was found that for C1C2V sequences, tongue dorsum movements toward V began on C1; and for VC1C2, tongue apex movements toward C2 began during the steady state of the V segment. This demonstrates that the tongue performs anticipatory movements for both vowels and consonants at least two segments in advance of the anticipated segment. Tongue apex movements in anticipation of the consonant were found to be larger and more frequent than tongue dorsum anticipatory movement. They also found that the feature tense/lax did not affect the amount and the extent of coarticulatory effects.

In her acoustic investigation of Irish and Hiberno-English laterals, Ni Chasaide (1979) found that in

Irish, which has three distinct lateral phonemes, laterals coarticulated very little with the adjacent vowels and that "coarticulation, where it did occur, was primarily Left to Right" (p.71). This minimal and restricted coarticulation of Irish laterals is ascribed to the "constraints of maintaining a multiple opposition" (p.71) imposed by the phonology of the language. In contrast, it was found that in Irish-accented English, which has only one lateral phoneme, laterals coarticulated freely and extensively with their preceding and following vowels.

Schouten & Pols (1979a, 1979b, 1981) carried out three acoustic studies to investigate the mutual spectral effects of coarticulation of Dutch vowels and consonants. Five Dutch speakers read a list of 120 meaningful words of the structure CVC containing all possible combinations of four vowels /i, ε, a, u/ and six consonants /t, d, n, X, p, r/ in isolation and in a text in which these words occurred as stressed syllables. The coarticulatory effects were described as trajectories in a vowel subspace derived from band filter spectra. The steady state part of the vowel did not vary systematically with variations in the consonantal context; the CV- and to a lesser extent, the VC- transitions were found to combine into a pattern that was quite consistent over speakers and conditions. In the second study they added the glides /w, j, l/. The precise position of the glides was found to depend very much on the spectral position of the

preceding or the following vowel. In the third study the remainder of the Dutch consonants were included. The average of CV- and VC- transitions were calculated and the loci of the consonants were determined.

Mann & Repp (1981) and Repp & Mann (1981, 1982) found that in American English the production and the perception of a plosive are affected by the preceding fricative, as it exhibits higher onset values of F3 and F4 when following /s/ than when following / ʃ /. Thus plosives coarticulate with their preceding fricatives.

Recasens (1984b) investigated tongue-dorsum coarticulation with adjacent vowels during the production of alveolar and palatal consonants in Catalan ([n], [ʎ], [ɲ], [j]) electropalatographically and acoustically. His data revealed that the degree of "V-to-C coarticulation varies inversely with the degree of tongue-dorsum contact required for the production of the consonant" (p.72), as the alveolar [n] showed maximum coarticulation, where tongue-dorsum was not involved during its production, while the palatal [j] showed minimum coarticulation as its production involves the dorsum of the tongue. He concludes that: "This systematic dependence of coarticulatory effect on the degree of linguopalatal contact suggests that, to a large extent, coarticulation is regulated by mechanical constraints on articulatory activity" (p.72). The data also revealed that perseverative coarticulation is larger than anticipatory

coarticulation.

Manuel & Krakow (1984) tested their hypothesis that languages which have a relatively small vowel system exhibit a more extensive vowel-to-vowel coarticulation than languages which have a relatively large vowel system acoustically across three languages: English, Swahili and Shona. Their data consisted of VCV disyllabic utterances in a carrier phrase, where C was /p/ or /t/ in Swahili and /p/ in English and Shona. The results revealed that both Swahili and Shona, which have a five-vowel system, exhibited a large vowel-to-vowel coarticulation affecting both F1 and F2. Furthermore, anticipatory effects were found to be more extensive than perseverative effects; anticipatory effects were statistically significant for both F1 and F2 while carryover effects were only significant for F2. Coarticulatory effects in English were found not to be as large as those in Swahili and Shona and were found to affect F2 only. Furthermore, perseverative effects were found to be significantly greater than anticipatory effects. Thus they conclude that the "relationship between number of vowels and coarticulation suggests that coarticulation is not simply a by-product of the demands of fluent speech on motor planning and execution. Motor systems, while yielding to the demands of fluent speech, appear to be constrained by the necessity of maintaining distinctiveness, which for each language is

defined in the phonology" (p.69).

The above studies have shown that lingual coarticulation is more constrained than labial coarticulation. It is not as extensive either, as it has shown to affect only two segments in either direction. This is probably due to the fact that the tongue is involved during the production of almost all the sounds, thus it is not free to coarticulate with other sounds. Labial consonants, which do not involve the tongue in their production, exhibit maximum coarticulations, while palatal consonants, which do involve tongue body in their production, exhibit very little or no coarticulation. Linguo-palatal coarticulatory effects were also shown to spread irrespective of syllable and word boundaries.

2.3   Linguo-Pharyngeal Coarticulation

In this section a review of some of the studies which investigated linguo-pharyngeal coarticulation during the production of the pharyngealized consonants in Arabic will be given.

Ali & Daniloff (1972b) investigated the coarticulatory effects of the emphatic consonants in Iraqi Arabic by means of cinefluorography. Three speakers read meaningful and nonsense sequences of the structure CVC, CVCC, CVCVC and CVCVCV containing the plain consonants

/b, s, t, k/ and their emphatic counterparts /ɓ, ʂ, ƭ, ƙ/. Anticipatory and perseverative coarticulation of tongue backing for the pharyngealized consonants were observed in the real and nonsense words. Left-to-right coarticulatory effects were found to be larger and more extensive than right-to-left coarticulatory effects. This led them to the conclusion that perseverative spread of retraction is deliberately programmed and not only a result of mechano-inertia effects. The data also showed that emphatic backing gesture can spread over two open syllables in multi-syllabic words, as in /ƭabaʃir/ ('chalk') where backing spread from /ƭ/ to the following /aba/ in a left-to-right direction, while it fails to spread over a mono-syllabic word of the type CVCC. This led them to the conclusion that "coarticulation of the backing gesture is not a function of C or V alone, but is a syllable-tied process" (p.103).

In his cinefluorographic and acoustic study, Ghazeli (1977) examined the effect of linguo-pharyngeal coarticulation of the emphatic consonants on the adjacent vowels and consonants in Tunisian Arabic. His data showed that pharyngealization spreads in both right-to-left and left-to-right directions irrespective of syllable boundary, while it is blocked by word boundary. Anticipatory pharyngealization was found to involve the whole word and that it can spill over as many as seven segments preceding the emphatic consonant as in the

word /matfayyɣiʃ/ where tongue backing associated with the emphatic /ɣ/ starts as early as the first segment /m/. Perseverative emphatic coarticulation was also found to cover the segments of a whole word as, for example, in /ʂamitla/ where the effect of /ʂ/ spills over the following six segments. High front vowels were found to weaken the spread of pharyngealization in both directions, but they do not block it: "The R-L backing gesture extends over the entire word and is coterminous with it ... Although palatal vowels, especially the long ones, can weaken this backing they do not completely block it. The extent of L-R gesture, on the other hand, is highly dependent on vowel quality and duration. The presence of only low vowels in a word containing a pharyngealized consonant secures the propagation of pharyngealization throughout the word regardless of syllable boundaries" (pp.127-128).

Younes (1982) investigated the spread of pharyngealization in Palestinian Arabic acoustically. His data revealed that segments both to the right and to the left of an emphatic consonant coarticulate with it. Anticipatory coarticulation was found to be more prominent than perseverative coarticulation; the presence of a syllable boundary did not hinder the spread of pharyngealization. The data also showed that there are several factors which block or weaken the spread of coarticulation, these factors were found to be: distance

from the emphatic consonant, the farther the segment is from the emphatic consonant, the weaker is the coarticulation; the presence of word boundary and some morpheme boundaries like /la/ and /ma/; the presence of long vowels and the front high vowel /i/; the presence of the palato-alveolar consonant / ʃ / and the velar consonant /k/.

In his electropalatographic and spectrographic study of emphatic coarticulation in Sudanese Arabic, Ahmed (1984) confirms the results of the previous studies on linguo-pharyngeal coarticulation of emphasis. Coarticulatory effects were found to spread to the right and to the left of an emphatic consonant across syllable boundaries. Word boundary did not seem to inhibit anticipatory coarticulation, while it did block perseverative coarticulation. The alveolar consonants /n/ and /s/ were found to enhance the spread of coarticulation in both directions; the palato-alveolar / ʃ / blocked the spread of emphasis across syllable boundary in the left-to-right direction only; while the velar /g/ constrained or blocked coarticulation in both right-to-left and left-to-right directions.

From the above studies, we may conclude that linguo-pharyngeal coarticulation can spread in both directions, right-to-left and left-to-right, across syllable boundaries but not across word boundaries. The spread

of pharyngealization within a word depends on the nature of the segments involved in that alveolar consonants and low open vowels seem to facilitate its spread while front high vowels and the palato-alveolar consonant /ʃ/ and the velars /k/ and /g/ seem to weaken or even block its propagation.

Kelsey et al., (1969), have investigated the coarticulation effects of the lateral pharyngeal walls (LPW) by using a pulsed ultrasonic technique to monitor the displacement of the LPW during the production of the nonsense utterances /iba/, /ibi/, /abi/ and /aba/. The results showed that the extent of VC and CV motion was different depending on the other vowel. Furthermore, the data showed that there was more displacement of the lateral pharyngeal walls during the vowel /a/ than during the vowel /i/, and that the displacement during /a/ varied as a function of the phonetic context.

2.4   Velopharyngeal Coarticulation

In his 1960 demonstration study of cinefluorographic technique, Moll found that velopharyngeal closure on vowels varied systematically "not only as a function of the vowel sound produced, but also as a function of the phonetic context of the vowel" (p.239). In his 1962 study,

Moll re-examined velopharyngeal closure on vowels. Ten speakers of American English produced 60 CVC nonsense syllables made of all possible combinations of the consonants /t,d,s,z,n,p/ and the vowels /i,a,ɑ,u/. It was found that velopharyngeal closure was not accomplished on vowels adjacent to the nasal /n/. Furthermore, the amount of opening was found to depend on the vowel sound and on the position of the nasal consonant. The open vowels /a/ and /ɑ/ exhibited greater velopharyngeal openings than the close vowels /i/ and /u/; there was also more opening when /n/ followed the vowel than when it preceded it, showing that anticipatory coarticulation is greater than perseverative coarticulation.

Moll & Shriner's (1967) cinefluorographic investigation of the activity of the velum showed that velopharyngeal activity for nasal-vowel CV syllables was dependent upon the rate of production, and was interpreted as a result of mechanical coarticulation. They hypothesized that there are only two modes of muscular activity in the velum during speech, ´on´ and ´off´ or lowered and raised and that "intermediate positions of the velum would then be due to varying mechanical restraints on velar movement and to the relative timing of the muscular signals, rather than to changes in the muscular forces applied to the velum" (p.59). In the experiment, two subjects produced CV syllables, where

V=/u/ or /a/ and C=/m/, at rates of one, two and four syllables per second. The results showed as the rate of the utterance increased the effect of the nasal consonant on the following vowel was greater as the velum "undershoots" the position that it would attain if enough time were available. Velic coarticulation was also found to be affected by the height of the tongue as the average level of velic elevation was higher for the syllables containing the high vowel /u/ than for those containing the low vowel /a/.

Lubker (1968) designed an electromyographic/cinefluorographic study to investigate the neuromuscular events associated with the movements of the velum during speech and to test Moll & Shriner's hypothesis. He found that a high tongue position is associated with a high velum position, and this he interprets as a result of neuromuscular command since greater velar elevation is needed to prevent high vowels from being detected as nasal in quality. Contrary to Moll & Shriner's study, neither velic position nor electromyographic activity showed significant differences between 'short' and 'sustained' durations. It was found also that coarticulation of velopharyngeal activity is a function of phonetic context and that perseverative coarticulatory effects of a nasal consonant extends over the neighbouring vowel.

In 1971 Moll & Daniloff investigated the timing and

the extent of velopharyngeal coarticulation in American English. Their study revealed marked anticipatory coarticulation of velic opening during /CVVN/ sequences as velic opening began during the transition from the consonant gesture to the first vowel in sequence. While anticipatory velopharyngeal coarticulation did not occur in /CCV/ sequences. Perseverative coarticulatory effects of velar opening was not often observed in /NVC/ or /NC/ sequences and was attributed to mechanico-inertial effects. Furthermore, the presence of a word boundary within the sequence did not affect the relative timing of coarticulatory behaviour.

Dixit & MacNeilage's (1972) electromyographic/aerodynamic study of the extent of velopharyngeal coarticulatory effects led to the following results: coarticulatory effects stretched across four segments, perseverative effects were as extensive as anticipatory effects, and the temporal scope of coarticulation was not restricted by syllable or word boundaries.

McClean (1973) investigated the effects of 'marked' junctural boundaries on the onset of anticipatory velopharyngeal coarticulation by means of cinefluorography. The term 'marked' was used to refer to "junctural boundaries prosodically modified in some manner to signal a higher level linguistic constituant such as a phrase, clause or sentence" (p.287). The sequence /rian/

(/CVVN/) was embedded in seven sentences with a variety of junctural boundaries falling between them. The results showed that when there was an unmarked junctural boundary between the two vowels the velic opening gesture to the nasal consonant started from the first vowel. This finding is consistent with the results of the Moll & Daniloff study. However, the onset of velopharyngeal coarticulation was found to be consistently delayed where there was a marked junctural boundary between the two vowels. This delay in the onset of coarticulation was explained by McClean to be "due to high level reorganization of the input commands to the velum" (p.295), that is to say that in those cases with marked junctural boundary, the phonetic sequence /ri/ would terminate the first input string, while /an/ would initiate the second input string.

Kent et al. (1974) also examined velic movements in American English by using isolated vowels and nasal consonants, nonsense syllables, and seven meaningful sentences containing CVVN, CVN and VNC sequences. Right-to-left coarticulation of velopharyngeal opening was evident in the data up to two segments before the nasal consonant regardless of word or syllable boundaries.

Ushijima & Hirose (1974) examined electromyographic recordings of the levator palatini muscle of two Japanese speakers while producing 28 meaningful disyllabic words to investigate the possible correlation between the

muscle activity and velopharyngeal height, especially for nasal coarticulation. Anticipatory nasal coarticulation was observed in the data, but it was affected by syllable boundary location. The velum did not lower during the vowel segments preceding a syllable boundary in CVV VN sequence. Perseverative coarticulatory effects were not as pervasive as the anticipatory effects. Furthermore, it was found that they are present for vowels following syllable initial nasals and not for vowels following syllable final nasals. Contrary to Moll & Shriner's study and Moll & Daniloff's study, Ushijima & Hirose conclude that motor command to the velum is not binary, and is thus not controlled by a single "on" and "off" mechanism. They also indicated that there are different mechanisms for anticipatory and perseverative effects of coarticulation at the level of motor commands.

Benguerel (1974) investigated velopharyngeal coarticulation in French through observing nasal airflow patterns. It was found that for both nasal consonants and nasalized vowels, velopharyngeal opening began well ahead of the nasal sound itself. When a nasalized vowel was preceded by a four consonant cluster, the opening gesture of the velum began two consonants before it, while nasal airflow started only one consonant prior to the nasalized vowel. When a nasal consonant was preceded by one or two vowels, velopharyngeal opening was observed to start earlier than the vowels. The

results were found to be consistent with Henke's look-ahead model.

Clumeck (1976) investigated vowel nasalization in 6 languages: American English, Swedish, French, Amoy Chinese, Hindi and Brazilian through the use of a nasograph. His results revealed that low vowels are more nasalized when adjacent to a nasal consonant than are high vowels. The extent of coarticulated nasality was found to be language-specific as the Americans and Brazilians showed the greatest amount of nasal coarticulation while the Amoy Chinese exhibited the least nasal coarticulation: "The degree of anticipatory nasalization during vowels preceding nasal consonants differs among speakers of different languages: early soft palate lowering is observed in speakers of American English and Brazilian Portiguese, whereas lowering is initiated at a later point during the vowel by speakers of Hindi, French, Swedish ... and Amoy Chinese" (p.348).

Benguerel et al. (1977a) examined velopharyngeal coarticulation in French by means of a wide angle· fiberscope. Experimental utterances included isolated CVC and VCV sequences and specially constructed utterances in which a vowel or its nasalized counterpart was preceded by a four consonant cluster and a nasal consonant was preceded by one to four vowels. The data showed extensive anticipatory coarticulation, in the phrase "quatorze frondeuses" /katɔ̃rzfrɔ̃døz/, for example, the

velum was noticed to start lowering for the nasalized vowel /ɔ̃/ during /z/ and by the end of the cluster it reached its maximum downward movement. The upward movement of the velum following a nasalized vowel was noticed to be significantly faster than the lowering movement preceding it. Also, it was observed that when a nasal consonant was preceded by two or three oral vowels, the velum started to lower much earlier than when it was preceded by only one vowel.

In 1977b, Benguerel et al. performed a parallel electromyographic study in which electromyographic recordings were made from the levator veli palatini and the palatoglossus muscles in an attempt to correlate velopharyngeal height and movement with the activity of the muscles of the velum. Anticipatory coarticulation for both nasalized vowels and nasal consonants were observed, whereas perseverative coarticulation was not observed. Syllable boundary location was not found to affect coarticulation. Nasalization, they say, "does not appear to be controlled by a simple binary mechanism. In particular nasalized vowels and nasal consonants appear to be controlled in different ways" (p.159).

The above studies have demonstrated that coarticulation is a very important phenomenon of speech production. It is the "crux of speech production"

(Hammarberg 1982, p.123) and the "essence of the speech code" (Liberman & Studdert-Kennedy 1978, p.163). In their study of coarticulation, investigators tried to shed some light on such questions as the nature and size of the programming units in speech production and on the value of coarticulated features as perceptual cues in decoding the speech signal. Thus coarticulation data can be used in the testing of speech production and speech perception models.

CHAPTER   THREE

EMPHATIC CONSONANTS

<u>3.1.</u>

<u>The articulatory and physiological characteristics of
the emphatic consonants</u>

Arab grammarians had realized the unique phonetic
quality of the emphatic consonants /ŧ/, /đ/, /%/ and /ə/
and tried to describe them in terms of their place of
articulation. The earliest definition or description of
these emphatic sounds date back to the works of early
Arab grammarians of the Middle Ages. Si:bawaih, in the
8th century, classified them as "al-ħuru:f al-muŧbaqah" in
his ´Kita:b´. According to him they all share the feature
of ´iŧba:q´ which he describes as raising the front of the
tongue to the front part of the palate and applying the
back of the tongue towards the ´upper´ palate. For
Si:bawaih then, emphasis involves a double articulation
where both the front and back of the tongue are
involved with the sound ´trapped´ between these two
strictures.

In the 12th century Zamaxshari in his ´Al-Mufassal´
classified the emphatic consonants /ŧ/, /đ/, /%/ and /ə/
along with the uvulars /X/, /ɤ/ and /q/ as "al-ħuru:f
al-mustaʕliyah" as they all according to him share the
feature of "al-istiʕla:?" which he describes as "the raising
of the tongue towards the palate with or without

´iƚba:qˊ" (p.190).

Another term used by Arab linguists in their classification of the emphatic sounds is "al-ħuru:f al-mufaxxama" which means "heavy" or "thick" sounds. This classification, unlike the other two which are articulatorily based, is acoustically or auditorily-based and includes both the "muƚbaqa" and the "mustaSˁIiya" consonants.

These "mufaxxama" sounds are what modern linguists refer to as the ´emphatic´, ´velarized´ or ´pharyngealized´ sounds. In this study we will be using the terms emphatic and pharyngealized interchangeably to refer to the ´mufaxxama´ consonants in Qatari Arabic which are /ƚ/, /ɣ/, /ʂ/ and /ƚ/.

Sacy (1810) was the first one to use the term "emphasis" in referring to the Arabic pharyngealized consonants which he says are articulated with "une sorte d´emphase. Ce que j´appelle emphase ou articulation emphatique est une espèce de renflement qu´il n´est pas aisé de définir mais qui fait en quelque sorte entendre un o sourd après la consonne" (p20).

Brücke (1860) gives a detailed articulatory description of the emphatic consonants. In describing /ƚ/ he states that glottal vibration of the following vowel starts with the release of its closure, thus referring to

the lack of aspiration characteristic of /ŧ/. He also observes the effect of the emphatic consonants on adjacent vowels by referring to them as being "thick" (´dicke´) or "fat" (´fette´) while they are "thin" (´dünne´) when adjacent to the non-emphatic consonants.

Meinhof (1921) and Panconcelli-Calzia (1924) investigated the effect of emphasis on the adjacent vowel and the role of the larynx in the production of emphatic sounds. They noted that the beginning of the vowel following an emphatic consonant is compressed as a result of lowering the epiglottis towards the laryngeal entrance and raising the larynx itself. Panconcelli-Calzia found from his kymographic study that /t/ has a much higher degree of explosion than /ŧ/ and that larynx vibration starts much earlier at the release of /ŧ/ than /t/. (Giannini & Pettorino, 1982).

Marçais (1948) conducted a kymographic, x-ray and palatographic study of emphasis in Maghreb Arabic. He found that the emphatic consonants are characterized by raising of the hyoid bone and the larynx, lowering of the tongue dorsum and retraction of the root of the tongue.

At present there are quite few phonological and phonetic studies which shed light on physiological properties of the emphatic sounds in some dialects of Arabic, either impressionistically or experimentally (Harris 1942, Moroccan; Marçais 1948, Algerian; Blanc 1953,

Palestinian; Ferguson 1956; Jakobson 1957, Palestinian; Harrell 1957, Egyptian; Gamel-Eddine 1959, Egyptian; Cantineau 1960; Lehn 1963, Egyptian; Cohen 1969; Khalafallah 1969, Egyptian; Delattre 1971, Iraqi; Ali and Daniloff 1972, Iraqi; Odisho 1973, Iraqi; Ghazeli 1977, Tunisian; Younes 1982, palestinian; Giannini & Pettorino 1982, Iraqi; Card 1983, Palestinian; Laradi 1983, Libyan; Ahmed 1984, Sudanese).

Most of the studies in the 40's, 50's and 60's were phonological studies. They tried to analyse emphasis as it occurs in the phonological systems of certain dialects of the Arabic language. They attempted to answer such questions as: How many emphatic sounds are there in the studied dialect? Is emphasis a property of the consonant system or the vowel system? Or is it a suprasegmental feature? If so what is its domain, consonants and /or vowels, or syllables? Is it an extra-linguistic feature determined by sex, register, social class, etc.?

Most of the studies concerned with emphasis in the seventies and eighties were experimental phonetic studies attempting to diagnose its physiological articulatory manifestation and its acoustic properties. These studies attempted to answer such questions as: do neighbouring sounds coarticulate with the emphatic segments? And if emphasis does spread what is its direction and magnitude? What are the aerodynamic and

timing properties of the emphatic sounds as opposed to the non emphatic sounds? What are the lingual-palatal contact characteristics associated with them?

It is a well established fact that the emphatic or pharyngealized sounds are produced with secondary articulation, that is to say that their articulation requires two points of stricture in the vocal tract, one of greater degree than the other called primary stricture, and the other of a lesser degree called secondary stricture: "the secondary articulation is a stricture of open approximation of the articulators, and as such involves less constriction of the vocal tract than the primary articulation does, whatever it may be." (Abercrombie 1967, p.62). This secondary articulation is what mainly distinguishes the emphatic consonants /ŧ/, /ṣ/, /ẓ/ and /ɫ/ from their non-emphatic counterparts /t/, /s/, /ð/ and /l/.

The primary articulation for /ŧ/ is the complete closure between the blade of the tongue and the alveolar ridge as it is a lamino-alveolar plosive; /ṣ/ is a lamino-alveolar fricative as its articulation involves a close approximation between the tongue blade and the alveolar ridge; / ẓ / is a dental fricative and its production requires a stricture of close approximation

between the tip of the tongue and the inside wall of the incisor; /ɬ/ is an apico-alveolar lateral as its production involves a complete closure between tongue tip and the alveolar ridge with an open lateral escape.

The secondary articulation which is common to all the emphatic segments is the retraction of the back of the tongue towards the upper posterior wall of the pharynx at the level of the second vertebra causing a depression of the tongue dorsum. This rearward movement of the tongue increases the volume of the oral cavity and reduces the pharyngeal cavity above the epiglottis. It also causes the retraction of the tongue tip and blade. This can be seen in the xeroradiograms for /s/ and /ʂ/.

Our xeroradiographic investigation, (see Chapter Five for details of technique, analysis and procedure), revealed that the emphatic voiceless fricative /ʂ/ (Figure 3.1.b) in the word /ʂaːd/ compared to its non-emphatic counterpart /s/ (Figure 3.1.a) in the word /saːd/, as said by FB, displays a longer and narrower area of constriction between tongue back and root and the back wall of the pharynx at the level of the second cervical vertebra. The back of the tongue bulges up and retracts towards the posterior pharyngeal wall, the tongue root is pushed downward and backward, the laryngeal ventricle is more open, the highest point of the tongue is under

Figure 3.1.a /s/ in /sa:d/ ´to prevail´
    as said by FB
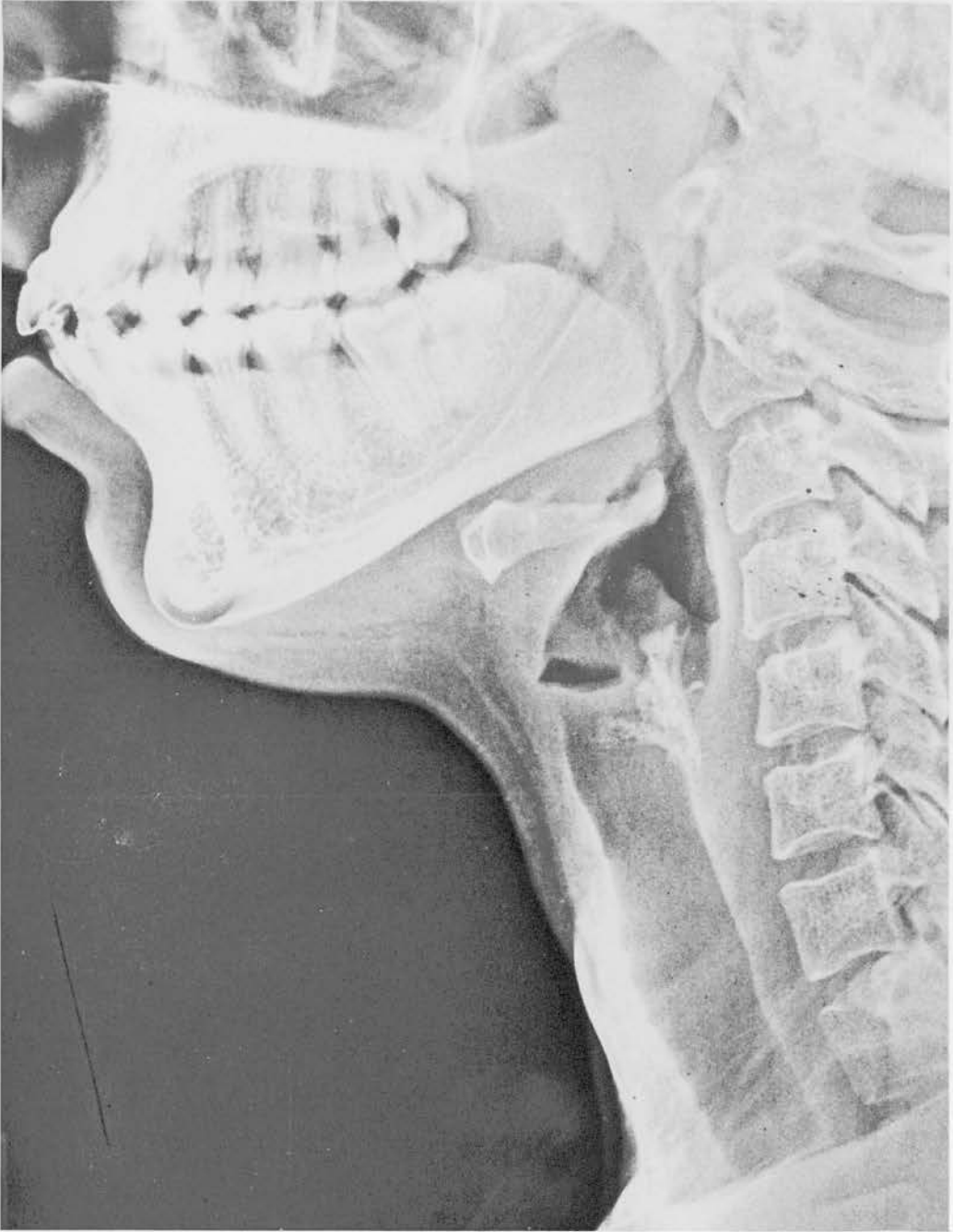
Figure 3.1.b /ə/ in /sa:d/ ´name of the letter s´
as said by FB

the soft palate while it is under the hard palate for /s/. Both hyoid bone and larynx positions do not change during the production of /ṣ/. Both /s/ and /ṣ/ exhibit the same lip posture and a velic closure is maintained during their production. The table below (Figure 3.1.c) shows the measurements for the concerned anatomical parameters (defined in Chapter Five) in mm.

A comparison of /s/ in /sa:d/ (Figure 3.1.d) and /ṣ/ in /ṣa:d/ (Figure 3.1.e), as produced by HJ, reveals that the larynx is raised by about 3 mm and the hyoid bone is raised by about 2 mm with its horns pointing towards the area between the third and forth cervical vertebrae. The tongue back and root and the epiglottis are retracted towards the posterior pharyngeal wall, leaving a very narrow oropharyngeal passage, with the narrowest constriction at the level of the third cervical vertebra (3 mm wide for /ṣ/ and 7 mm wide for /s/). The table below (Figure 3.1.f) shows the measurements for the concerned anatomical parameters in mm.

Lehn (1963) defines emphasis as the "cooccurrence of the first and one or more of the following articulatory features: (1) slight retraction, lateral spreading, and concavity of the tongue and raising of its back, (2) faucal and pharyngeal constriction (pharyngealization), (3) slight lip protrusion or rounding (labialization), and (4) increased tension of the entire

Para-meters	1	2	3	4	5	6	7	8	9
At rest	10	4	12	9	2	5	4	34	5 5 13
sa:d	12	9	0	5	5	6	3	32.5	4 3.5 4
sa:d	12	7	0	1	5	6	3	33	5 4 4

Figure 3.1.c

Parameters from xeroradiographic analysis

FB

Figure 3.1.d /s/ in /sa:d/ ´to prevail´
      as said by HJ
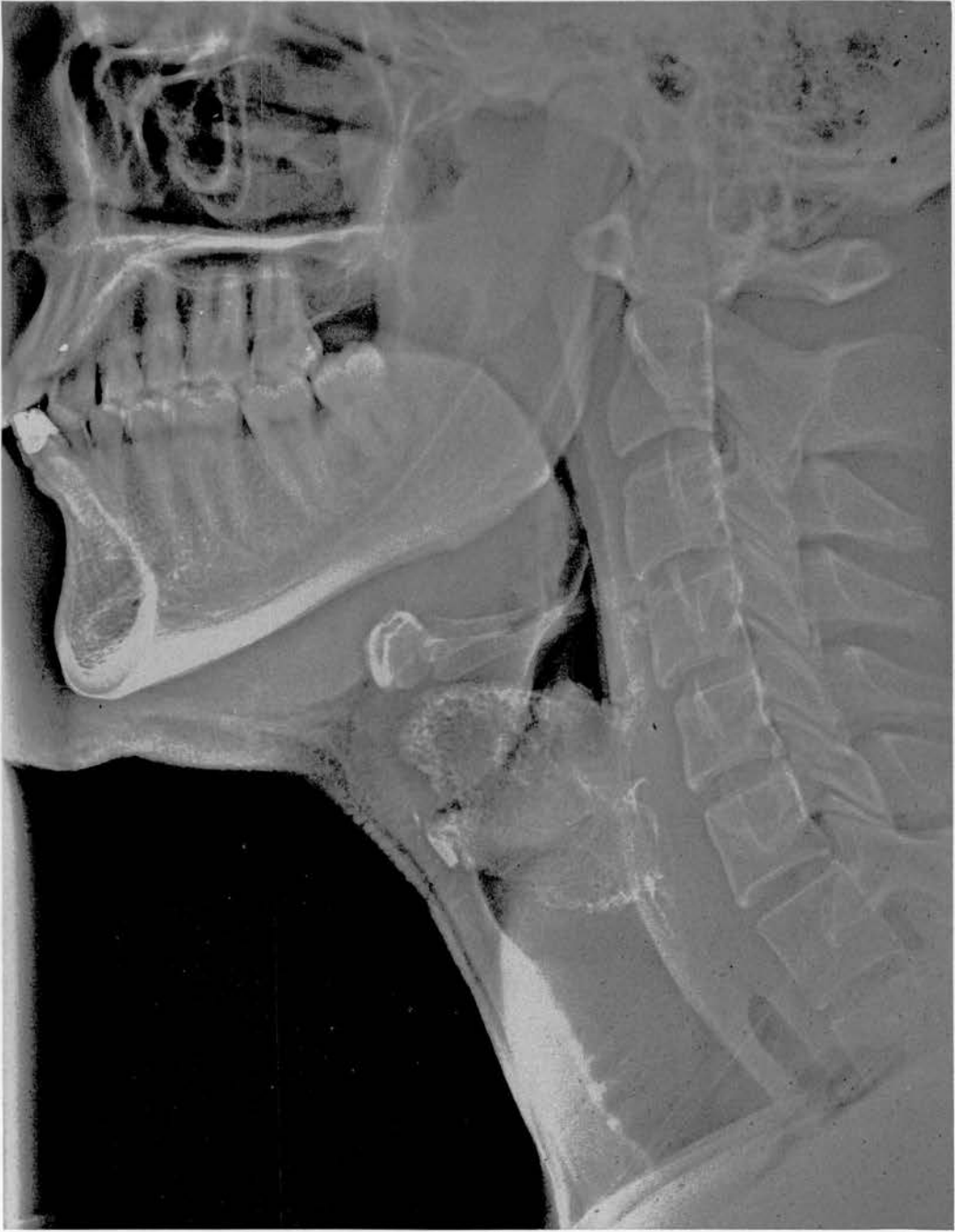
Figure 3.1.e /s/ in /sa:d/ 'name of the letter s'
as said by HJ

Param-eters	1	2	3	4	5	6	7	8	9
At rest	0	13	11	16	8	16	4	46	6 4.5 10
sa:d	–	11	0	11	7	11	3	43	4 4 6
sa:d	2	7	0	5	3	5	4	42.5	4.5 4 8

Figure 3.1.f

Parameters from xeroradiographic analysis

HJ

oral and pharyngeal musculature resulting in the emphatic being noticeably more fortis than the plain segments." (p.30).

Ali and Daniloff (1972), in their lateral-view cinefluorographic study, investigated the role of the tongue root, the velum, the posterior pharyngeal wall and the hyoid bone during the production of emphatic consonants as opposed to their non-emphatic counterparts. Their results showed that the tongue plays the most important role in differentiating between the emphatic and non-emphatic sound production. The lowering of the tongue dorsum and the rearward movement of the back of the tongue are the main movements responsible for the particular quality of the pharyngealized consonants, "the tongue dorsum and/or tongue root is the primary articulator for emphatic sound production. Viewed sagittally, the lingual profile exhibits simultaneous depression of the palatine dorsum and rearward movement of the pharyngeal dorsum during articulation of emphatic sounds; all emphatic consonant cognates examined in this study displayed this differential tongue movement. The net physiological result of this differential movement is a marked, localized pharyngeal constriction and a simultaneous, slight expansion of the oral cavity in front of this constriction." (pp.99-100). Their results also showed no

differences in the movement of the pharyngeal wall, the velum and the hyoid bone nor in the articulator velocity, duration of movement or closure, or of timing between the emphatic and non-emphatic consonants.

Ghazeli (1977), in his cinefluorographic study of pharyngealization in Tunisian Arabic, found similar results to those of Ali and Daniloff (1972) concerning tongue movement. All the pharyngealized sounds exhibited a rearward movement of the back of the tongue towards the back wall of the pharynx and a depression in the tongue dorsum . But he observed that the degree of tongue backing was not the same for all the emphatic consonants, it was most back for /t̪/ and least for /s̪/. The average difference in the position of the back of the tongue between /t/ and /t̪/ was 10 mm., between /s/ and /s̪/ was 6 mm. and the backing for /ʧ̪/ was less than /t̪/ but more than /s̪/. Ghazeli did not observe any difference in the width of the lower pharynx between the pharyngealized and non-pharyngealized segments. He also observed no hyoid bone and larynx displacement nor lip rounding or protrusion associated with the pharyngealized sounds.

Laradi (1983), in her videofluorgraphic and endoscopic investigation of pharyngealization in Libyan Arabic, states

that the differences between the emphatic consonants and their non-emphatic cognates are as follows "the constriction in the pharynx made mainly by the rearward movement of the tongue is the main factor which gives these sounds their special characteristics of resonance affecting all the adjacent vowels and consonants. Other manifestations in the pharyngeal cavity that show the difference between pharyngealized and non-pharyngealized consonant lie in the movement of the epiglottis and the lateral walls of the pharynx which are considerably constricted in the case of the pharyngealized group. The other difference lies in the front part of the vocal tract manifested in a slight retraction of the tip or blade of tongue and a firm contact of the sides of the tongue against the upper teeth". (pp.325-326). She also observed a difference in the larynx movement as the laryngographic trace for the pharyngealized consonants showed a "stronger and more vigorous pull downwards of the larynx, followed by a rapid upward recovery movement". (p.284). Her airflow results showed no significant difference in the pattern of the airflow wave form between the pharyngealized and non-pharyngealized sounds.

Ahmed (1984) conducted an electopalatographic and electrokymographic experiment to investigate the emphatic sounds in Sudanese Arabic. His results revealed

that in contrast to their non-emphatic cognates the emphatic consonants exhibited the following: (1) lower rates of airflow, (2) longer voice onset time for plosives, (3) less area of lingual-palatal contacts in the back and central regions of the palate. (p.230)

As for the intra-oral pressure during the production of the emphatic and non-emphatic consonants both Al-Jazary (1981) and Ahmed (1984) found no significant difference.

3.2 Electropalatographic investigation of Emphasis

We carried out the following electropalatographic (EPG) and electro-kymographic experiment to investigate the physiological coarticulatory effects of the pharyngealized consonants /ṭ/, /ṣ/ and /ḷ/ on the neighbouring non-pharyngealized consonants and vowels in Qatari Arabic.

As we have seen above, the main physiological characteristics of the pharyngealized consonants is the retraction of the back of the tongue towards the upper posterior wall of the pharynx causing slight retraction in the primary place of articulation and lowering of the body of the tongue away from the palate. If the effect

of pharyngealization is to spread across the neighbouring vowels and consonants we expect these affected sounds to exhibit similar physiological features which can be detected indirectly by using electropalatography.

3.2.1 Technique

E lectropalatography is a dynamic technique for investigating the location and timing of tongue contacts with the palate during continuous speech. The system used in this experiment is the micro-computer controlled electropalatograph developed in the Department of Linguistic Science at the University of Reading. It employs the use of a very thin acrylic palate (0.5 mm thick) with 62 electrodes embeded in it, and is made to fit the subject's palate (see Figure 3.2.1). This unit of the system, the artificial acrylic palate with its electrodes, is made in the Phonetics Laboratory of the Linguistics Department at the University of Edinburgh.

The electropalatograph's four multiplexers and preamplifiers are contained in a small box, $15 \times 9 \times 3$ cm, which is to be worn by the subject around his neck, and the palate connector is plugged into it. Thus the wires from the palate which carry low level signals are kept short and the buffered output signals are fed over a
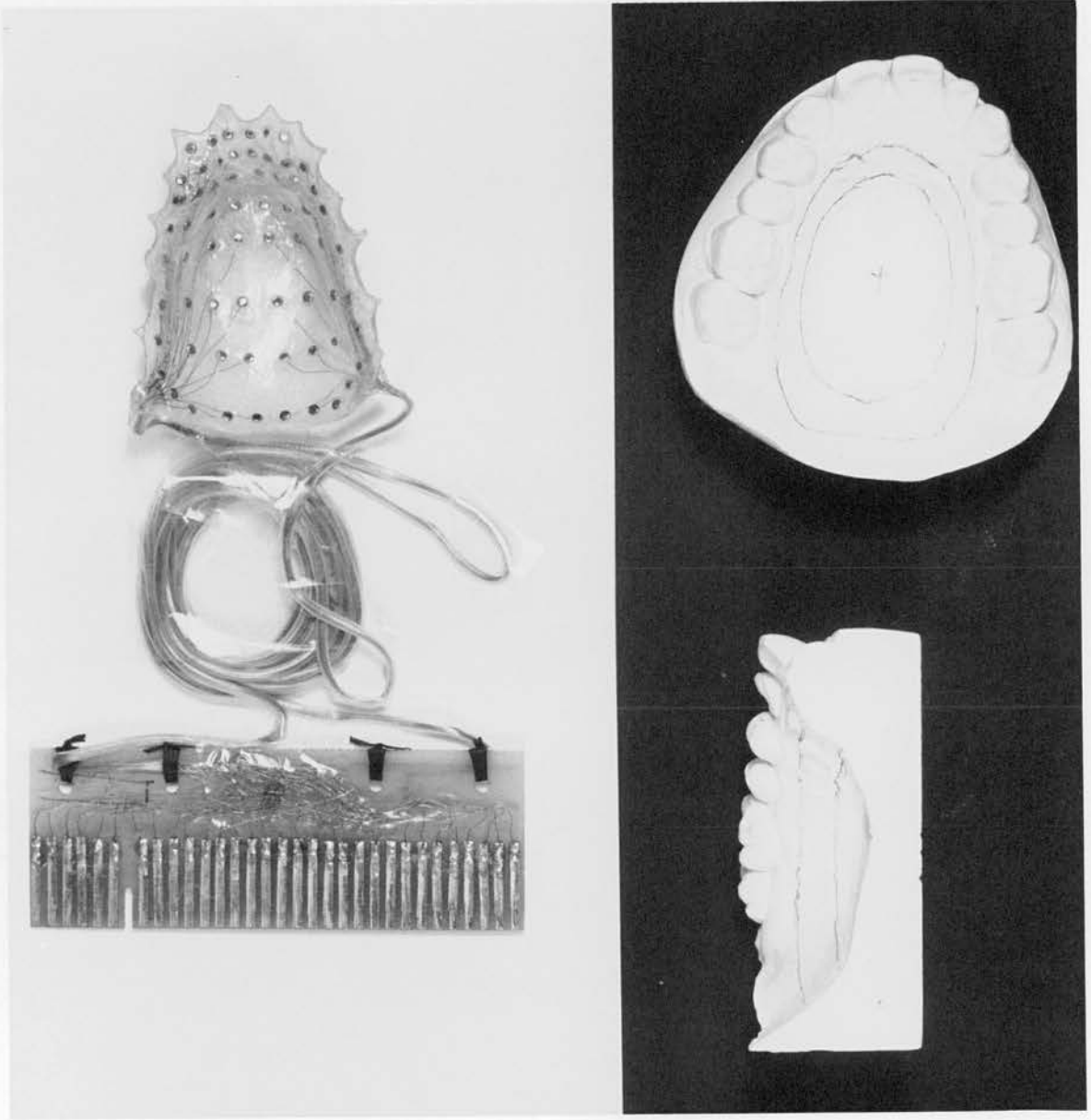
Figure   3.2.1

relatively long cable to the main unit. The main circuit board with the batteries and computers connections are contained in a box, 22×23×7 cm, (computer interface unit), which plugs into the micro-computer.

The computer used is the Commodore CBM 4000 Series which is based on the 6502 microprocessor. The subject holds a brass rod in his hand so that an A/C signal is supplied to his body when the tongue touches the electrodes in the palate and an electrical circuit is completed. The A/C signal supplied to the body electrode is 300 mV r.m.s. at 15 KHz with the current limited to 50 microamps. This signal current is well below the limit generally accepted as representing a significant micro shock hazard.

"The time taken to detect the presence of a signal is 200 microseconds which allows a scan of all 62 electrodes including data storage to be completed in 4 milliseconds. This scanning rate is sufficient to allow the dynamic movements for the tongue to be resolved without appreciable skew in the data.

The signals from the 4 multiplexers are amplified, peak detected and compared against a present reference level. The reference level is common to all the 4 channels and is set to discriminate against a background level of unwanted signals due to capacitive coupling and conduction through saliva. The computer circuits give

digital outputs which are optically coupled and latched to be read by the computer." (Jones, 1985).

3.2.2 Subject

The subject was the author of this study, a female native speaker of Doha Qatari Arabic.

3.2.3 Data

The test items consisted of a list of 14 meaningful minimal pairs, eleven pairs were isolated monosyllabic and polysyllabic words and three were meaningful phrases. The list was randomized and read three times by the subject at a normal conversational rate and effort. The list was made up of

/ʃo:t/	´kicking´
/ʃo:ʈ/	´electric shock´
/ris/	´origin´
/riʂ/	´compress!´
/naʃi:d/	´anthem´
/naʃi:ʈ/	´active´
/ti:n/	´figs´
/ʈi:n/	´clay´
/si:n/	´name of the letter "s"´

/ʃi:n/	´china´
/sa:d/	´to prevail´
/ʂa:d/	´name of the letter "ʂ"´
/sid/	´block!´
/ʂid/	´turn away!´
/tal/	´to pull´
/ʈal/	´to look out´
/sa:matla/	´she asked about the price for him´
/ʂa:matla/	´she fasted for him´
/nisi:b/	´relative by marriage´
/niʂi:b/	´luck´
/Xalle:na:/	´we left it´
/Xaɬɬe:na:/	´we emptied it´
/be:t ta:jir/	´a rich man´s house´
/be:t ʈa:jir/	´a flying house´
/ħat ismi/	´he scraped off his name´
/ħaʈ ismi/	´he put his name down´

3.2.4 Experimental setup

The subject was seated comfortably on a chair and wore the artificial acrylic palate with its connector plugged into the multiplexer´s box which she was wearing around her neck. The multiplexer box was connected to the computer interface which was plugged into the microcomputer. In one hand the subject was holding an

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electrode (a brass rod), and in the other she was holding
a rubber face mask which covered the nose and the mouth
area. The mask was fitted with a pneumotach (Mercury
flowhead, Gaeltec differential pressure transducers and
amplifiers). An accelerometer was placed on her larynx
so that the vocal folds' activity could be recorded.

The microcomputer which stores and processes the
electropalatographic signal at a sampling rate of 100 Hz
provided a synchronizing pulse which was recorded onto
one track of a multi-channel FM tape recorder.

Oral and nasal airflow together with the acoustic
signal from a microphone placed inside the mask (just
outside the outlet from the oral flow-head) and the
larynx signal from the accelerometer were recorded
simultaneously on separate channels of the recorder.

Permanent records of the filtered aerodynamic
tracing, the synchronizing pulse, the acoustic signal and
accelerometer signal were obtained from an eight channel
mingograph. Figure 3.2.4.a shows a typical mingograph
output. The traces represent from top to bottom: time
(25 cm per sec), filtered oral airflow, filtered nasal
airflow, acoustic signal, larynx signal and synchronizing
pulse (100 frames per second).

The time and place of the contacts between the
tongue and the palate were recorded and processed by
the Commodore CBM and displayed on its VDU, and a

Figure   3.2.4.a
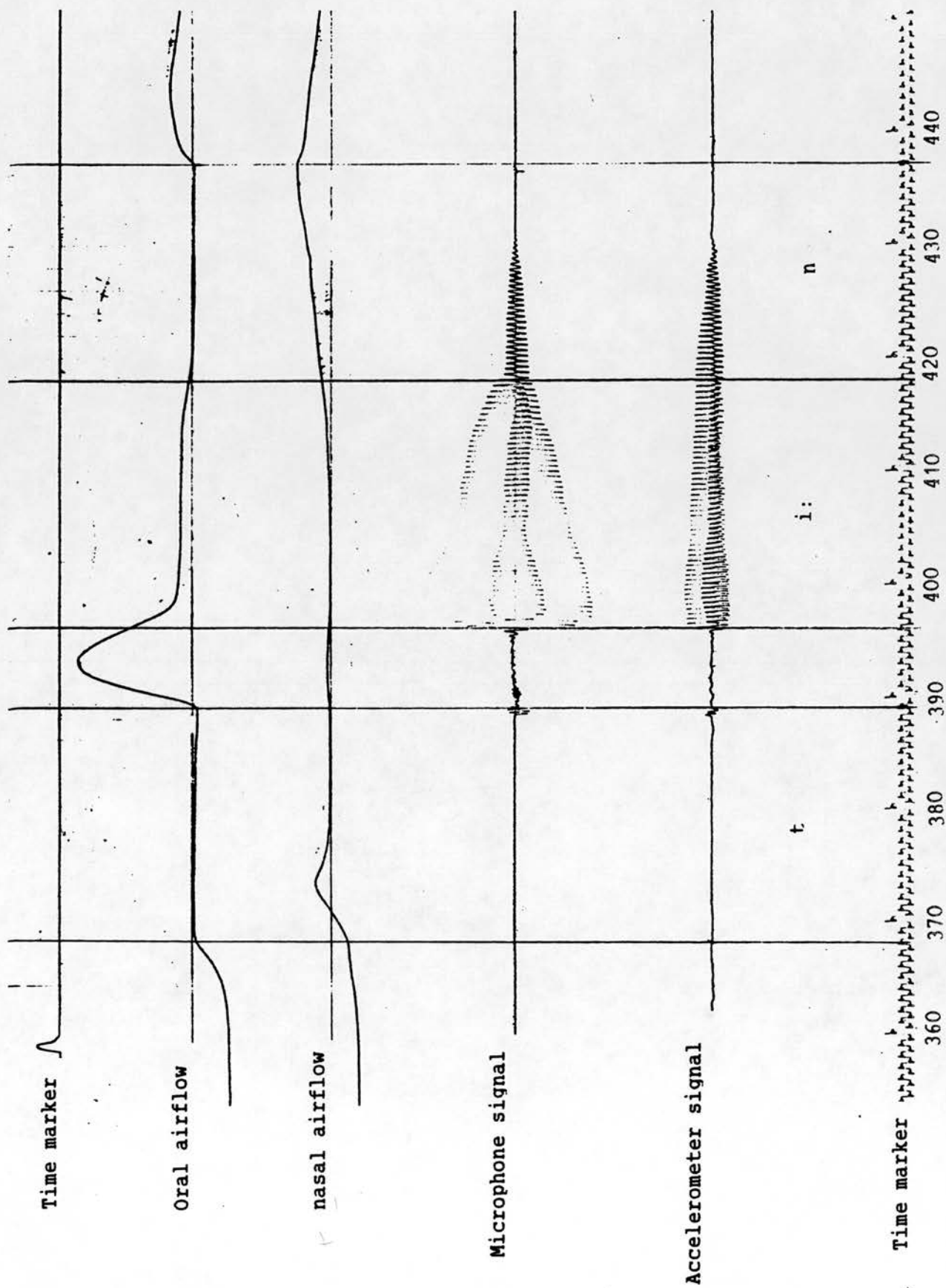
permanent record of the lingual-palatal contacts was printed by the computer printer. (See Figure 3.2.4.b).

Each small palate-shaped diagram represents the arrangement of the 62 electrodes on the artificial palate. It contains 8 lines or rows with 6 electrodes in the first row and 8 electrodes in the next seven rows. The top row represents the beginning of the alveolar region, just behind the upper teeth, and the bottom row represents the end of the palatal region.

The presence of a tongue contact is indicated by a zero ´0´ and the absence of contact is represented by a period ´.´. The printout is read from left to right with 7 prints on each line and the sampling rate is 100 frames per second with 10 msec. intervals. So one frame represents 1 csec. of time. The computer-generated synchronizing pulse enables one to correlate the pattern of the lingual-palatal contacts with the aerodynamic features.

3.3 Analysis

One of the three-time repeated test items is chosen for analysis.

The start and end of each word was segmented with reference to the airflow records.

Figure 3.2.4.b

/ti:n/

The number of contacts on each of the first four lines were entered into the computer and a graph representing the pattern of contact along with time for each of the four lines was plotted for each of the test items (see Figure 3.3.1.c). Figure 3.3.1.e represents two graphs for one of the minimal pairs in the data. The top graph represents the total number of contacts of the first four rows, the alveolar region, for the words with emphatic and non-emphatic cognates. The bottom graph represents the total number of contacts of the last four lines of the palate (lines 5-8), the palatal region, for the same minimal pair. Such graphs were drawn for all the 14 minimal pairs.

3.3.1 /ʃoːt/ & /ʃoːtˤ/

If we compare the EPG data for the two words, Figure 3.3.1.a & b (appendix F), and the graphic representation of the data in Figures 3.3.1.c, d, e, we notice that in the emphatic context /ʃ/ has fewer number of lingual-palatal contacts in the alveolar region. The main area of contact is in lines 3 and 4 where there are two touched electrodes on each side of the palate leaving a wide untouched central area. The reduction in the number of contacts in the anterior part of the palate could be interpreted as a result of the tongue

Figure 3.3.1.c

/ʃo:t/

Figure   3.3.1.d

/ʃoːɛ/
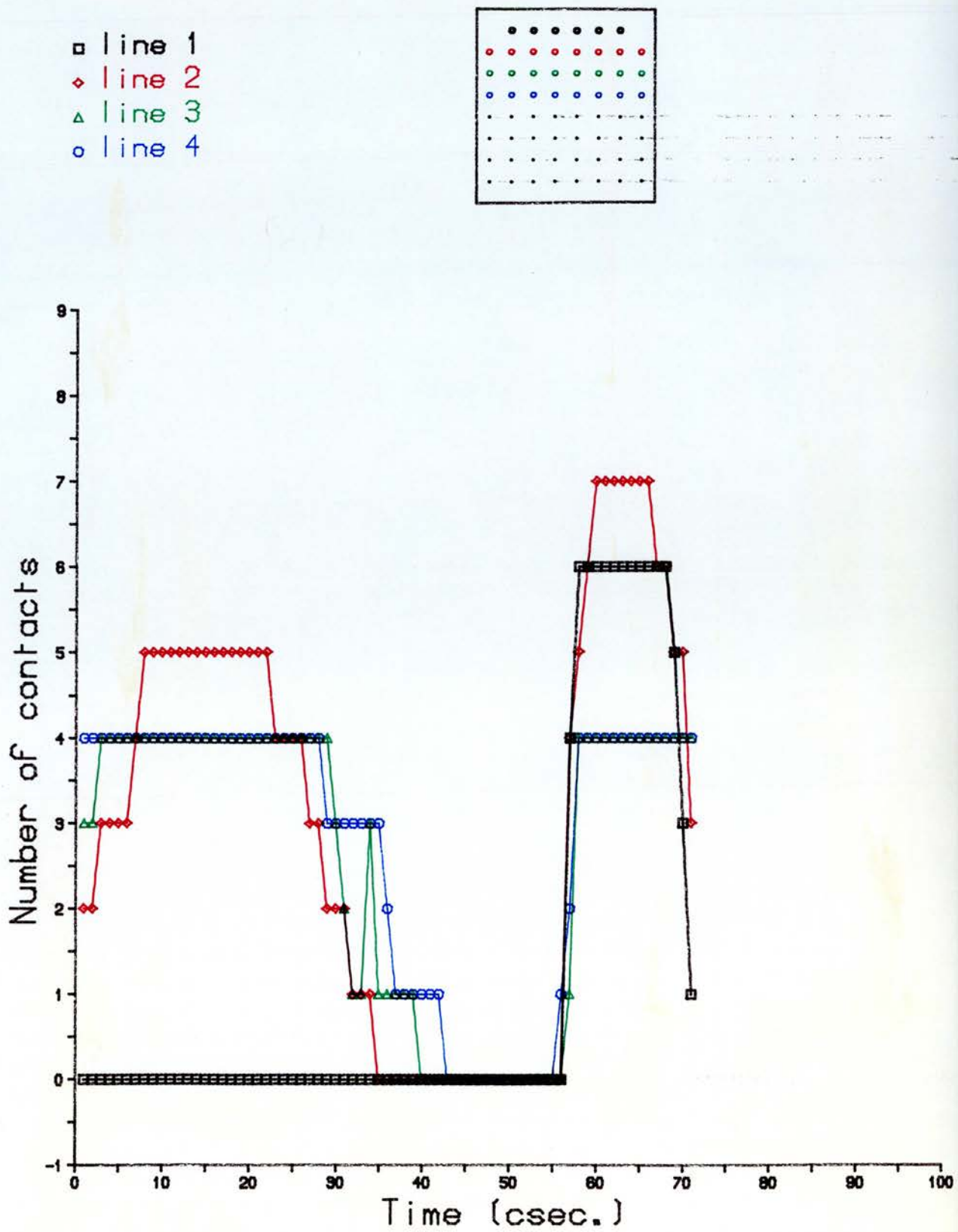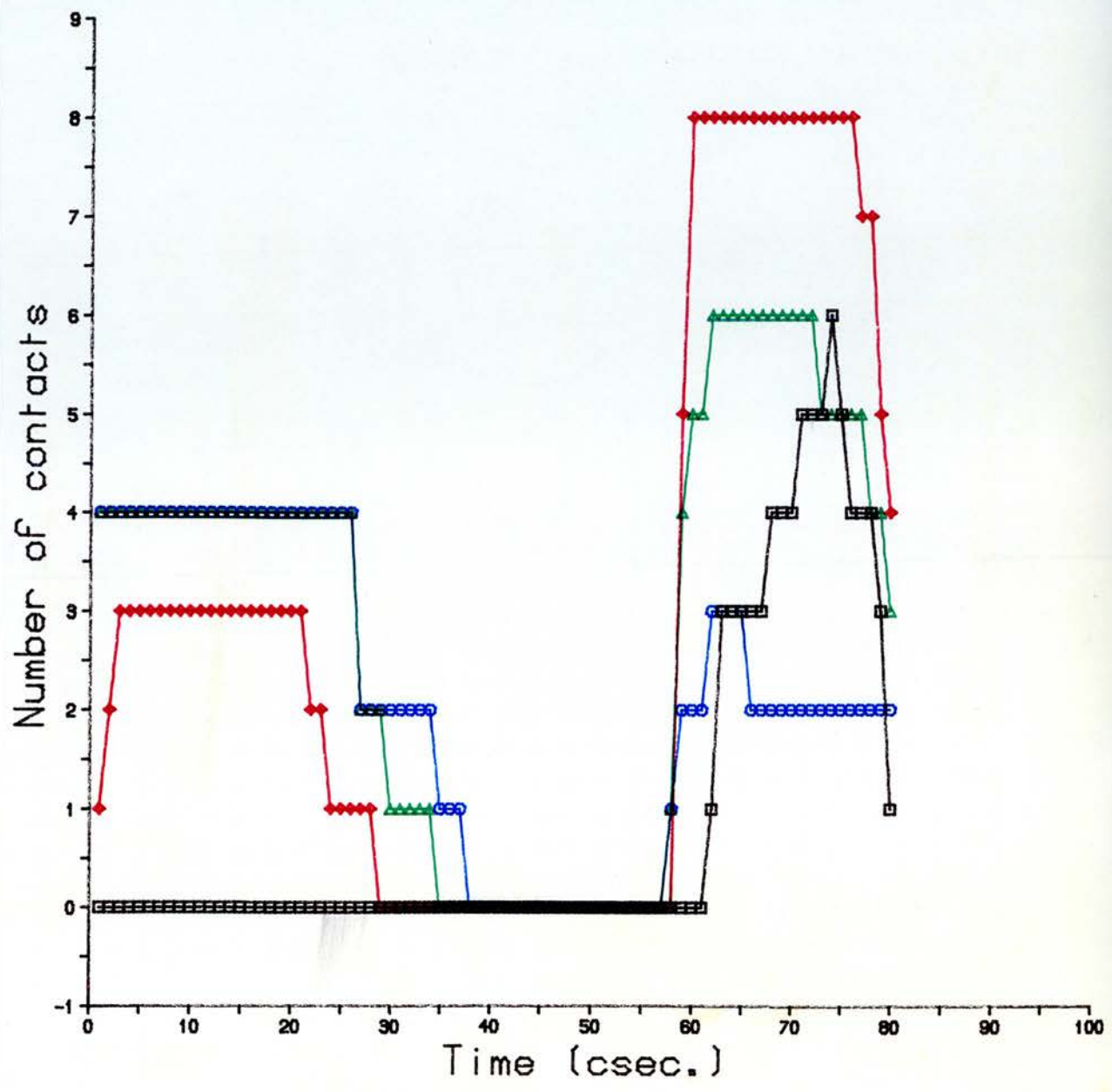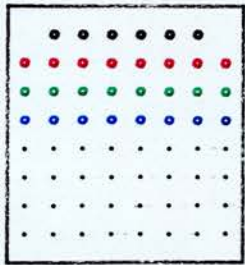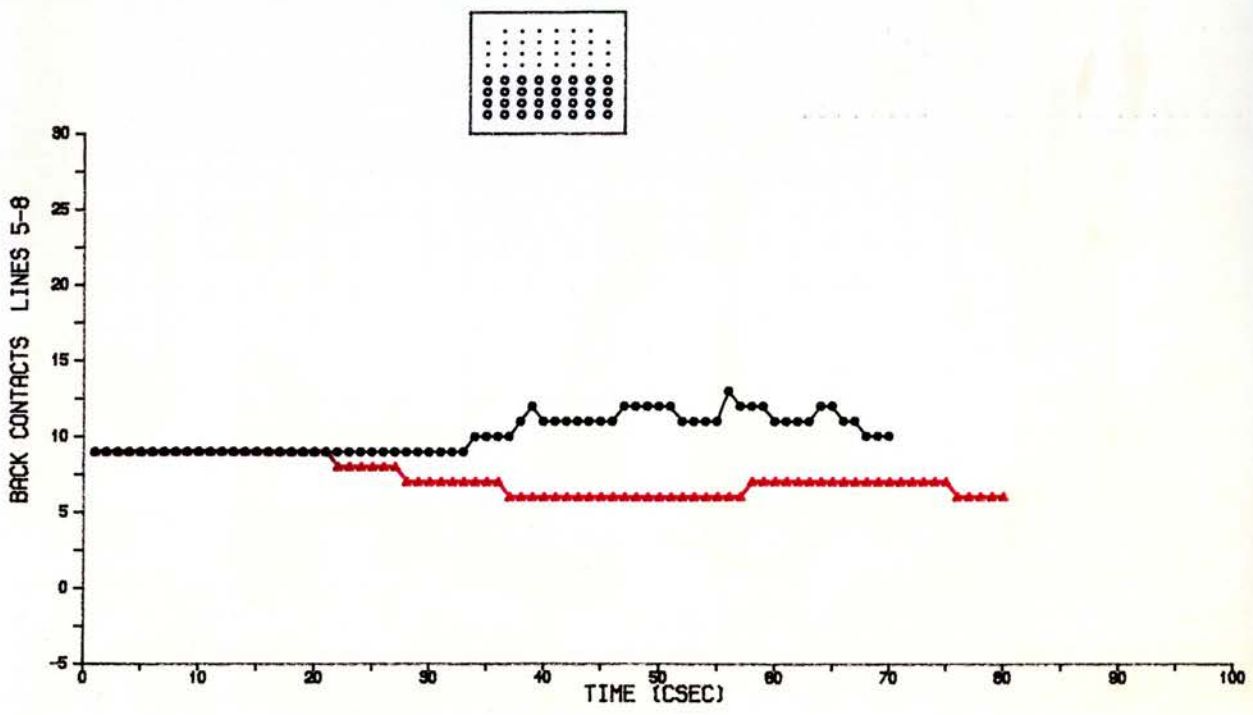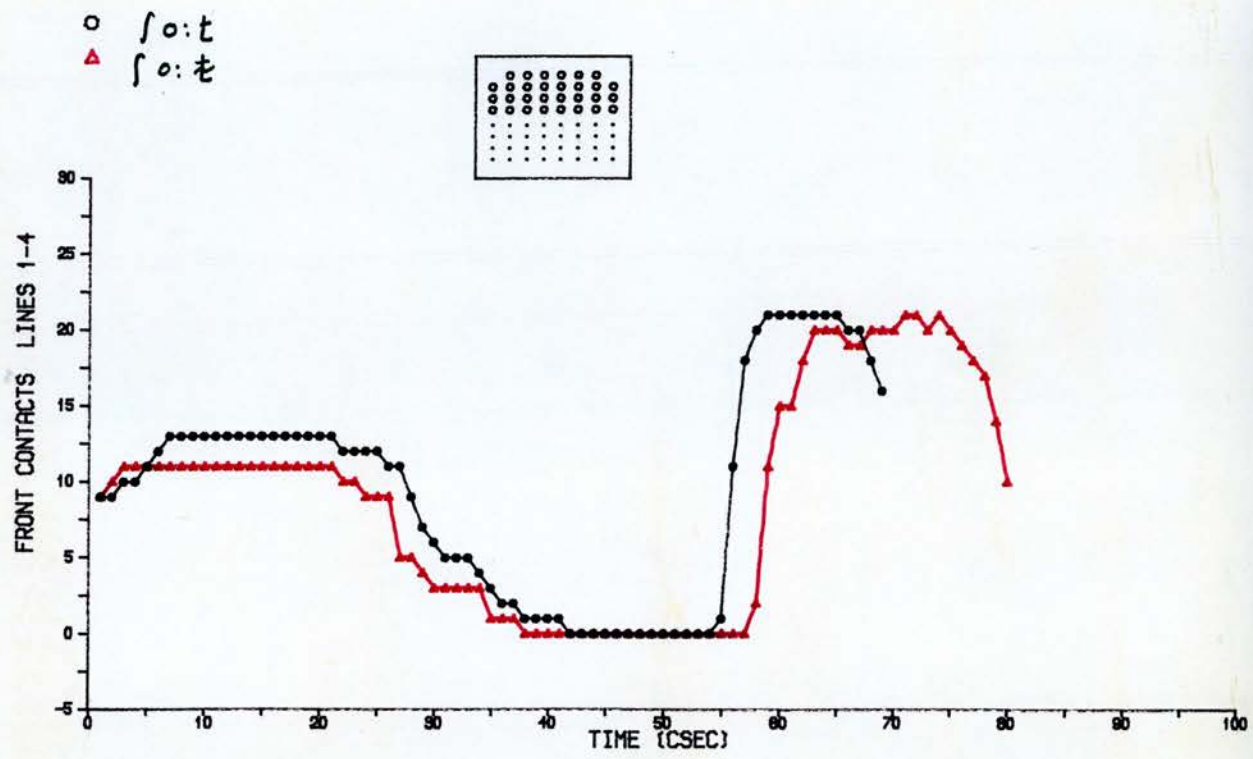
Figure   3.3.1.e

retraction, as the body of the tongue moves horizontally towards the posterior wall of the pharynx; and the decrease in the number of central contacts could have resulted from the hollowing of the tongue in anticipation for the emphatic consonant ahead. The back vowel /o:/ becomes more backed and lowered as it exhibits less lingual-palatal contacts in the posterior palatal region of the palate. /ŧ/ exhibits more contacts in the anterior region of the palate as it covers all of line one and two and part of line three, while /t/ covers only line one and part of line two. The reverse is true for the back region of the palate as there are much less lingual-palatal contacts for /ŧ/ than for /t/.

The increase in the lingual-palatal contacts in the alveolar region for /ŧ/ as compared to /t/ could be interpreted as a result of the musculature tenseness associated with the production of the emphatic sounds. The increase in the intra-oral pressure and tenseness results in a larger and firmer area of contact for a longer period of time.

Comparing the airflow patterns for /ʃo:t/ and /ʃo:ŧ/, Figures 3.3.1.f & g, we find no major difference. In the emphatic environment /o:/ is 30 msec. longer in duration, and /ŧ/ is 70 msec. longer than /t/. /ŧ/ also exhibits a lower airflow peak at its release. The amplitude of the accelerometer or voicing signal is much bigger for the pharyngealized word.
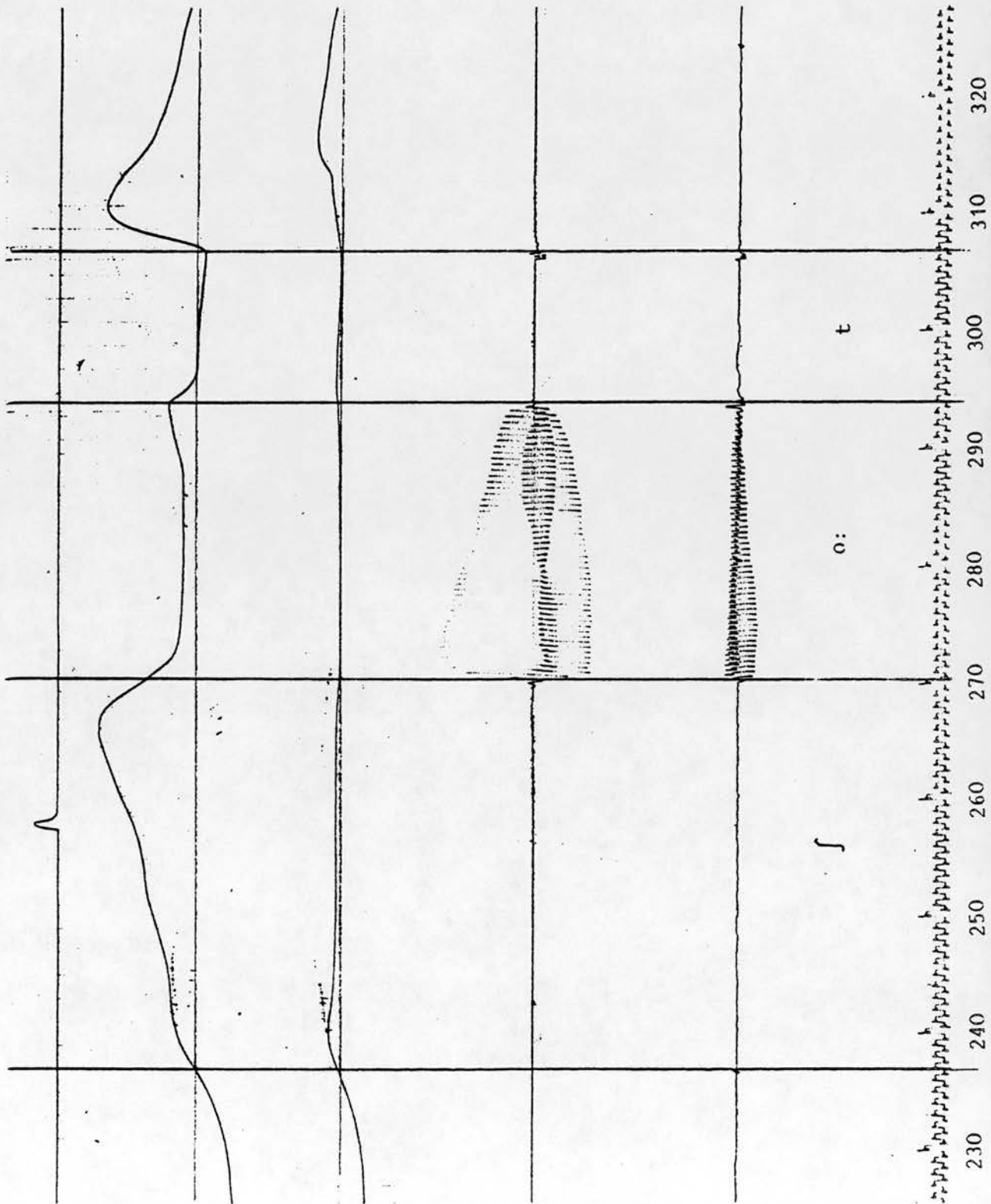
Figure   3.3.1.f

Figure 3.3.1.g

3.3.2   /ris/ & /ris̱/
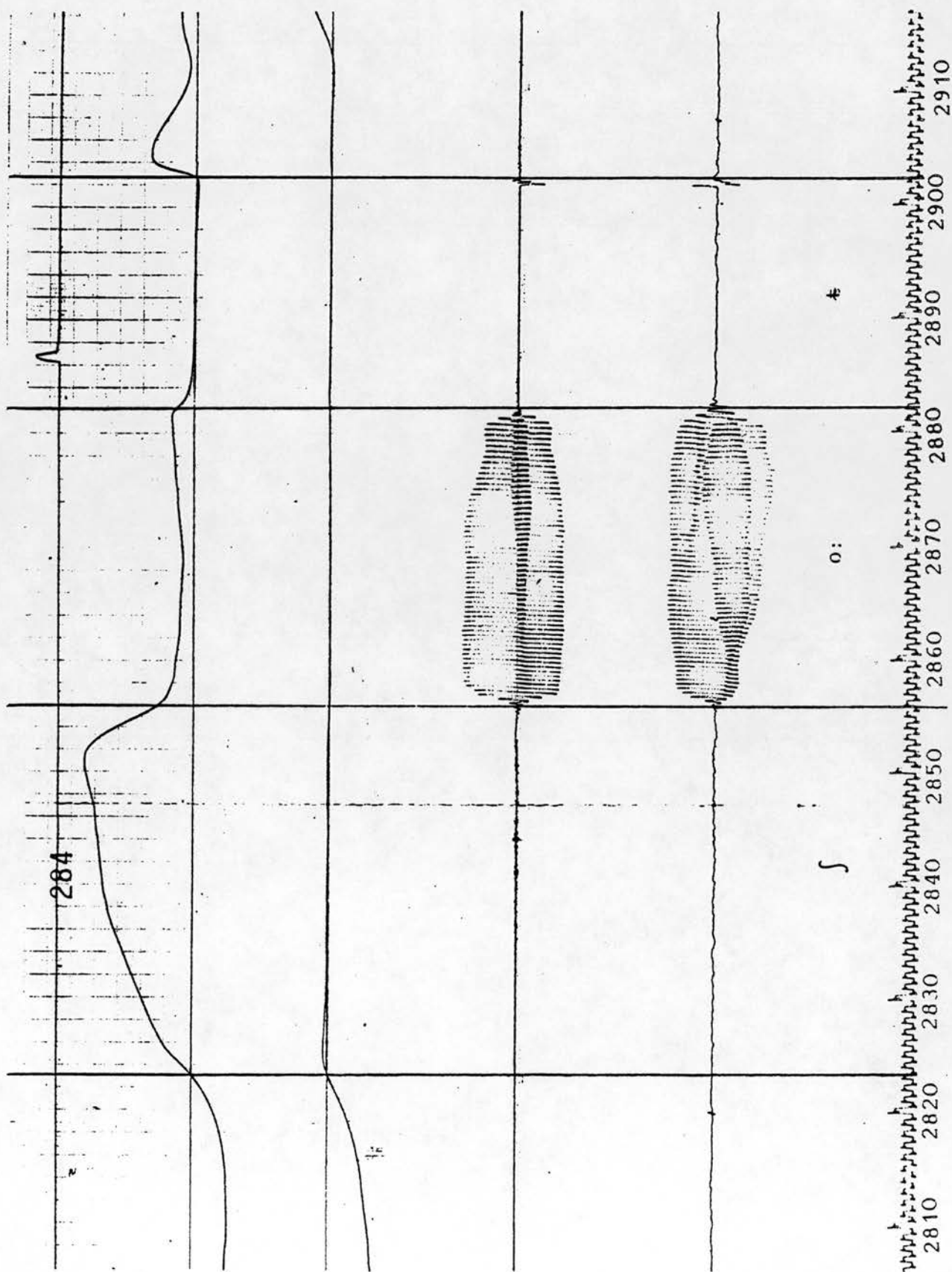
Comparing EPG data, Figures 3.3.2.a & b (see appendix F), and the graphic representation of the data, Figures 3.3.2.c, d,e, one notices that /r/ in the emphatic context has more contacts in the alveolar region indicating a firmer lingual-palatal contact. /i/ has fewer contacts in the anterior part of the palate and shows a retracted place of articulation as contacts start on the third line instead of the second line. So it becomes a central instead of a front vowel. /s̱/ has a firmer lingual-palatal contact as it has more contacts in the front part of the palate, lines 1-4. But it has less contacts in the back region, lines 5-8, as a consequence of tongue lowering and retraction.

As for the airflow pattern, Figures 3.3.2.f, g, on the whole /ris̱/ has a lower oral airflow rate than /ris/ and longer duration. /r/ is 20 msec longer, /i/ is 10 msec longer and /s̱/ is 30 msec longer in duration. The larynx signal also has a higher amplitude for the emphatic word.

3.3.3   /naʃiːd/ & /naʃiːṯ/
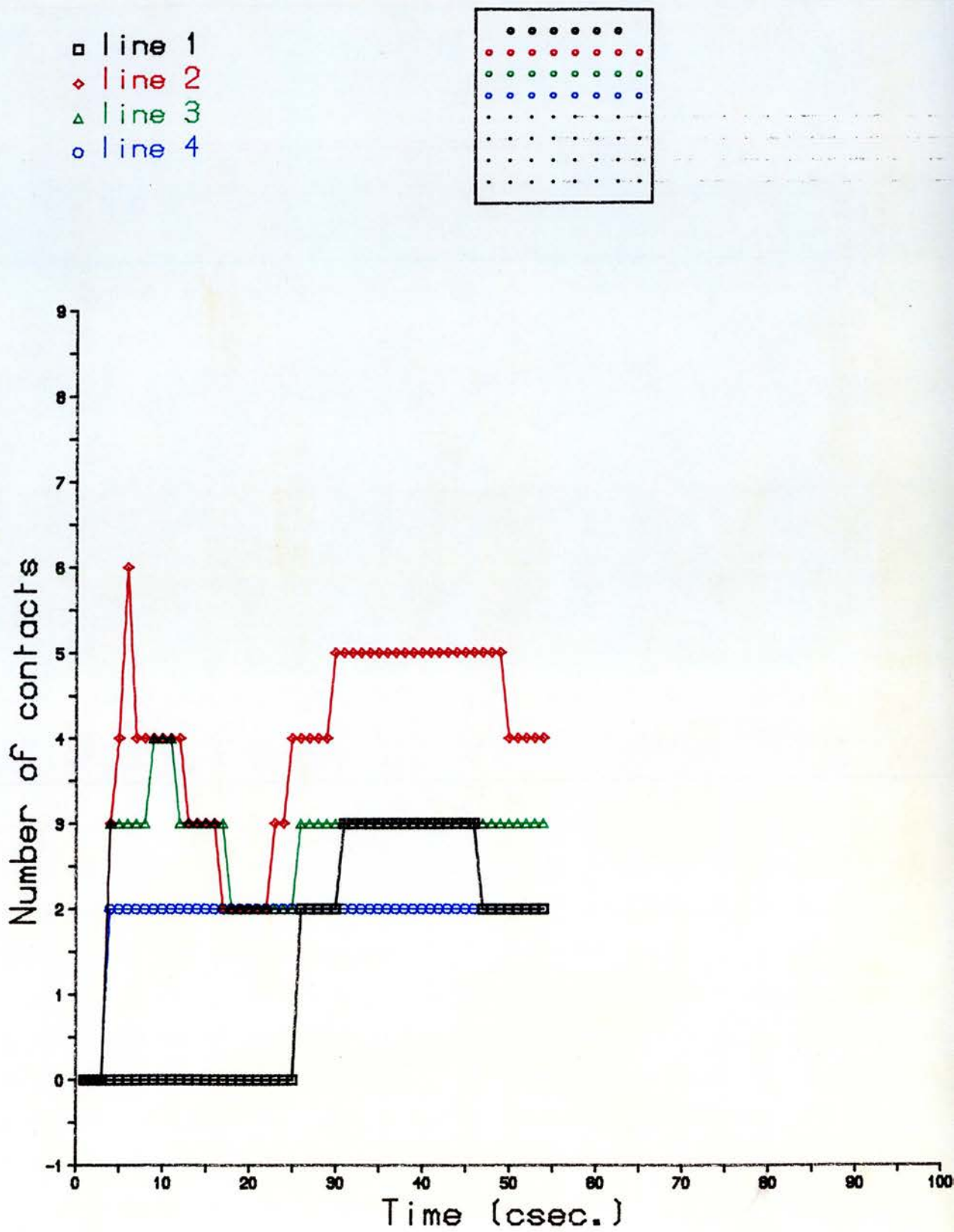
Figure 3.3.2.c

/ris/

Figure 3.3.2.d

/ris/
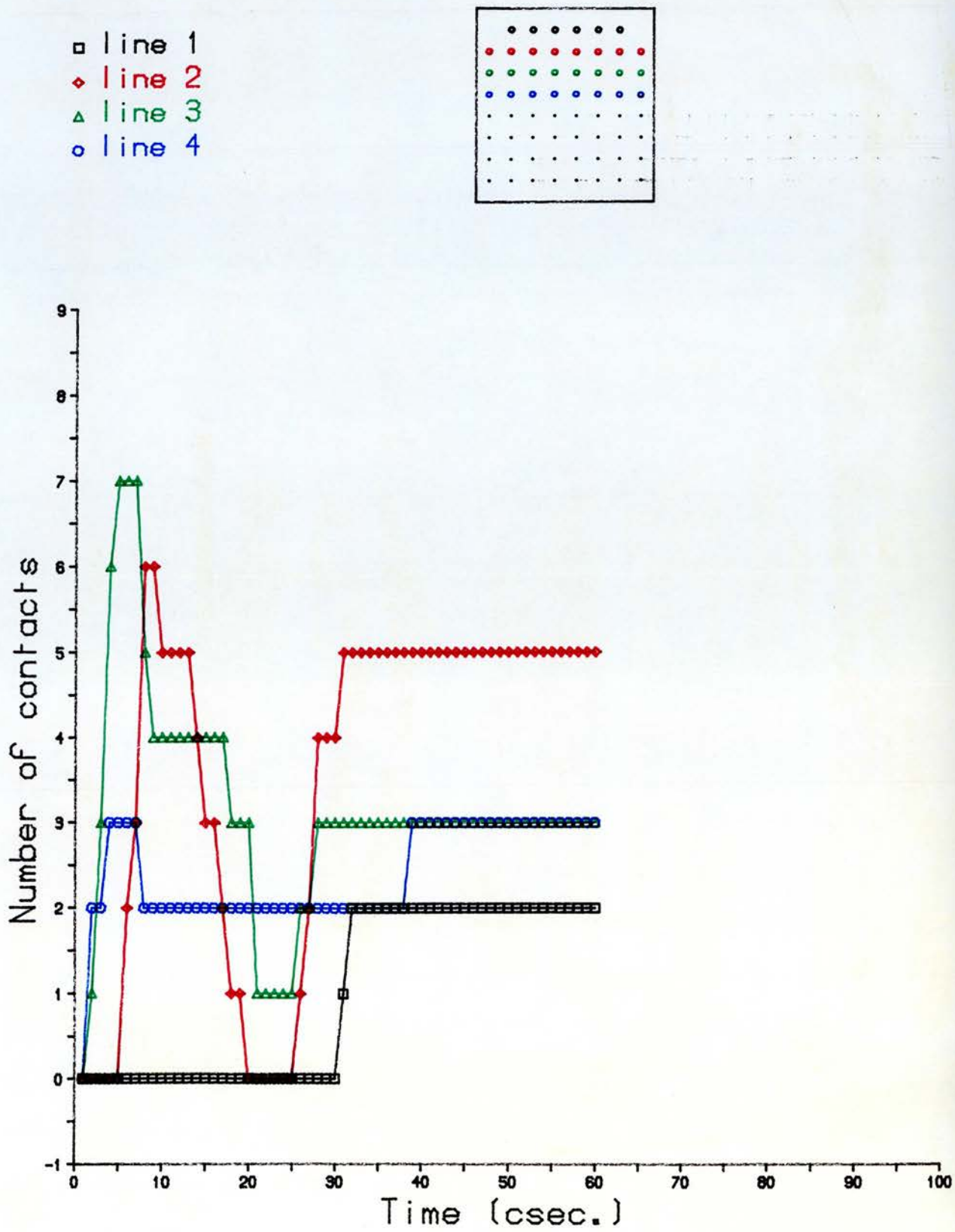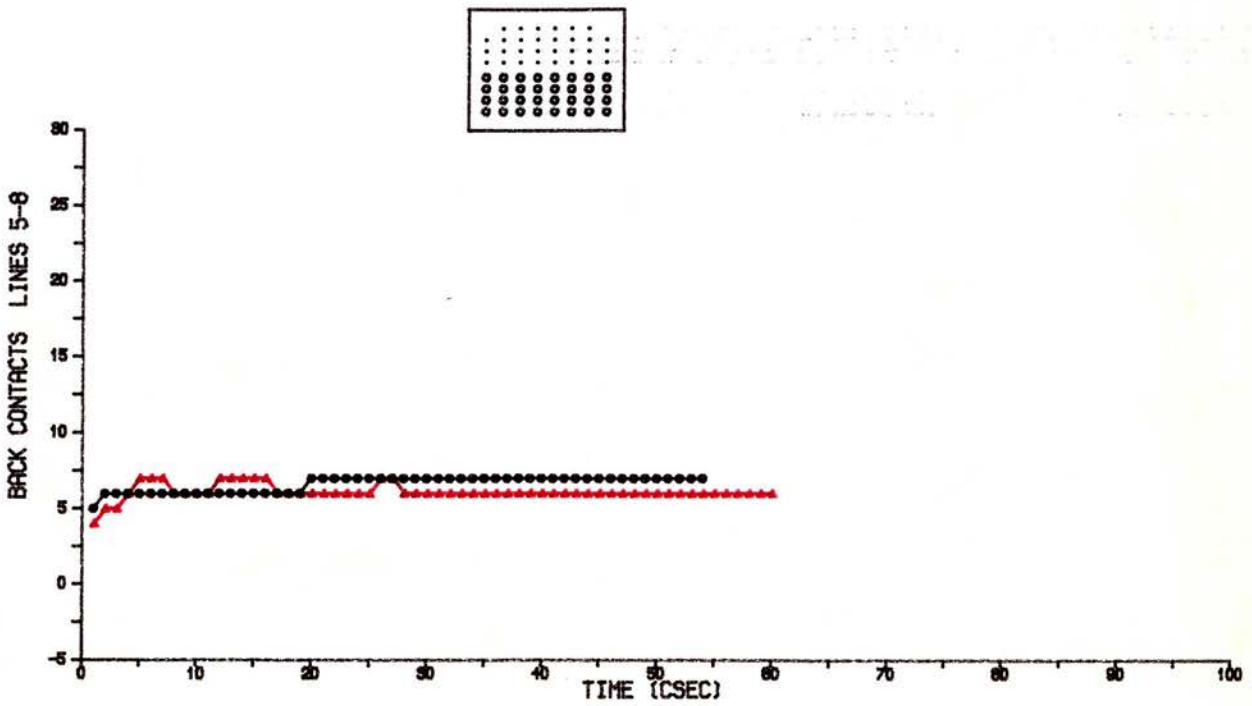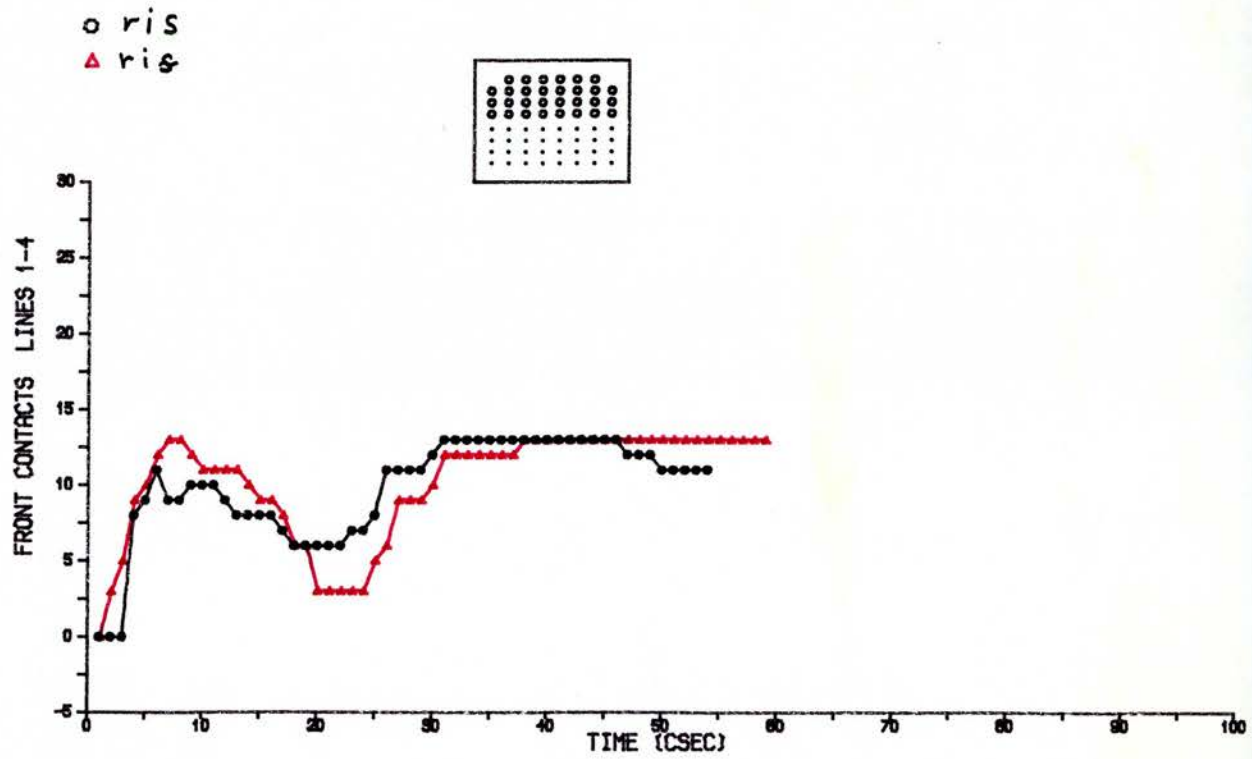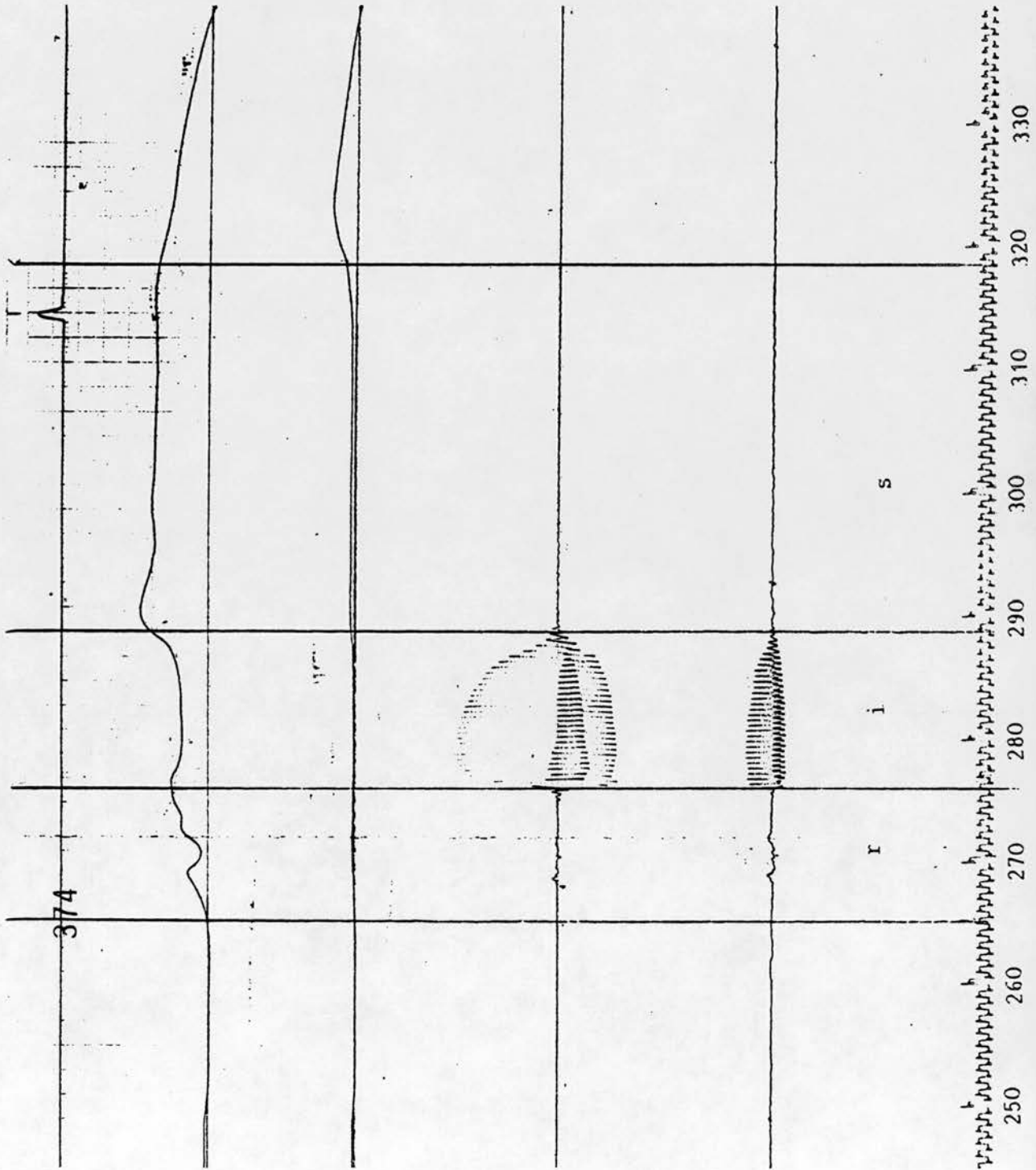
Figure   3.3.2.e

Figure 3.3.2.f
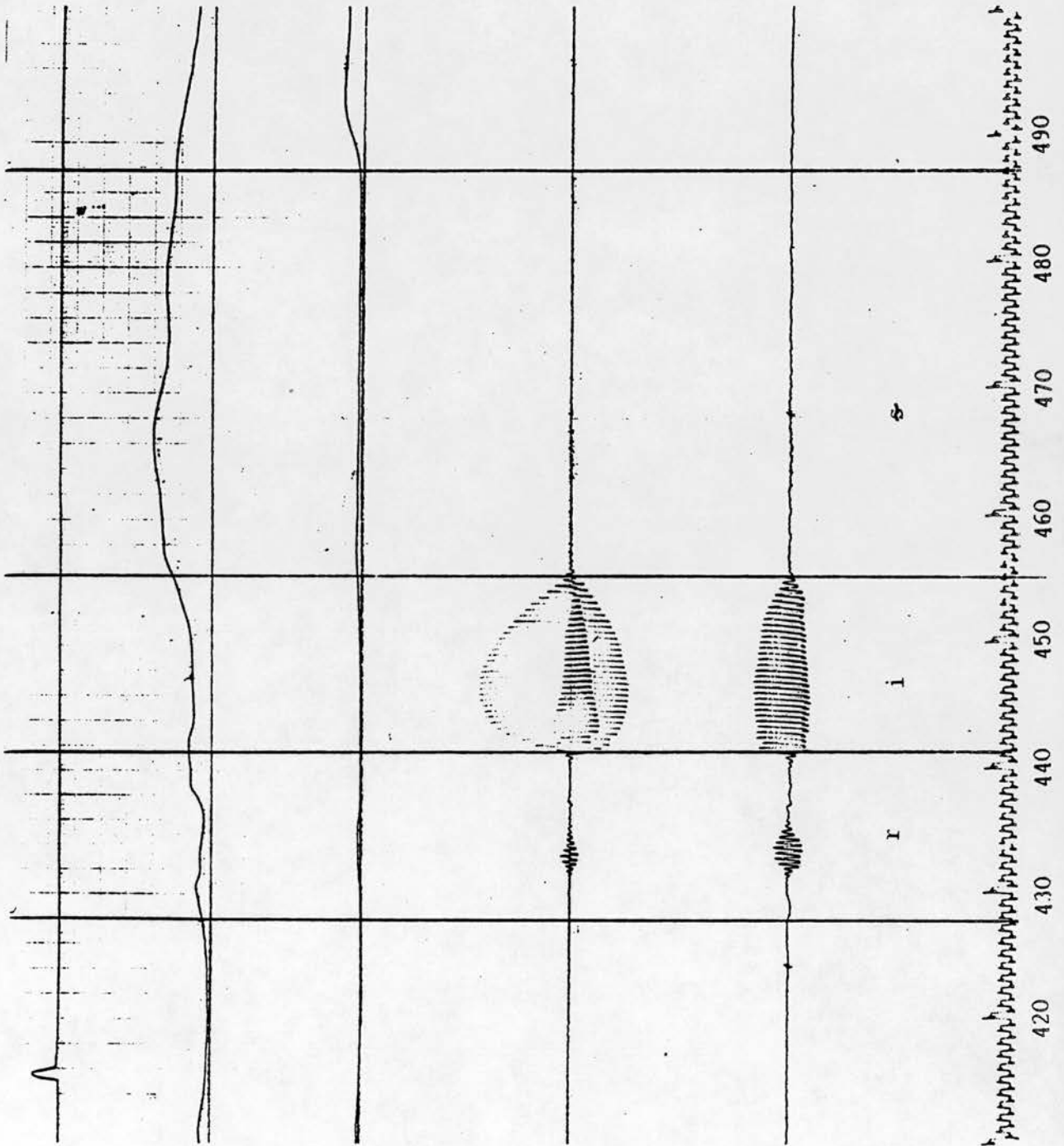
Figure 3.3.2.g

Compare EPG data Figures 3.3.3.a-b (see appendix F), and the graphic representation of the data, Figures 3.3.3.c,d,e. In the pharyngealized environment /n/ has more contacts in the anterior region of the palate as they cover the first two rows of the alveolar ridge indicating a firmer closure. And it has fewer contacts in the posterior region of the palate indicating the effect of the anticipatory pharyngealization. The vowel /a/ also shows signs of pharyngealization as it has much fewer contacts both in the front and back regions of the palate, leaving a wider central untouched area as a result of the hollowing and retraction of the tongue. /ʃ/ exhibits fewer lingual-palatal contacts in the alveolar and palatal regions of the palate in the emphatic context. /i:/ has much fewer lingual-palatal contacts both in the anterior and posterior regions of the palate with a wider untouched central area.

/æ/ has a much bigger area of contact than /d/ which results in the increase in the number of touched electrodes in the front part of the palate. But the reverse is true for the back region of the palate as /æ/ has less contacts than /d/ as a result of tongue backing effect.

Comparing the airflow records, Figures 3.3.3.f,g, we notice that /naʃi:d/ has a slightly lower airflow rate than /naʃi:æ/. This could be due to the effect of the voiced plosive /d/, as it has been proved in the

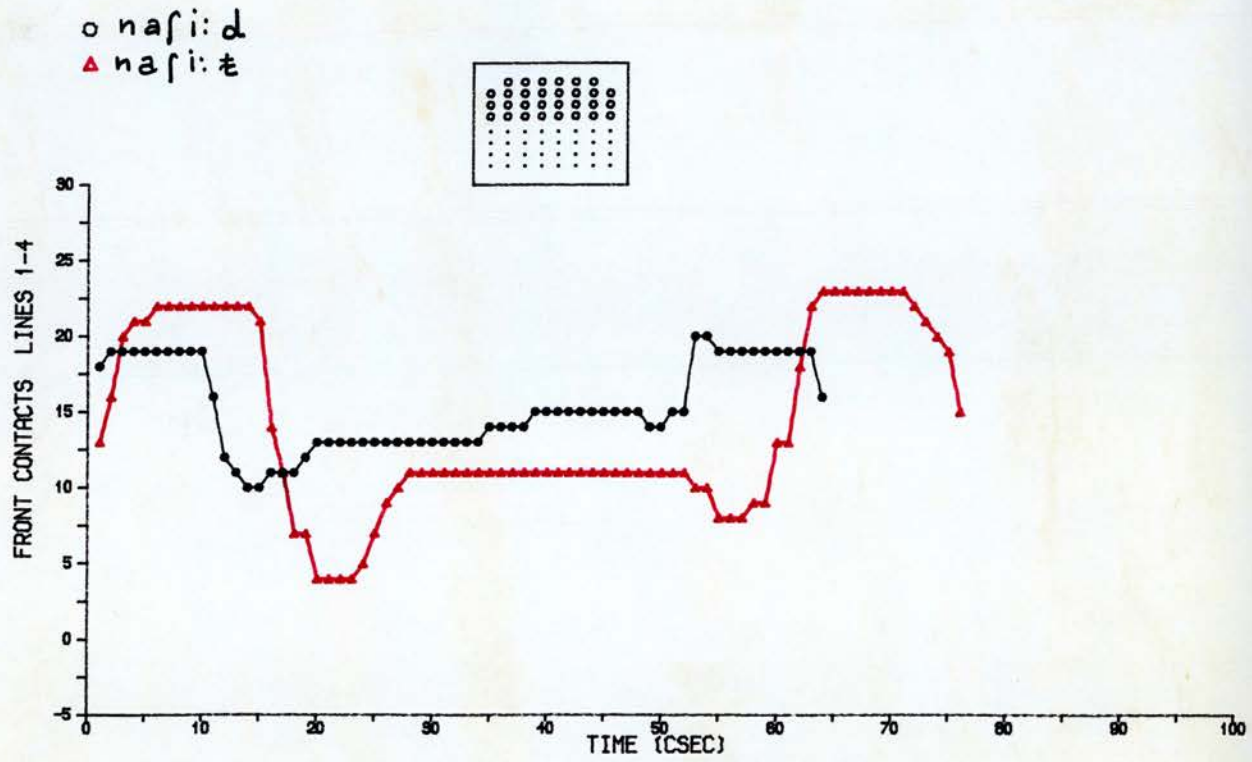Figure 3.3.3.c

/naʃi:d/

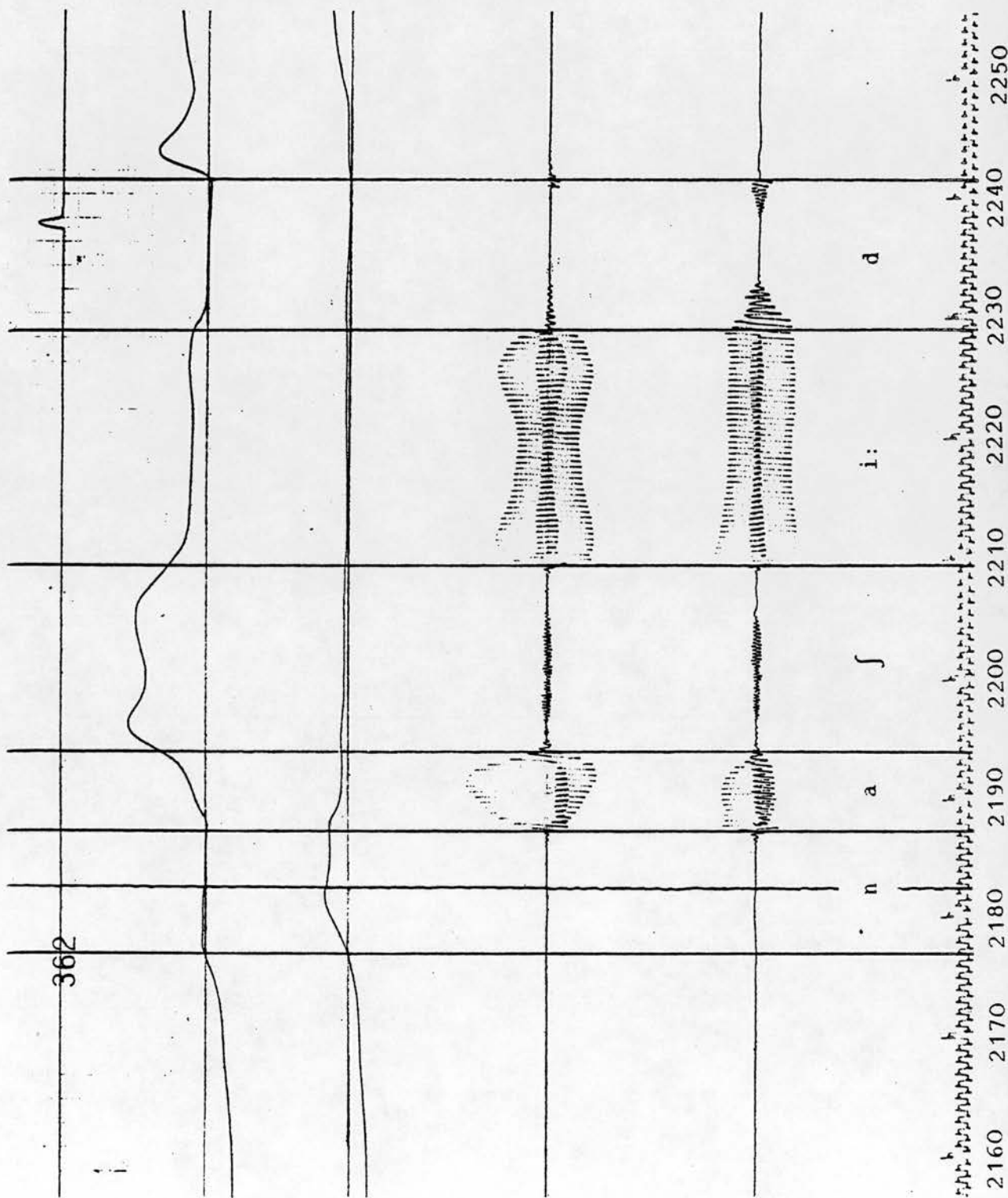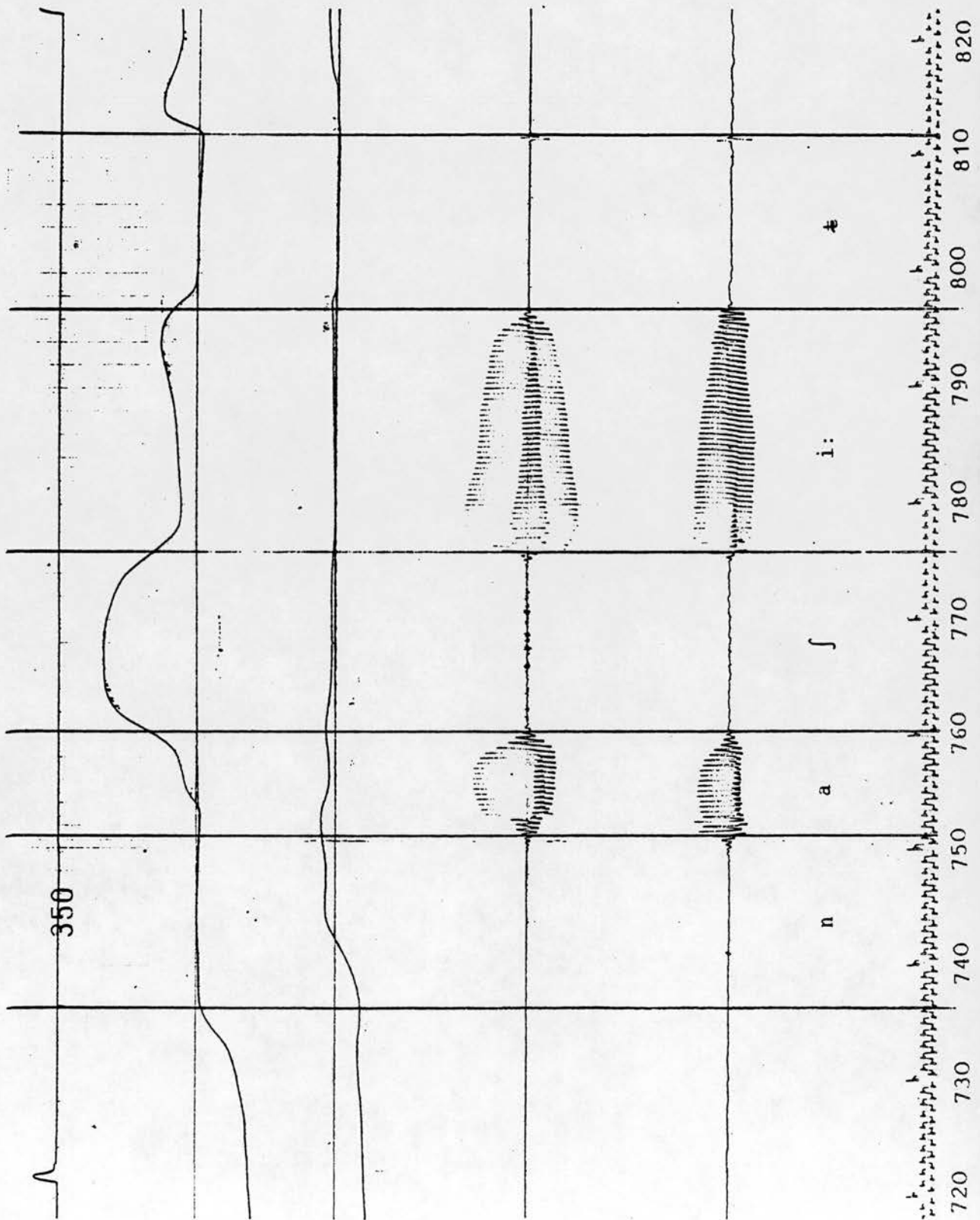Figure   3.3.3.d

/naʃiːモ/
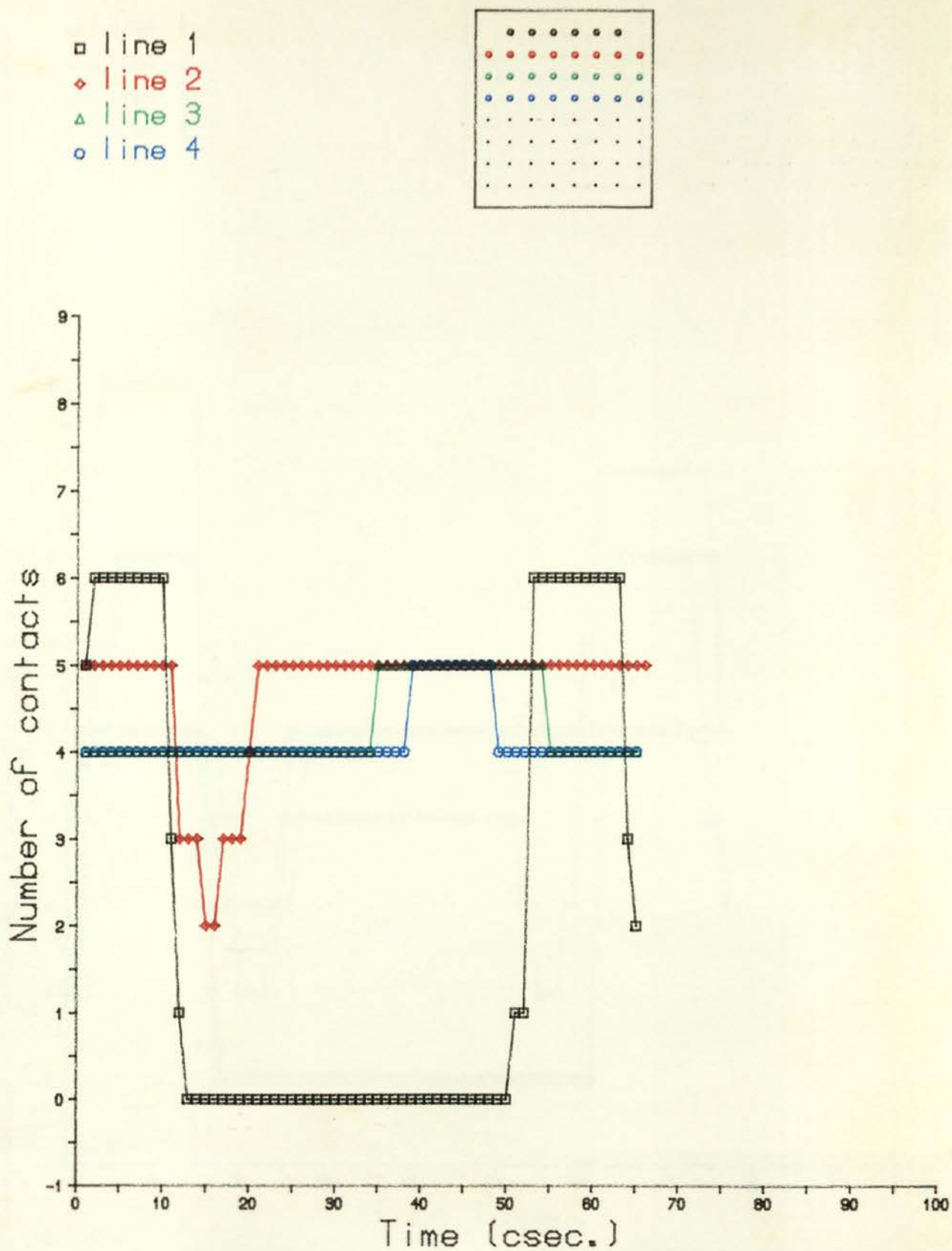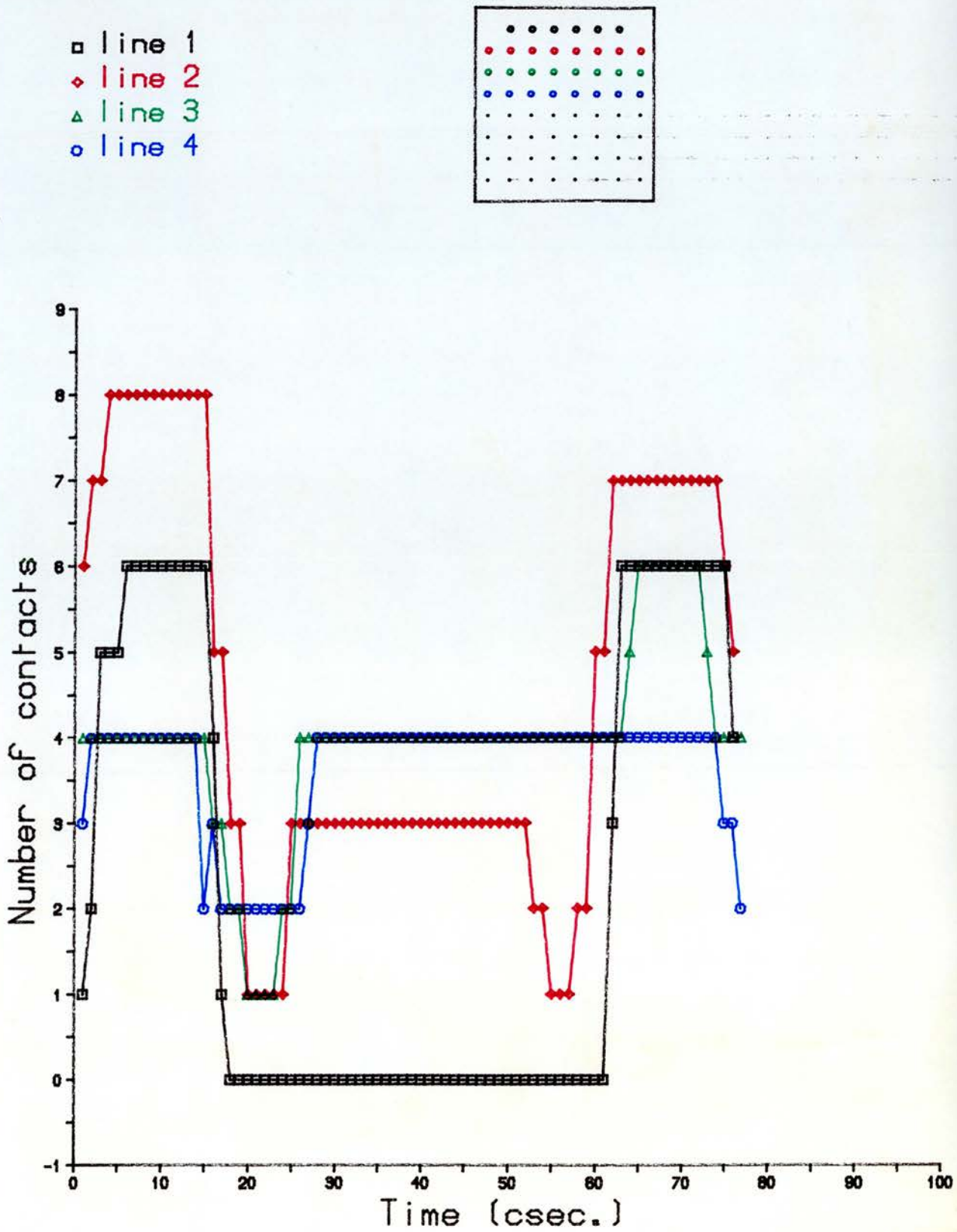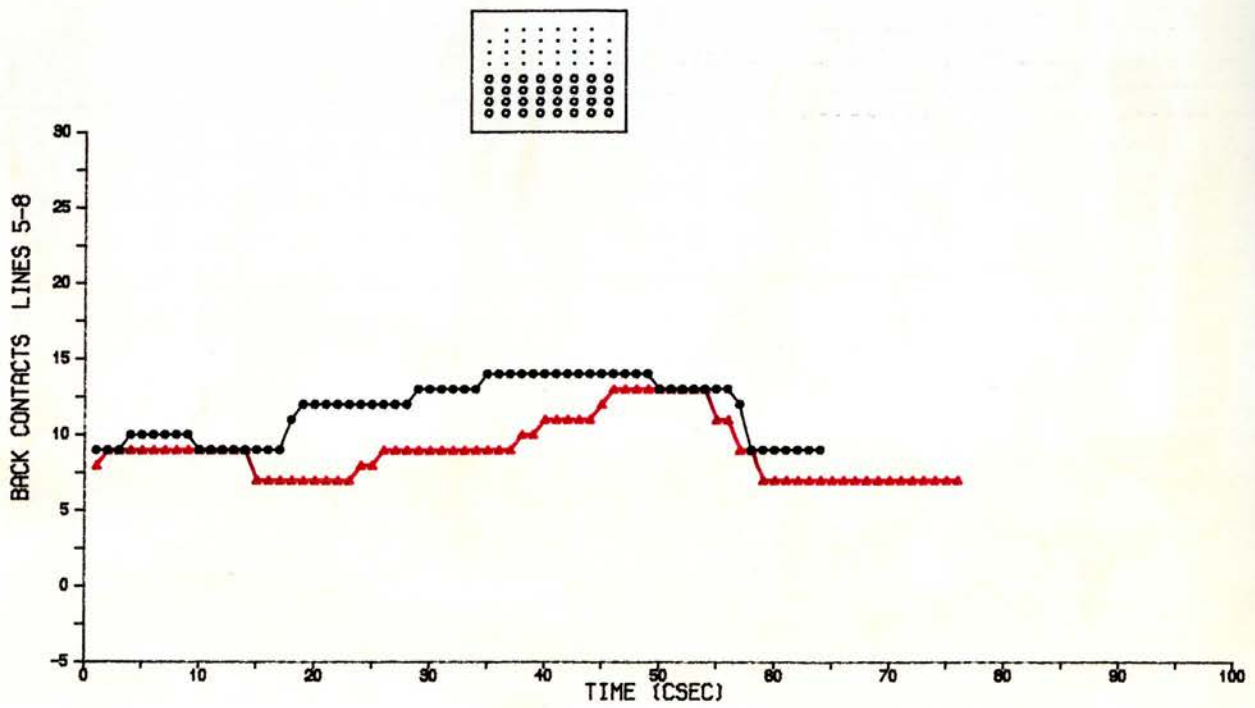
Figure 3.3.3.e

Figure 3.3.3.f

Figure 3.3.3.g

literature that voiced sounds have a lower rate of airflow. In the emphatic context /n/ has a slightly higher nasal airflow rate and is 50 msec longer in duration. /a/ has more or less the same rate of oral airflow and 20 msec longer. /ʃ/ has the same duration, but different airflow pattern . /i:/ exhibits a higher airflow rate and 20 msec longer duration. /ɬ/ has a lower airflow peak at its release and about 30 msec longer than /d/.

3.3.4   /ti:n/ & /ɬi:n/

Comparing the EPG data for the two words, Figures 3.3.4.a,b, (see appendix F), and the graphic representation of the data, Figures 3.3.4.c,d,e, one notices that /ɬ/ has much more contacts in the anterior part of the palate than /t/ and has fewer contacts in the posterior part of the palate. The touched area covers lines one, two and three for /ɬ/ while it covers only line one and two for /t/. /i:/ has fewer lingual-palatal contacts in the anterior region of the palate next to /ɬ/ indicating tongue retraction and lowering resulting in a wider central groove. /n/ has a retracted place of articulation in the emphatic context as it covers the second and the third rows while it covers the first and the second rows in the non-emphatic environment. This retraction of
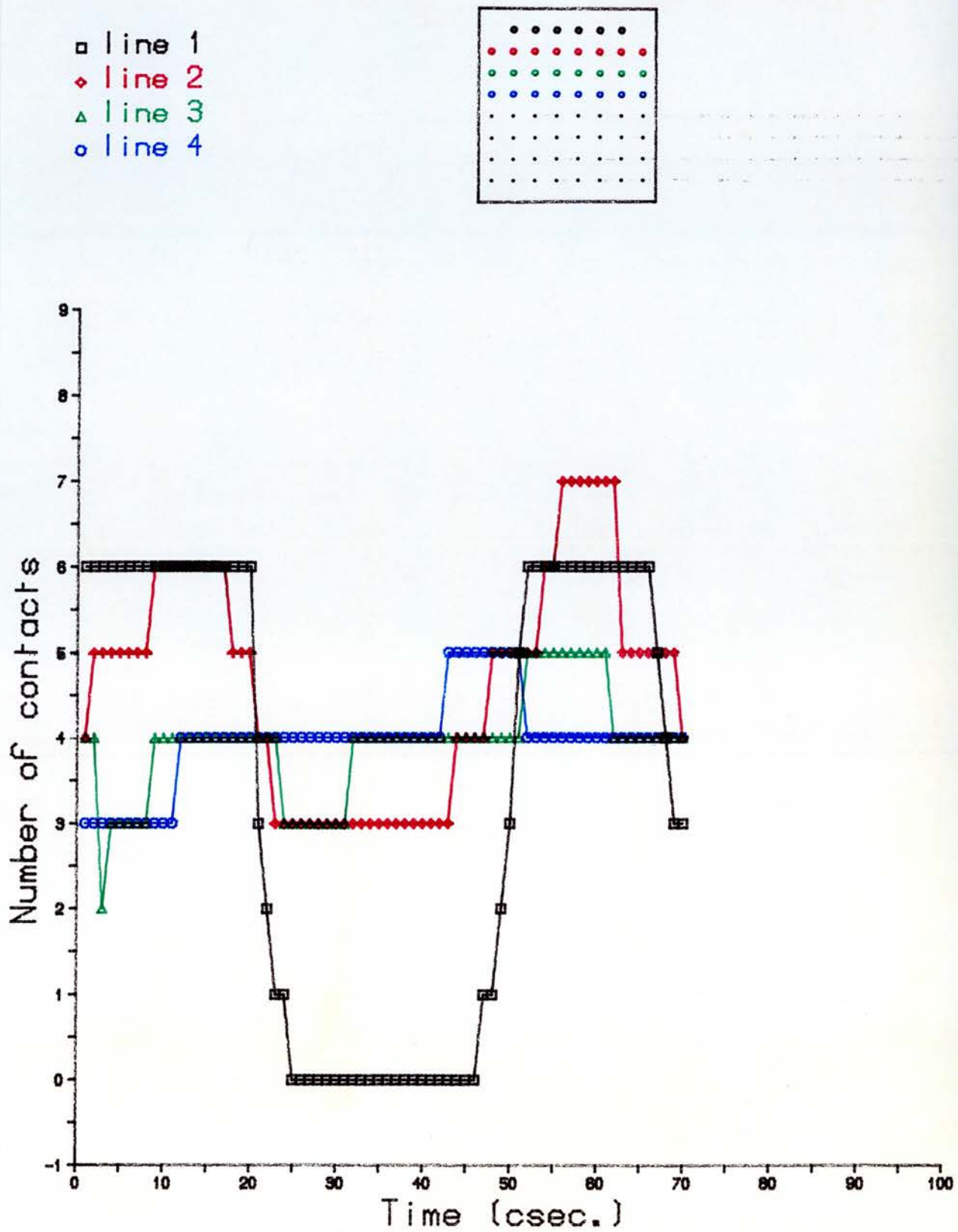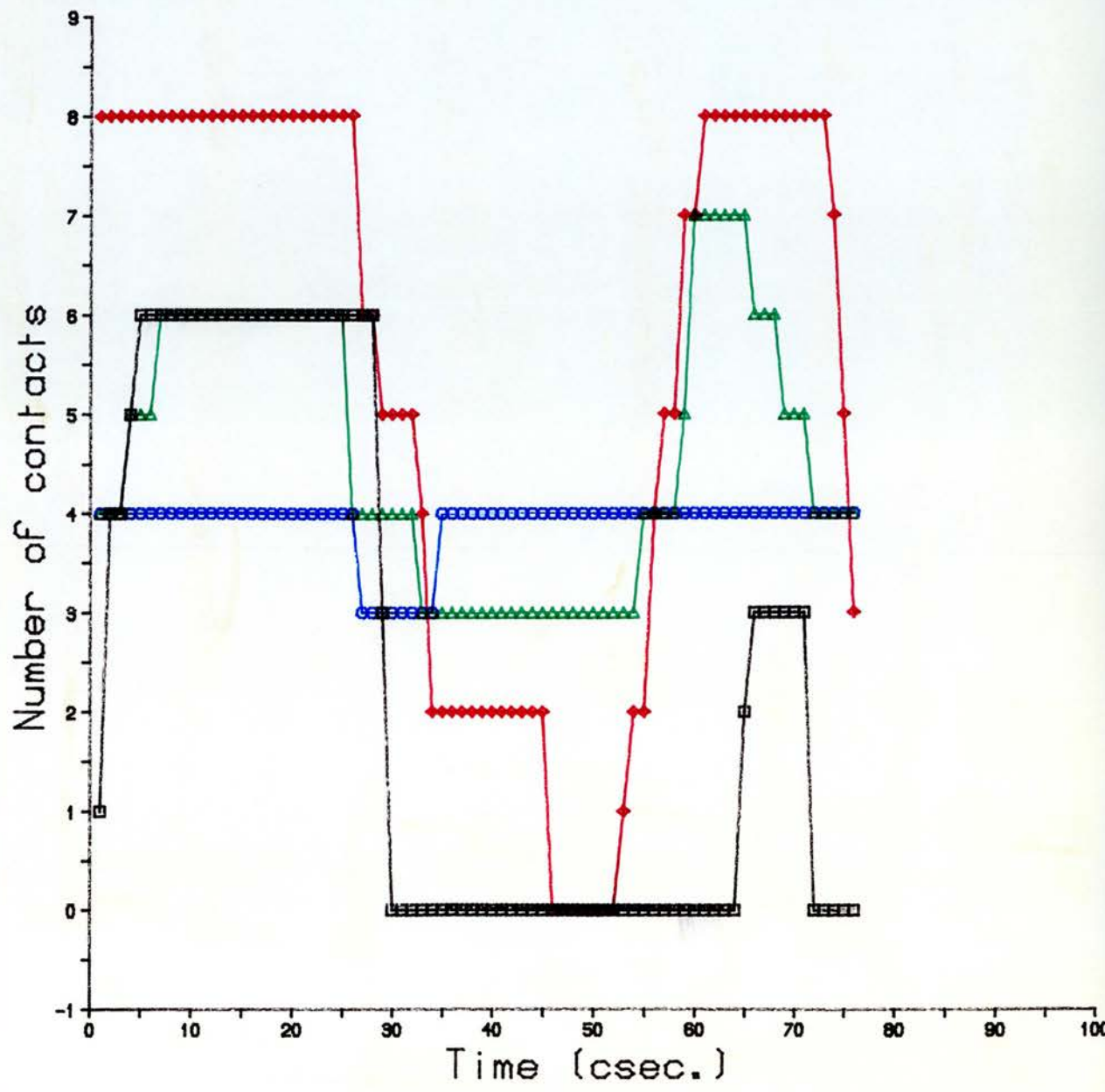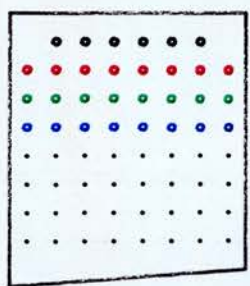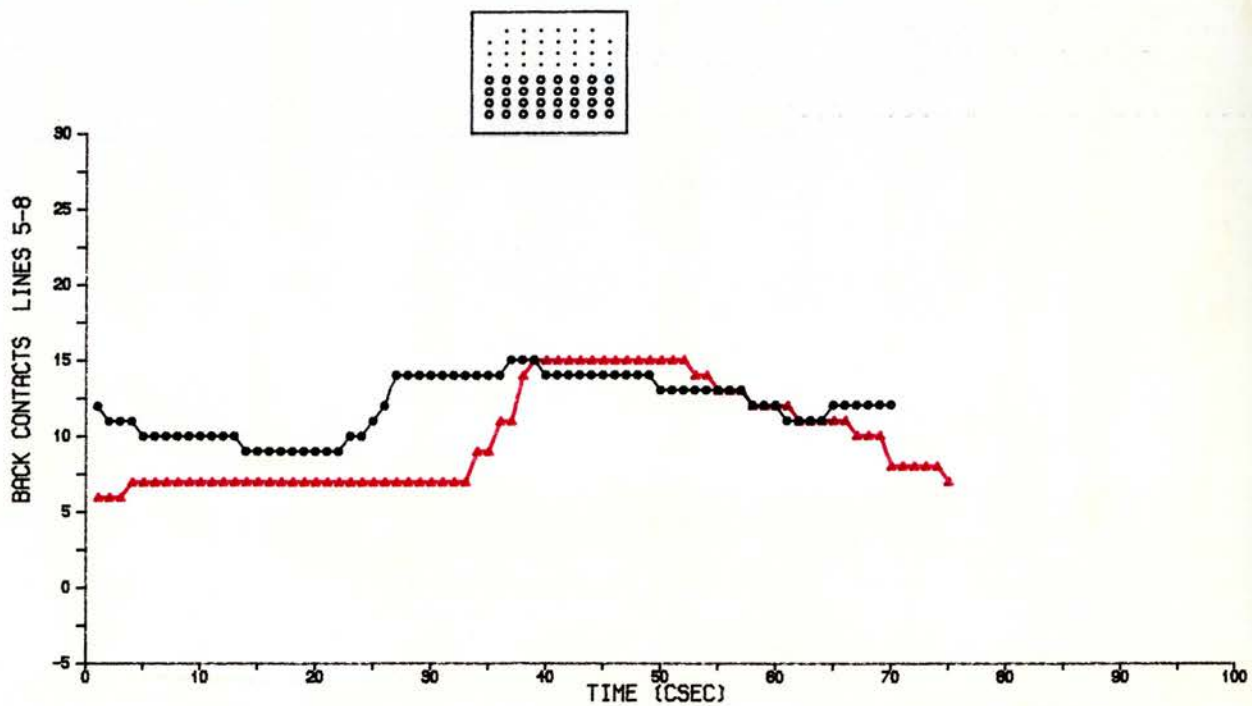
Figure   3.3.4.c
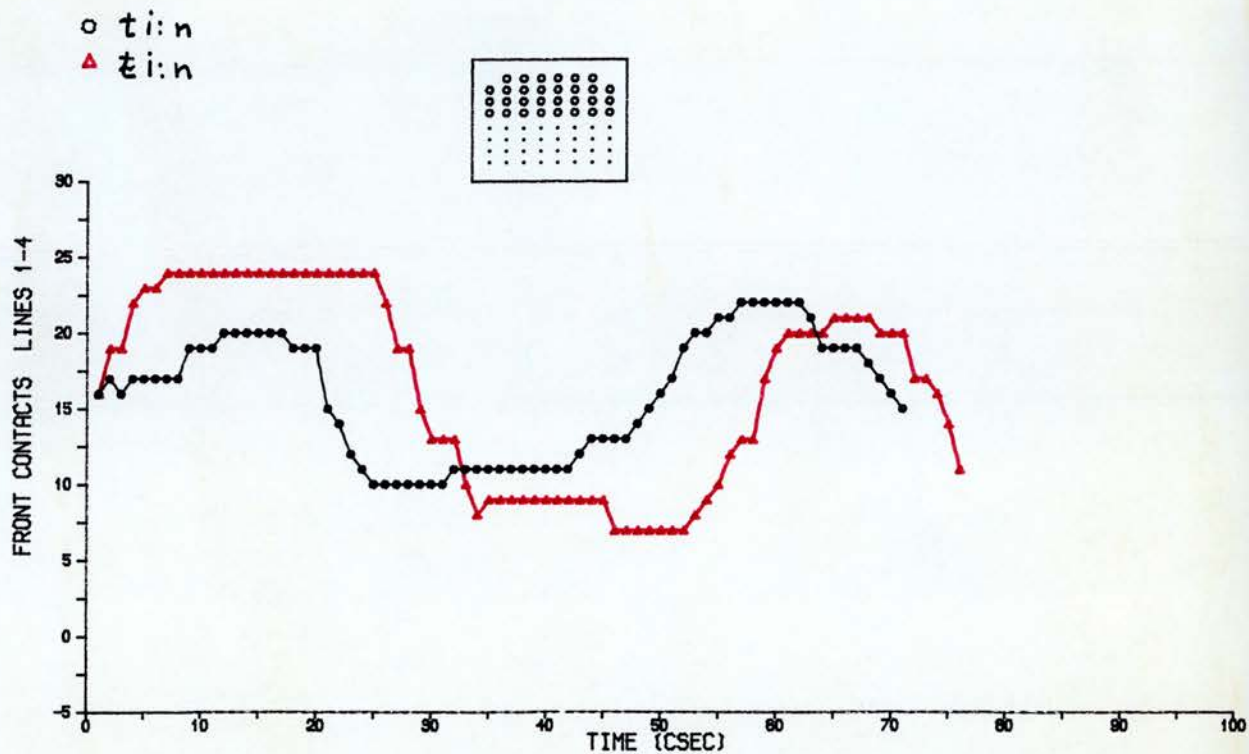
/ti:n/

Figure   3.3.4.d
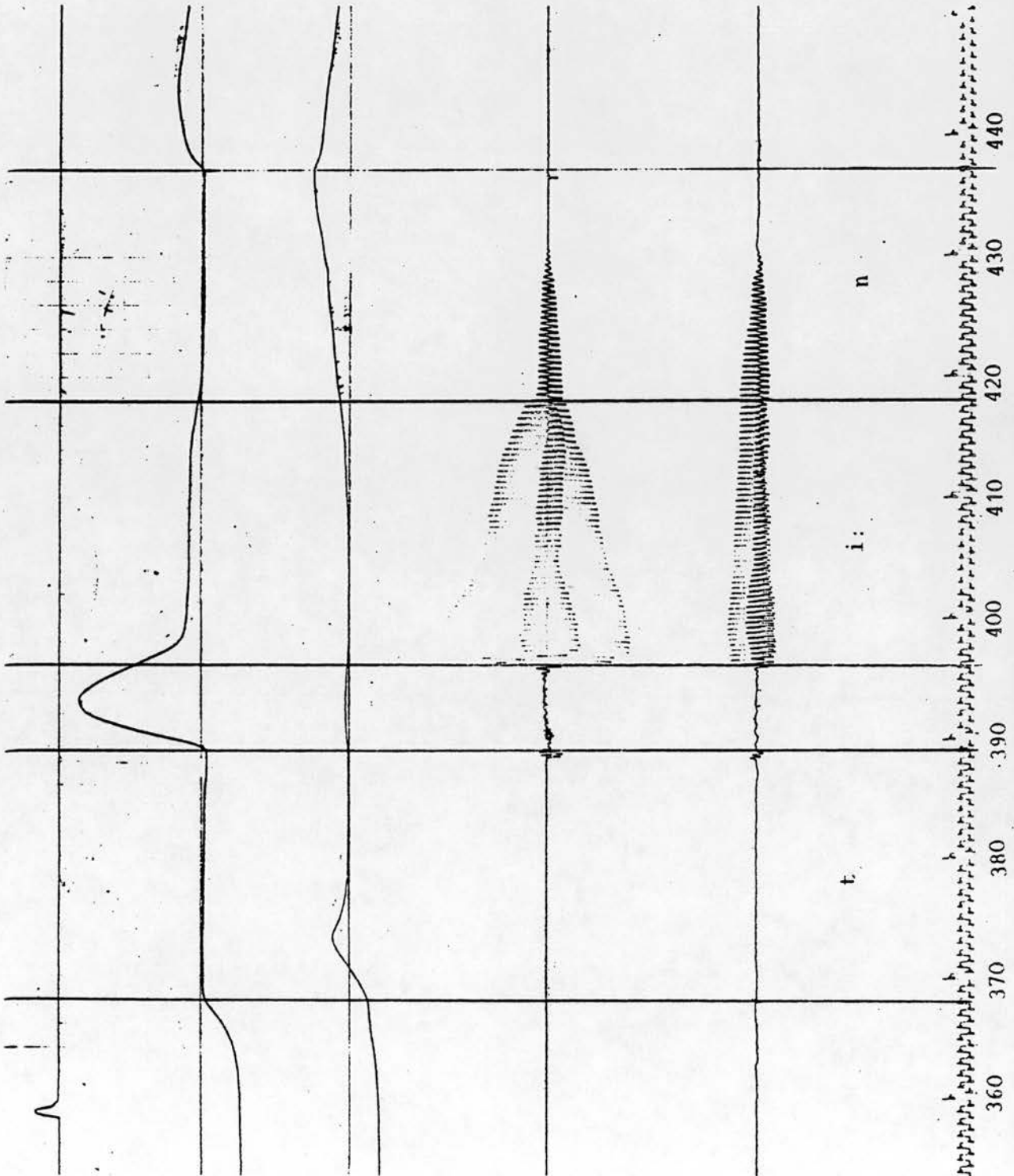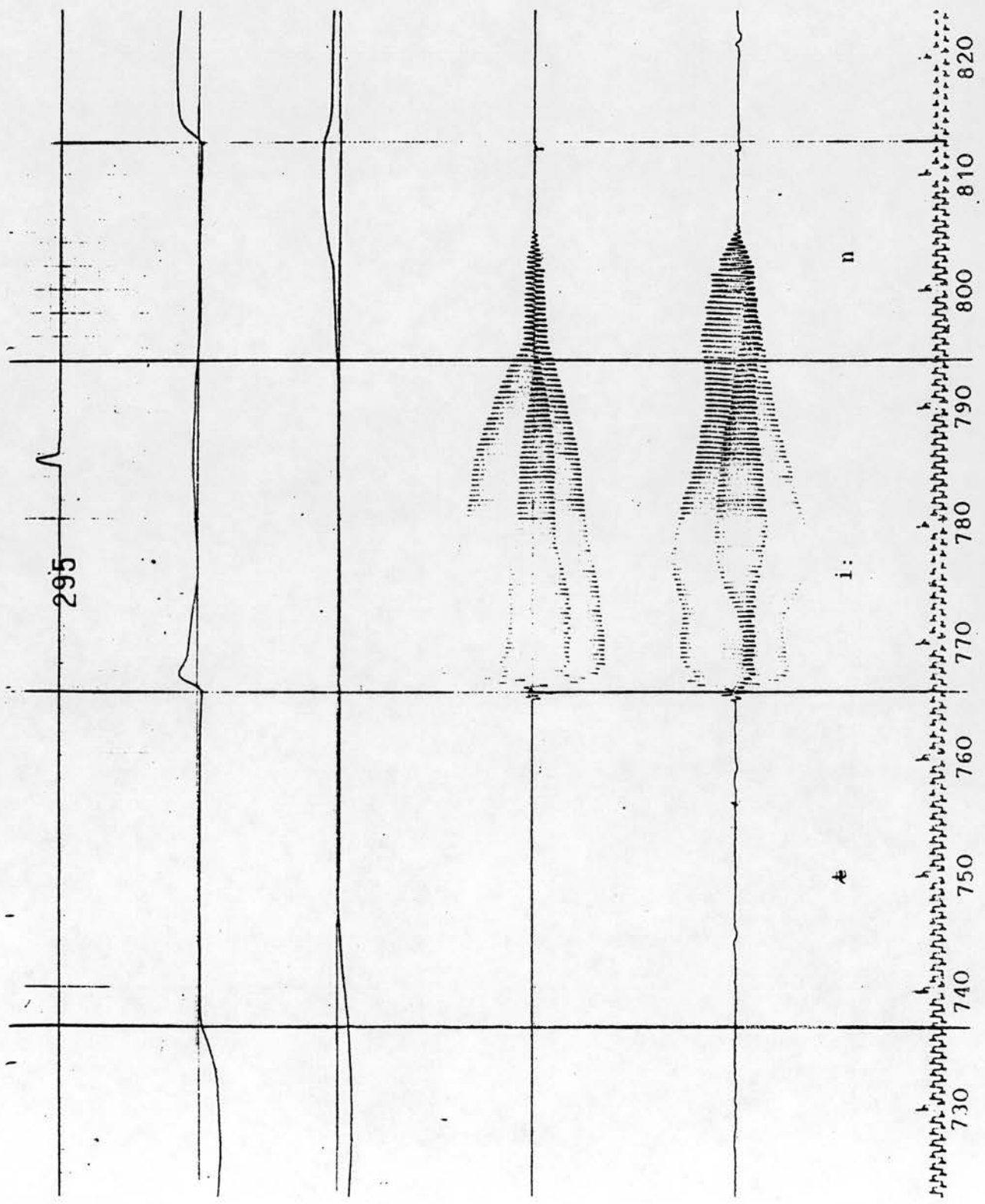

/ɛi:n/

Figure 3.3.4.e

Figure   3.3.4.f

Figure 3.3.4.g

tongue tip and blade is a consequence of the rearward movement of the back of the tongue required for the production of the pharyngealized consonant /ŧ/. /n/ also exhibits fewer contacts in the posterior region of the palate.

Comparing the airflow records of the two words, Figures 3.3.4.f,g, one notices that the release of /ŧ/ results in a much lower airflow rate than /t/ and a zero VOT (defined as the time between the release of complete articulatory closure or constriction and the onset of the quasi-periodic vocal folds vibration, in other words, it is the length or duration of the voiceless noise or aspiration following the release of voiceless plosives), while /t/ has a 70 msec VOT. So /ŧ/ is an unaspirated plosive as upon its release the vocal folds start vibrating indicating the start of the following vowel /i:/. This contradicts Ahmad's (1984) findings where the results of his experiment showed a longer VOT for the emphatic plosive than the non-emphatic cognate. /ŧ/ is also 80 msec longer in duration than /t/. /i:/ has much lower oral airflow rate and 60 msec longer in duration in the emphatic context. The nasal airlow is much lower for /n/ in the emphatic context and starts much later. While nasal airflow is anticipated in the last third of the preceding vowel /i:/ in the non-emphatic context, it does not start till after the nasal started in the emphatic context.

3.3.5   /siːn/ & /sˤiːn/

Comparing the EPG data Figures 3.3.5.a,b (see appendix F) and the graphic representation of the data, Figures 3.3.5.c,d,e, we notice that /sˤ/ has more lingual-palatal contacts in the anterior region of the palate than /s/, indicating a firmer lingual-palatal contact. The following vowel /iː/ is retracted as its contacts start on the second row instead of the first row, resulting in fewer front contacts. /n/ exhibits much more contacts in the alveolar region in the emphatic context as a result of a firmer primary constriction. But it exhibits much less contacts in the palatal region as a result of the secondary articulation.

Comparing the airflow records, Figures 3.3.5.f,g, one notices that /sˤ/ has a slightly lower airflow rate and 10 msec longer in duration than /s/. In the emphatic context, /iː/ exhibits slightly lower airflow rate and 20 msec longer in duration. /n/ also has a slightly lower nasal airflow which is anticipated in the last third of the preceding vowel, while in the non-emphatic environment it is anticipated in the first third of the preceding vowel. /n/ is also 30 msec longer in the emphatic context.
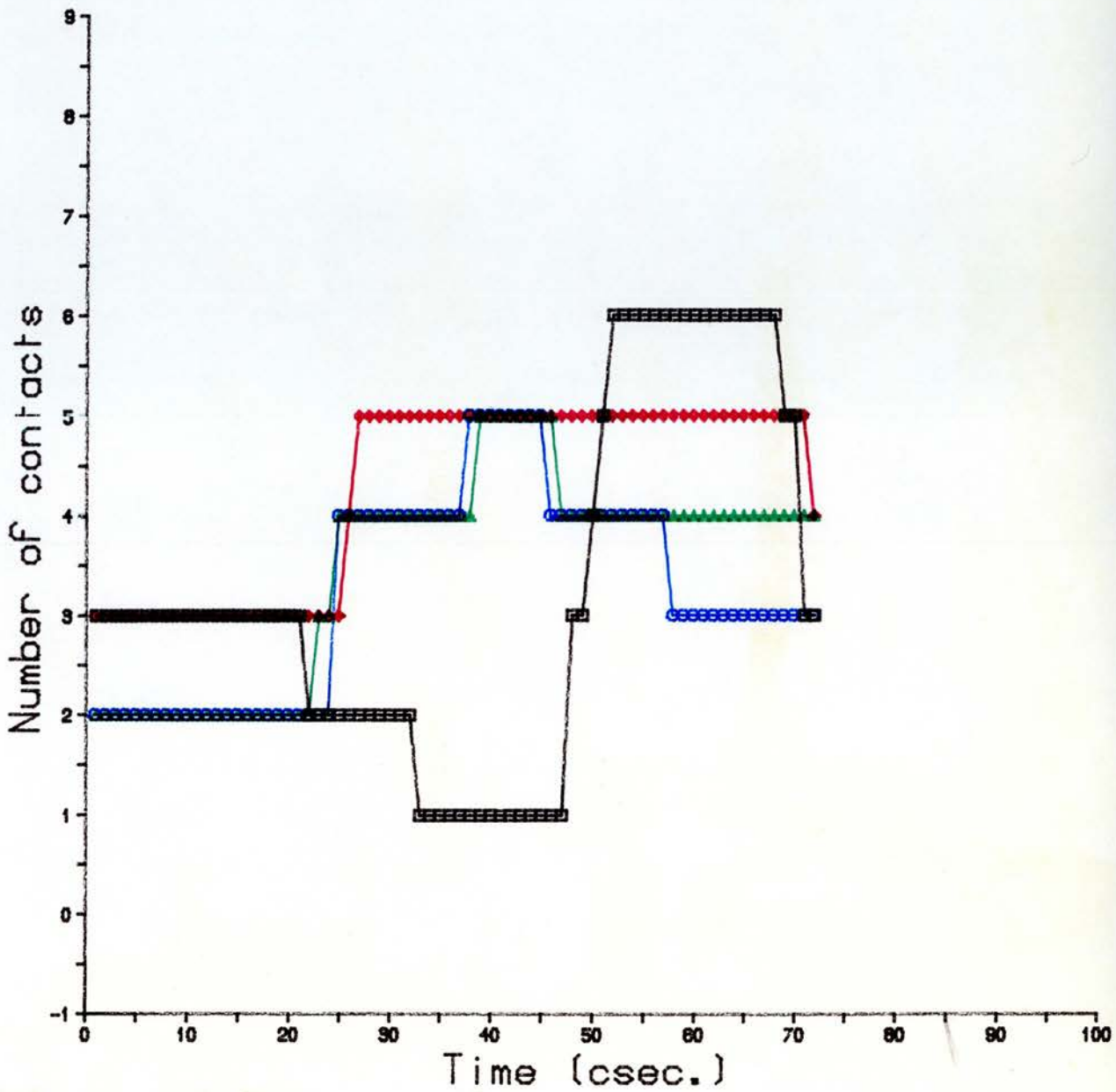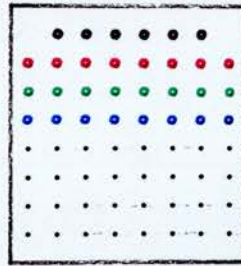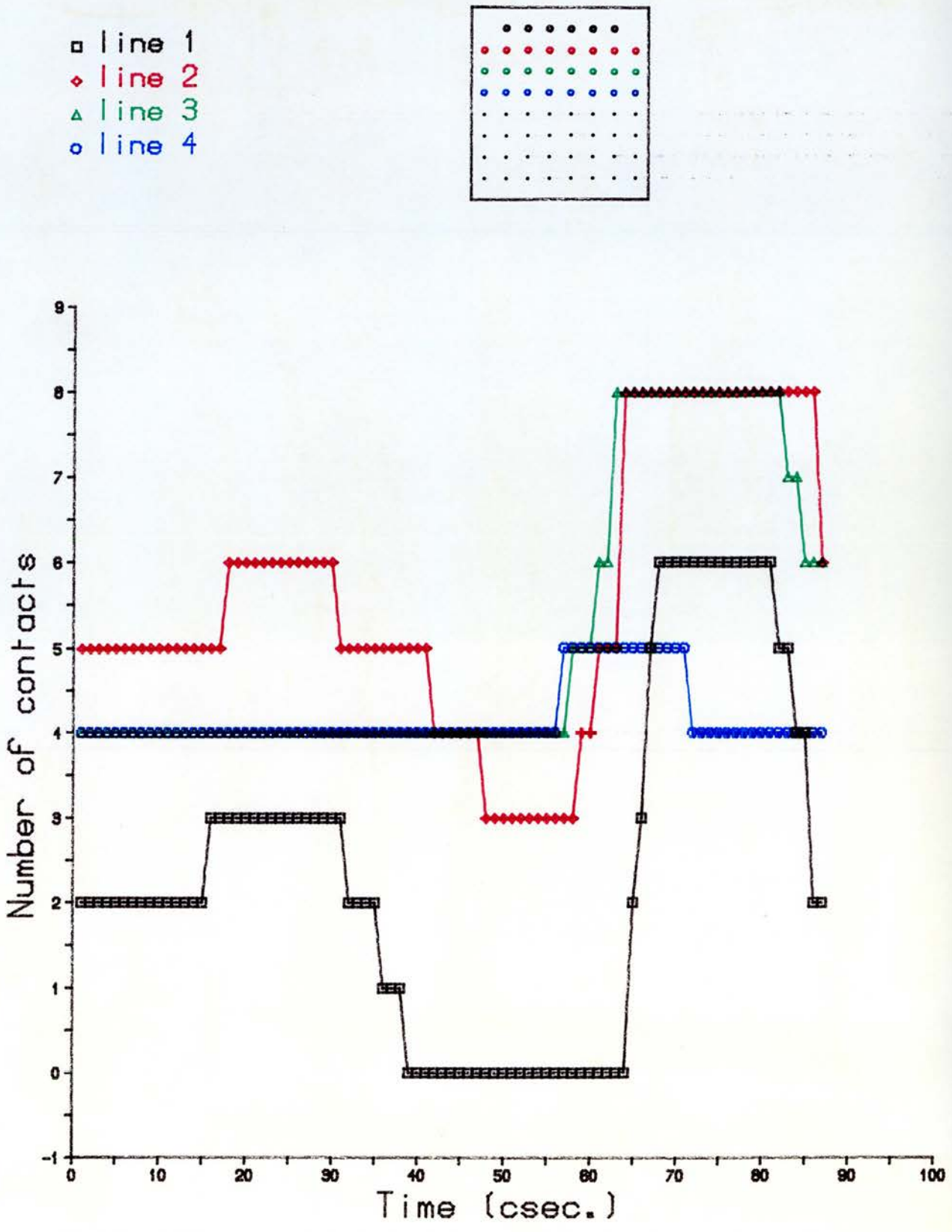
Figure   3.3.5.c
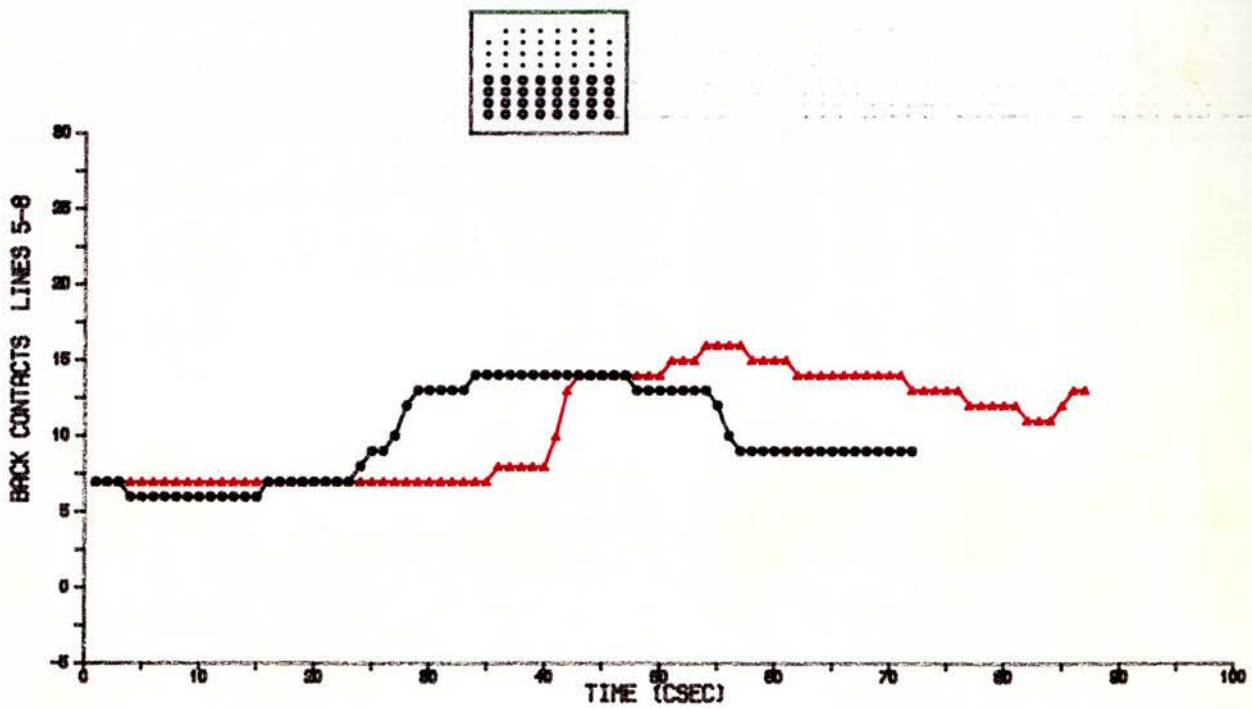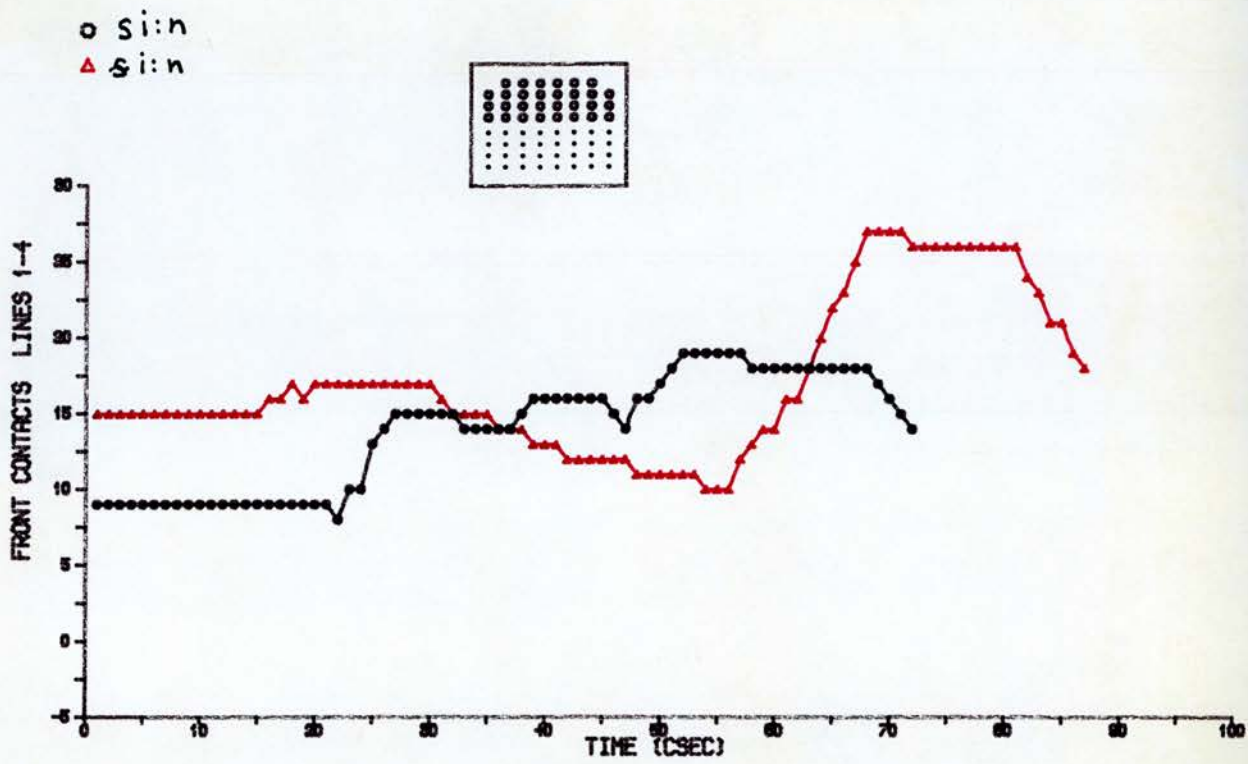
/si:n/

Figure   3.3.5.d
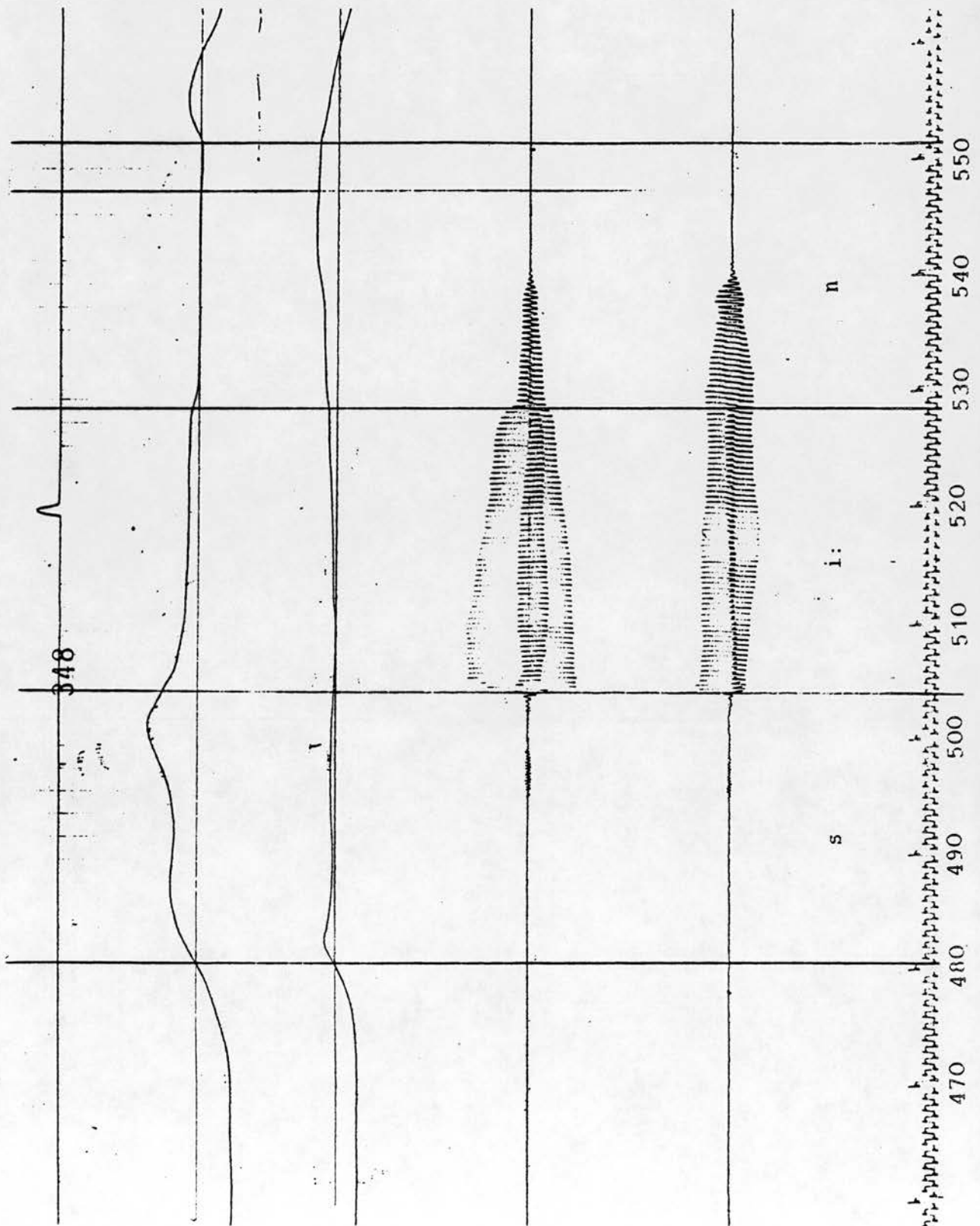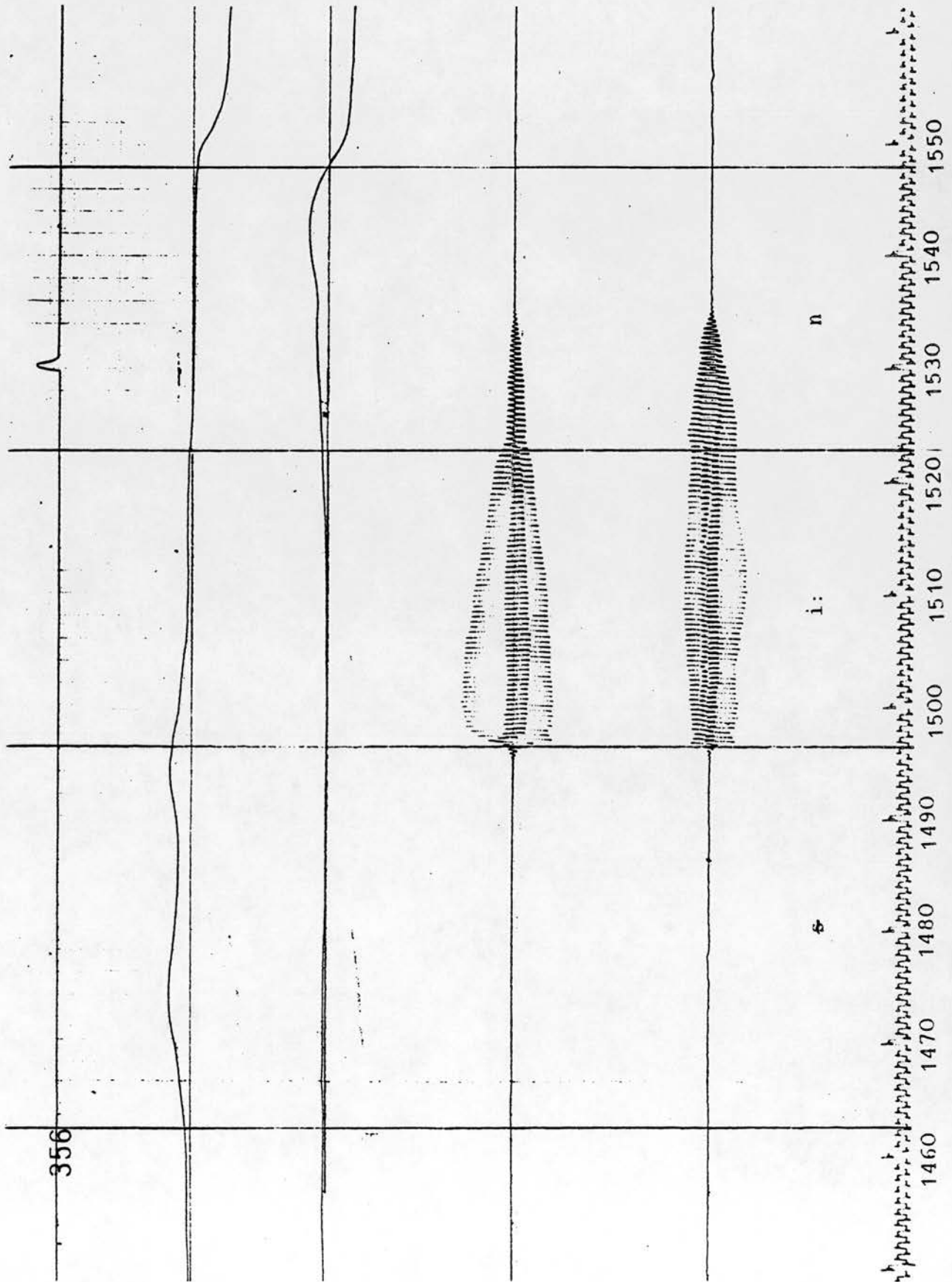
/si:n/

157

Figure   3.3.5.e

Figure 3.3.5.f

Figure   3.3.5.g

3.3.6   /saːd/ & /ṣaːd/

Comparing EPG data for this pair, Figures 3.3.6.a,b (see appendix F), and the graphic representation of the data, Figures 3.3.6.c,d,e, we notice that /ṣ/ starts with having less contacts in the front part of the palate than /s/, but gradually the number of contacts increases for /ṣ/ and decreases for /s/. As for the back region, lines 5-8, /ṣ/ has fewer contacts than /s/ all the way through. /aː/ being an open back vowel has zero-contacts in the anterior region of the palate, lines 1-4, in both words. But it has fewer contacts in the posterior part, lines 5-8, in the emphatic context. /d/ has a firmer lingual-palatal contact in the alveolar region as it has more contacts in rows 1-4; but it has fewer contacts in the palatal region, rows 5-8, revealing the effect of pharyngealization.

Comparing airflow traces, Figures 3.3.6.f,g, we observe that /ṣ/ has slightly lower airflow rate and 20 msec shorter in duration than /s/ which is contrary to our expectation. In the emphatic context, /aː/ has a slightly lower airflow and 10 msec longer in duration. /d/ has a lower airflow peak at its release and 20 msec longer in duration. Another thing we notice is that the accelerometer signal has a higher amplitude in the emphatic word than non-emphatic cognate.
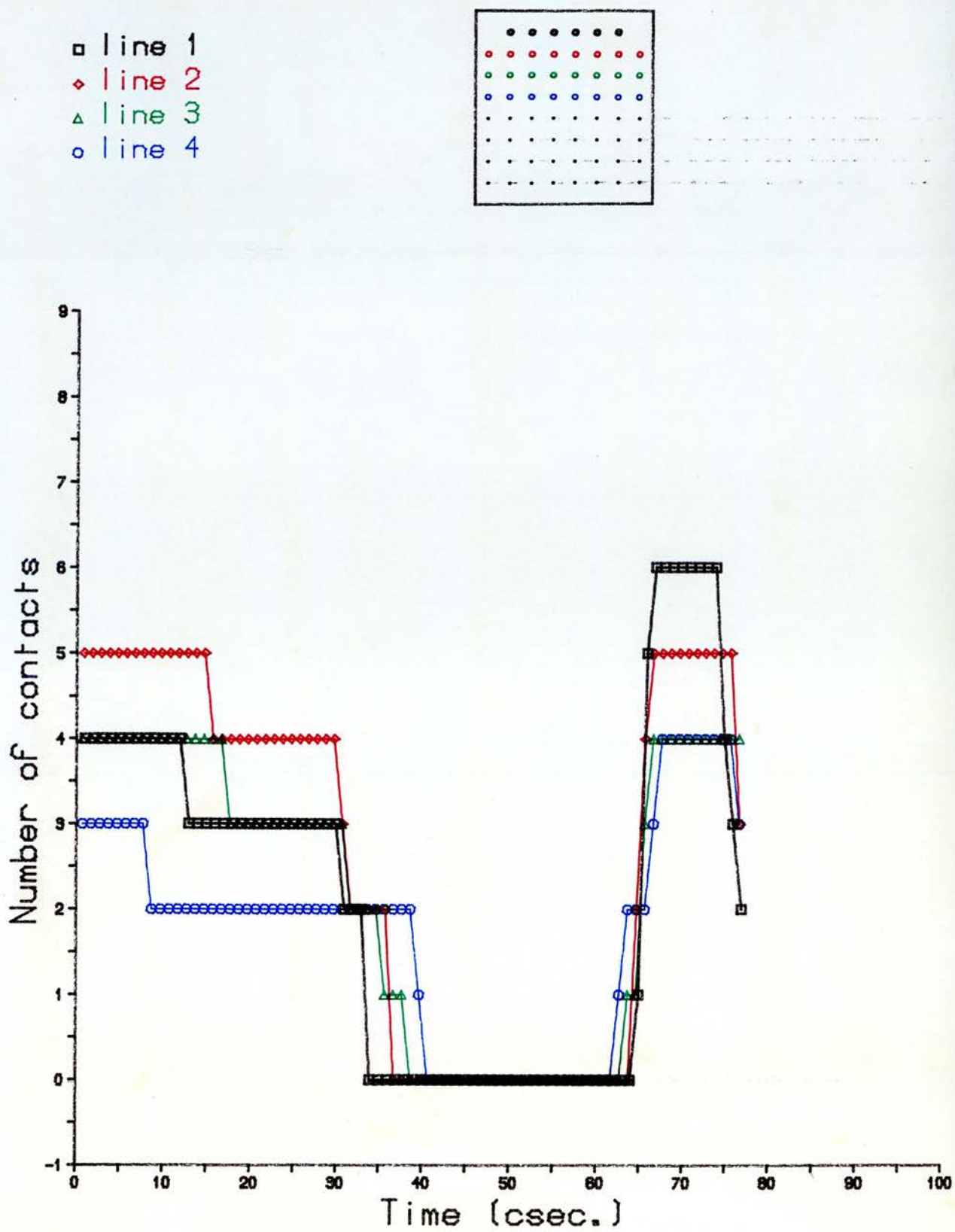
Figure 3.3.6.c

/sa:d/
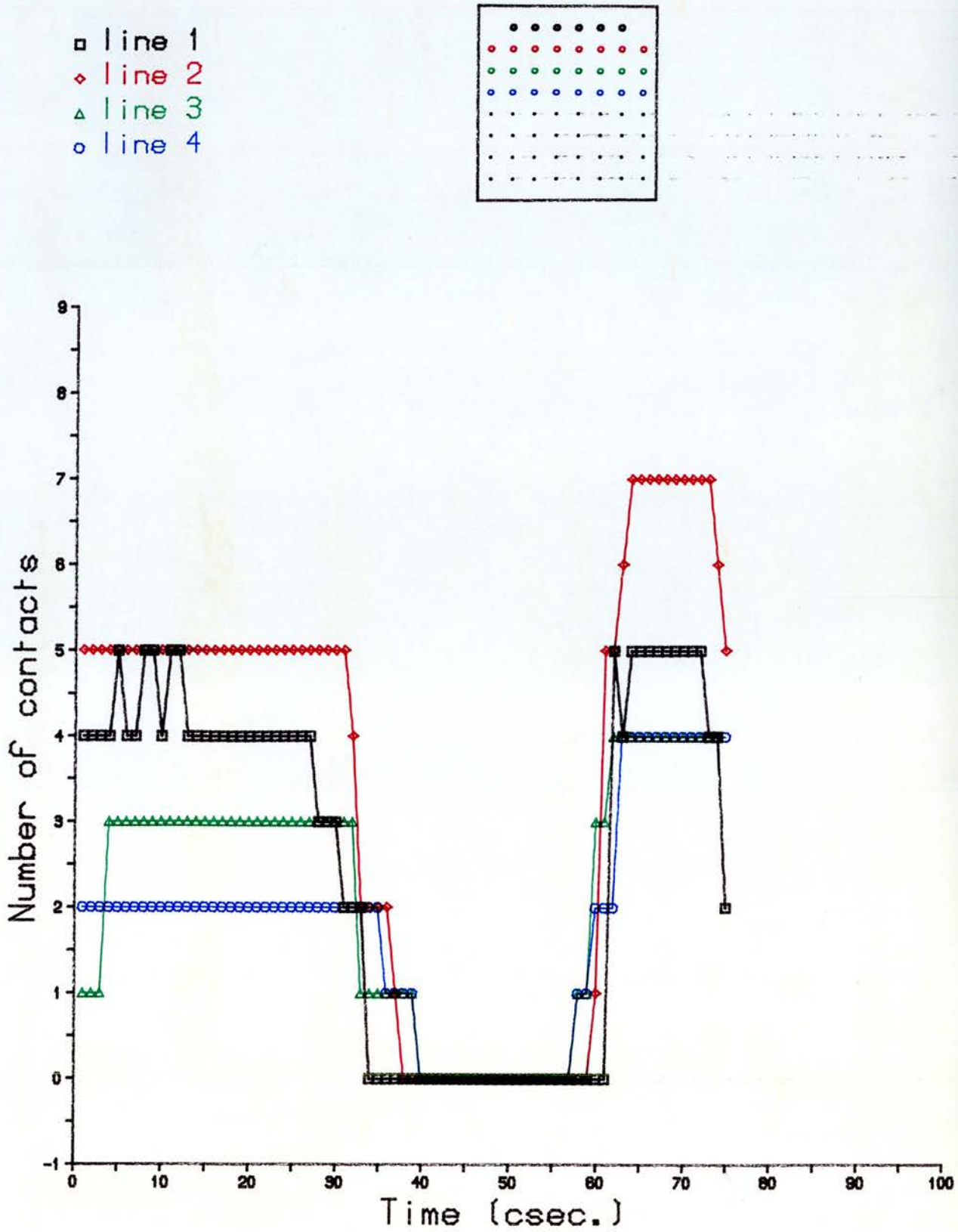
Figure 3.3.6.d

/ɛa:d/
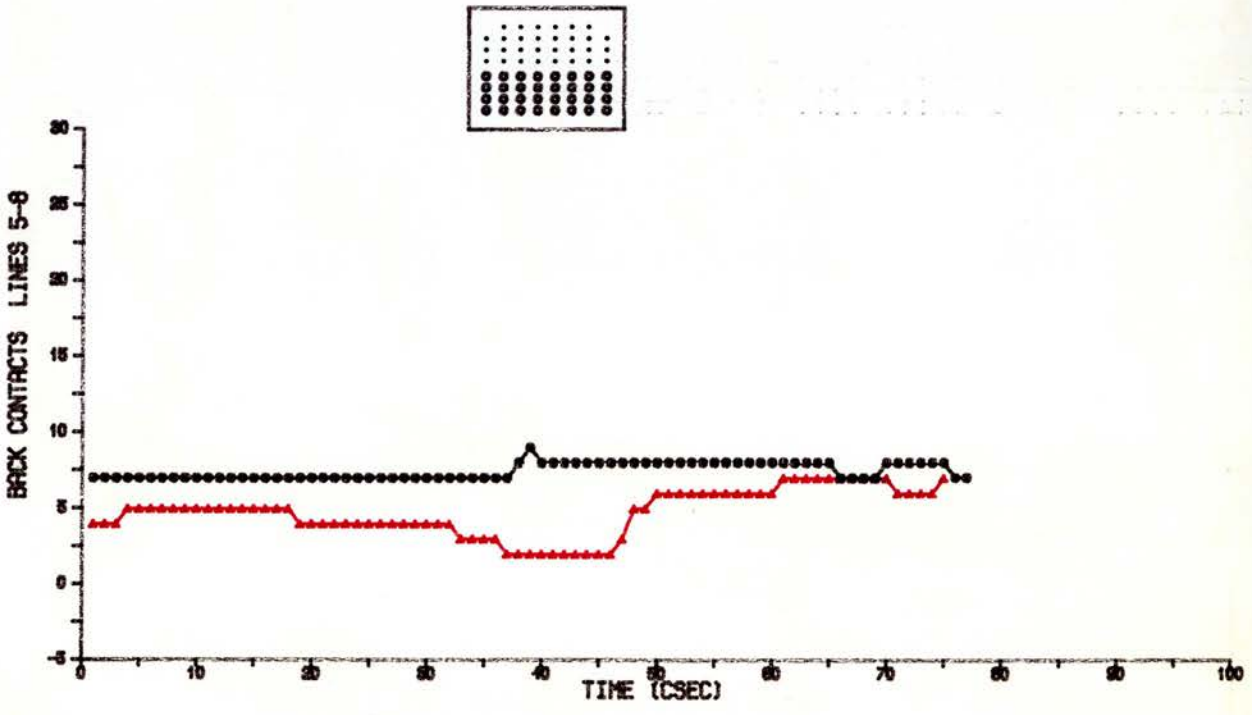
Figure   3.3.6.e

Figure   3.3.6.f

Figure 3.3.6.g

3.3.7   /sid/ & /ṣid/

Comparing the EPG data, Figures 3.3.7.a,b (see appendix F), and the graphic representation of the data, Figures 3.3.7.c,d,e, we notice that /ṣ/ has more contacts in the first four rows of the palate, indicating a firmer lingual-palatal contact in the alveolar region. But it has fewer contacts in the palatal region, indicating pharyngealization. /i/ is also pharyngealized as it is retracted to line two and shows fewer contacts in the posterior region of the palate. /d/ exhibits a firmer lingual-palatal constriction in the alveolar region, as it has a bigger number of touched electrodes; while it has fewer number of touched electrodes in the palatal region.

The airflow records for the two words, Figures 3.3.7.f,g, reveal that /ṣ/ has a different airflow pattern than /s/. It does not have the two-humps shape characteristic of the voiceless fricative. /ṣ/ also is 20 msec longer in duration. In the emphatic context, /i/ starts with a lower airflow rate and is 20 msec longer. /d/ is also 20 msec longer in duration.

3.3.8   /tal/ & /ṭal/
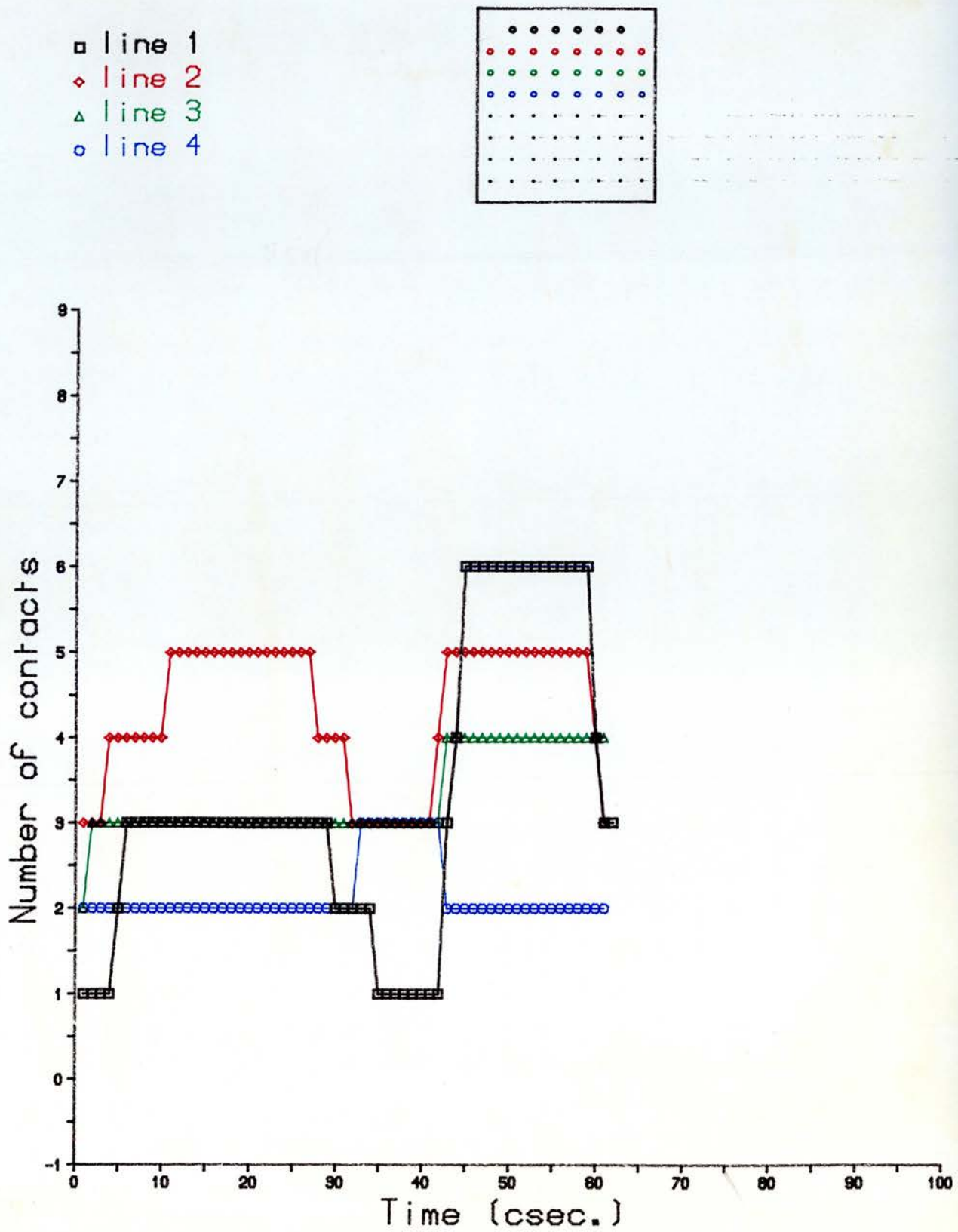
Figure 3.3.7.c

/sid/
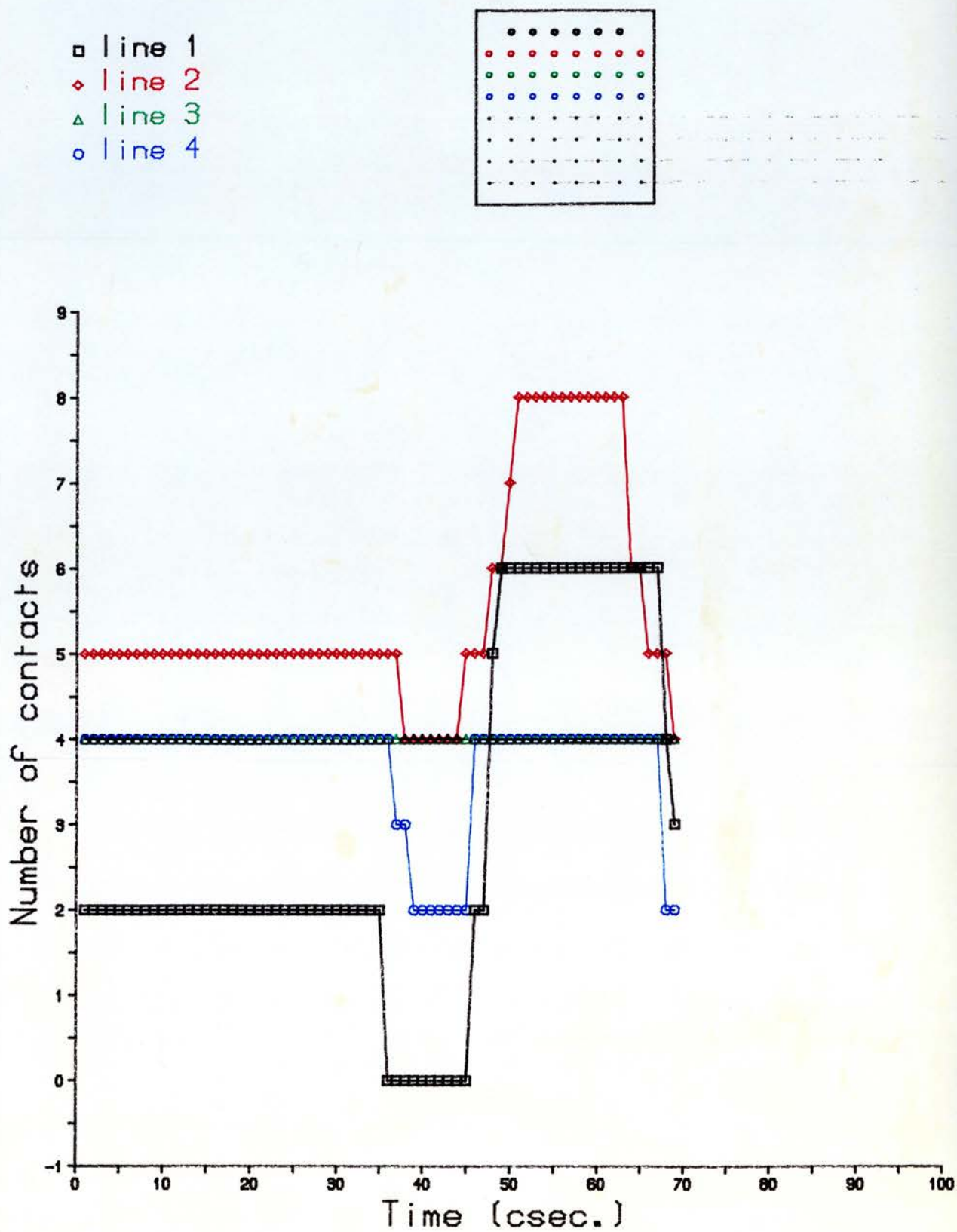
Figure 3.3.7.d

/sid/
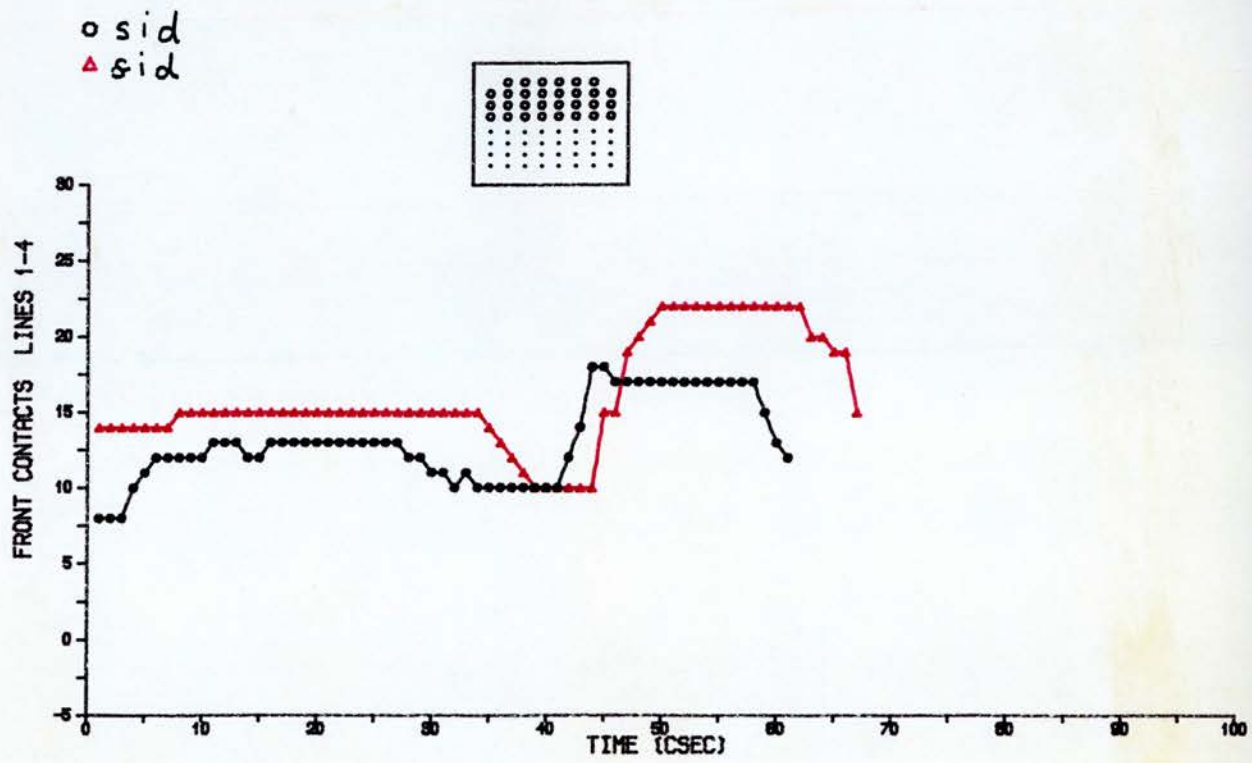
Figure 3.3.7.e

Figure 3.3.7.f

Figure   3.3.7.g

Comparing the EPG data, Figures 3.3.8.a,b (see appendix F), and the graphic representation of the data, Figures 3.3.8.c,d,e, we observe that /ŧ/ has a much larger area of contact covering almost the whole alveolar region. But it has more or less the same number of contacts as /t/ in the palatal region of the palate. /a/ in both words has zero-contacts in the alveolar region, but it has much fewer contacts in the palatal region in the emphatic context, indicating pharangealization. /l/ is retracted in the pharyngealized context, as the lingual-palatal contacts covers the second and third lines of the alveolar region, while it covers the first and second lines in the non-pharyngealized environment. Also we notice that /l/ exhibits zero contacts in the posterior lines 5-8, indicating tongue hollowing and retraction.

The airflow records in Figures 3.3.8.f,g show that /ŧ/ has zero VOT, while /t/ has 50 msec VOT. /ŧ/ also has a lower airflow peak at its release and almost double the length of /t/. In the emphatic context, /a/ has a lower oral airflow rate and is about 10 msec longer; /l/ exhibits a lower airflow rate too and is 20 msec longer in duration.

3.3.9   /sa:matla/ & /ṣa:matla/
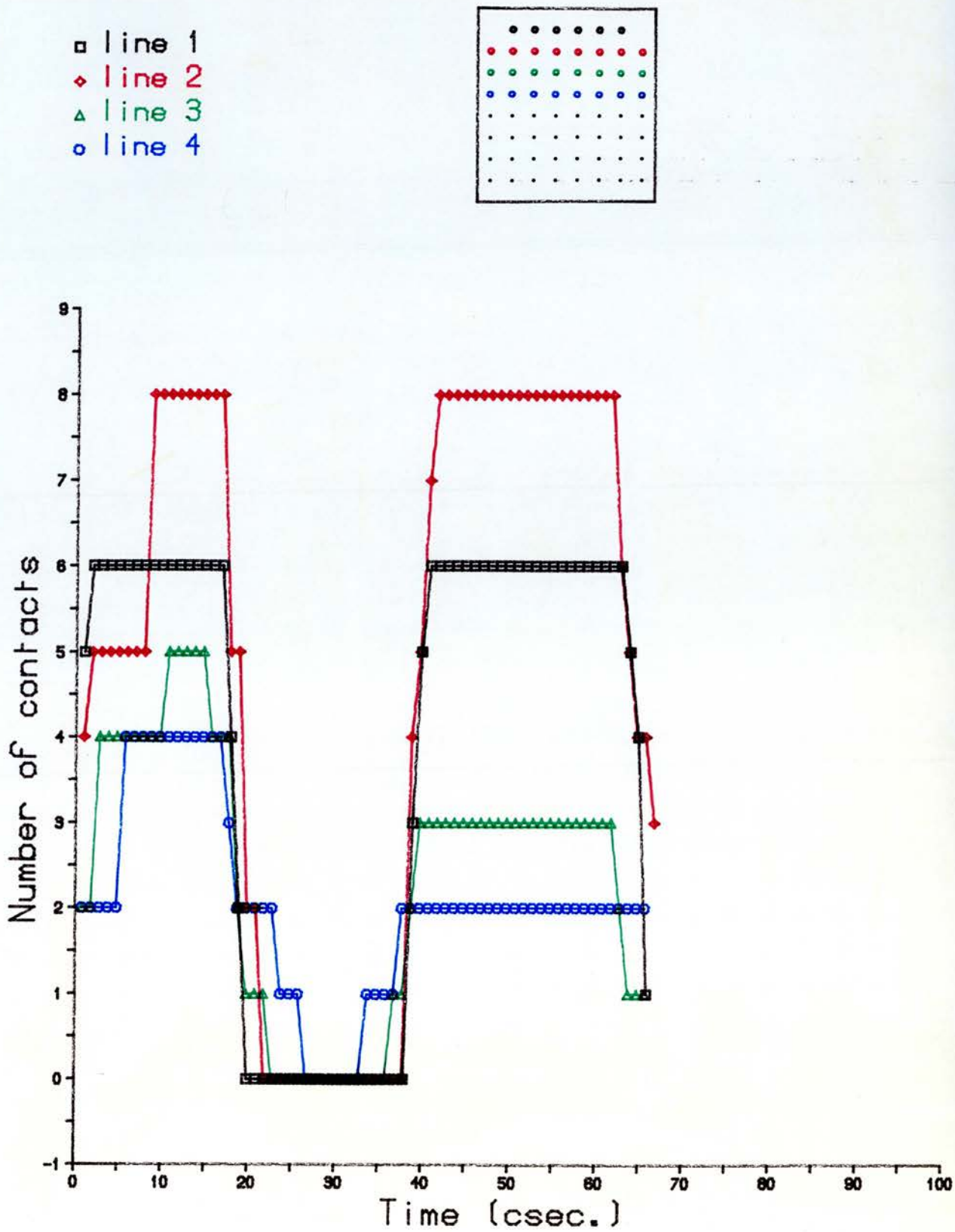
Figure 3.3.8.c

/tal/

Figure 3.3.8.d

/ɬal/

Figure   3.3.8.e

176
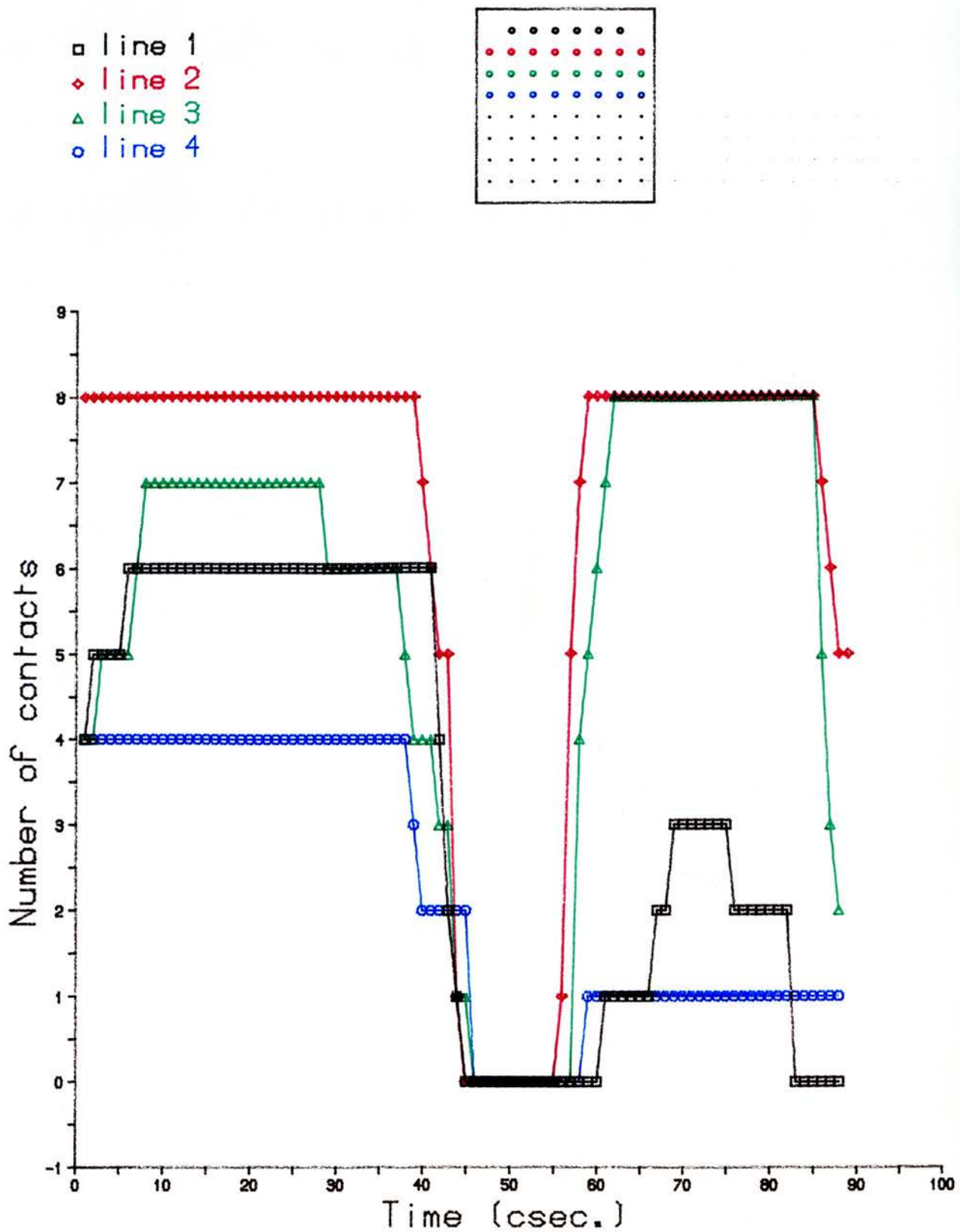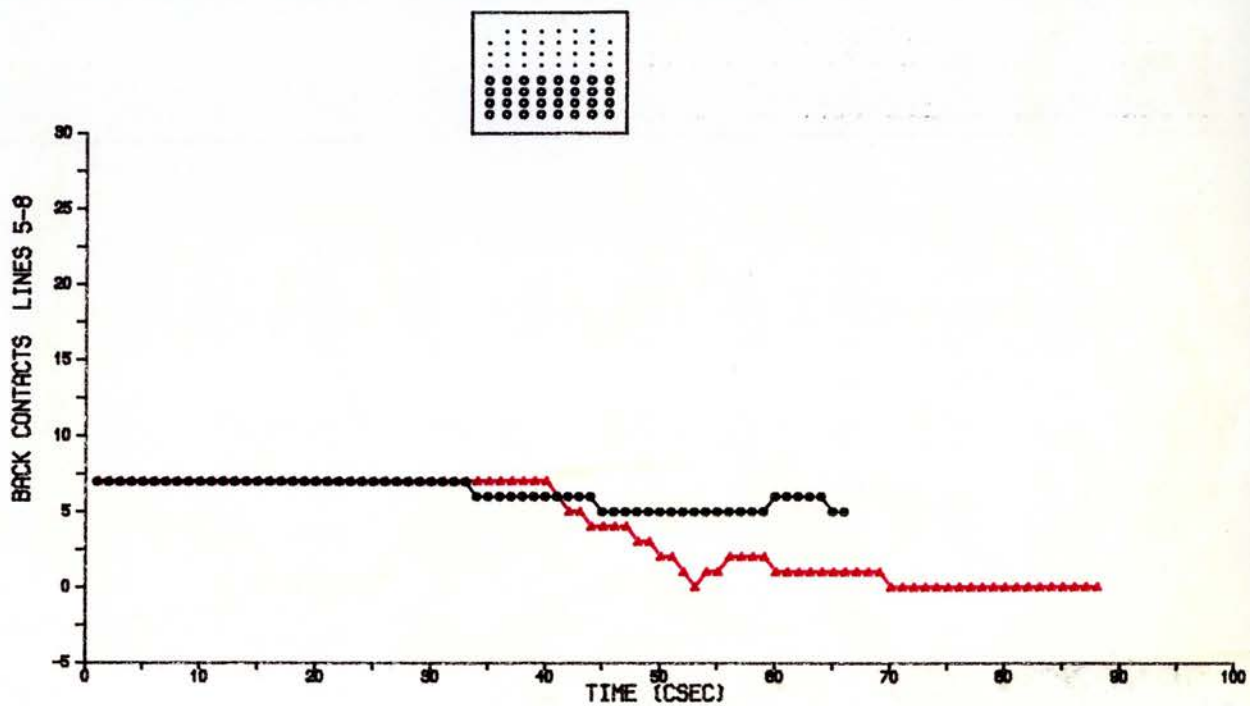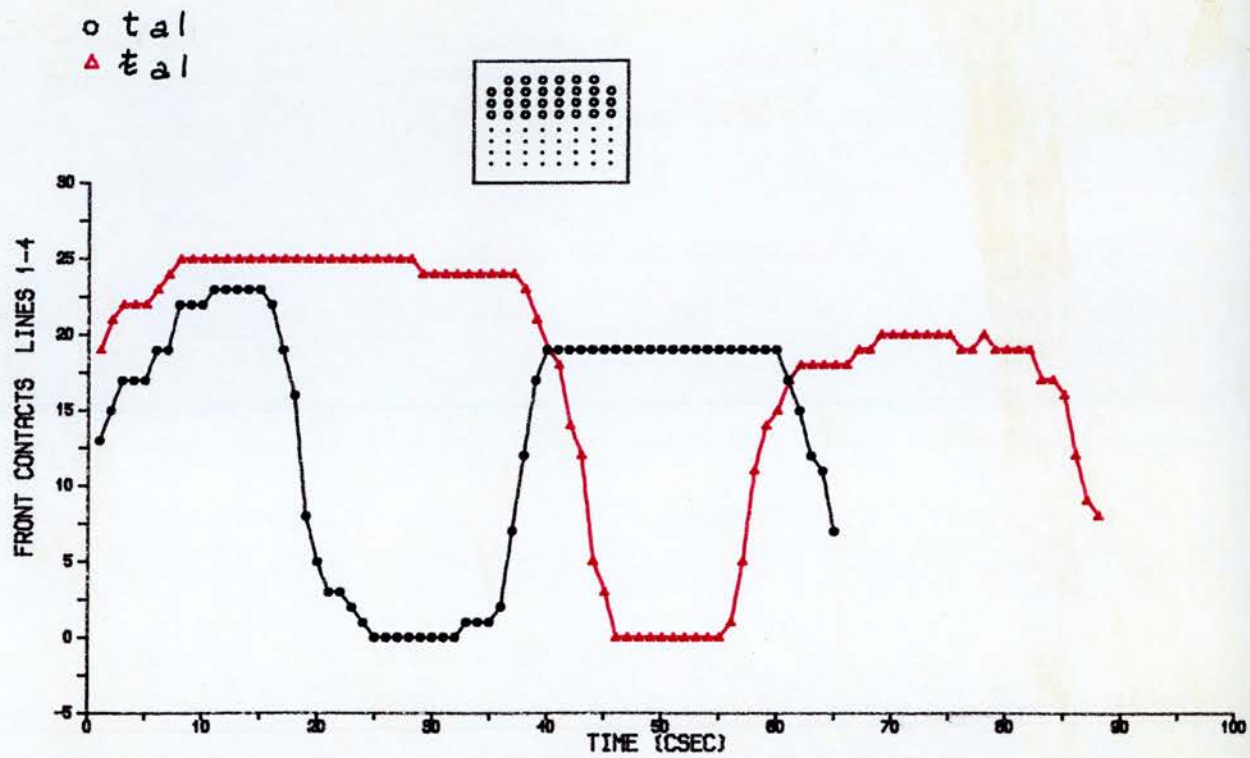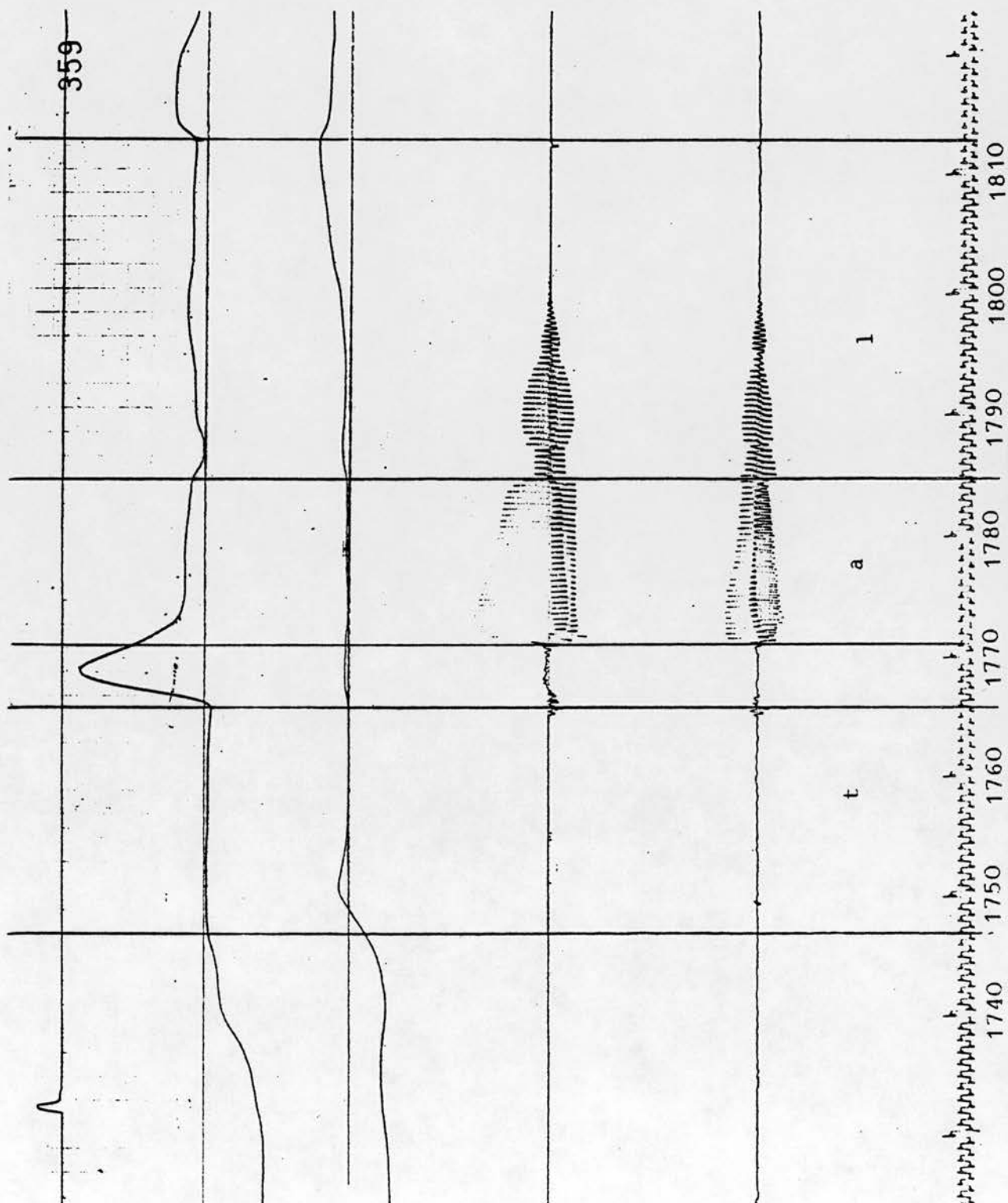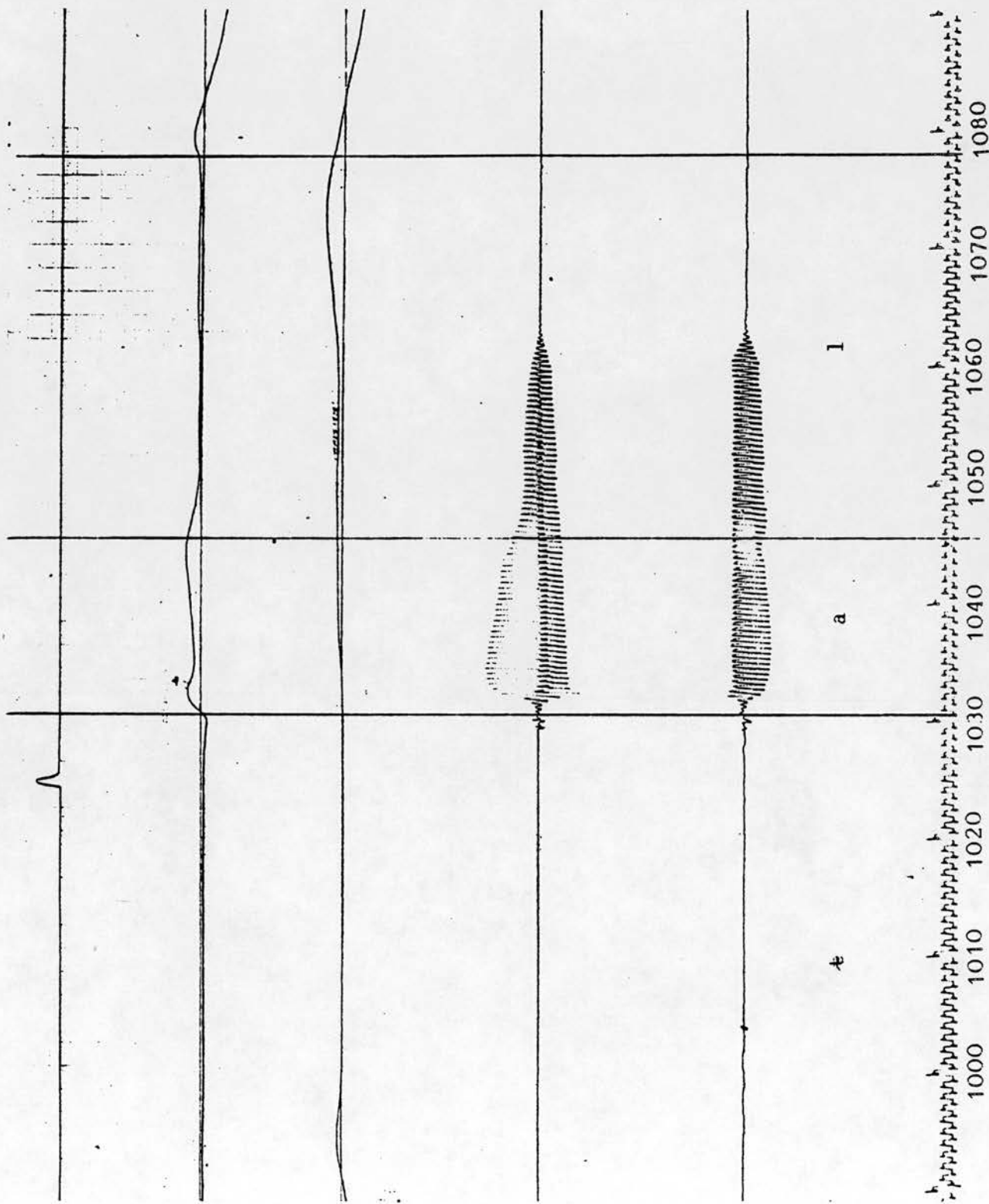
Figure 3.3.8.f

Figure   3.3.8.g
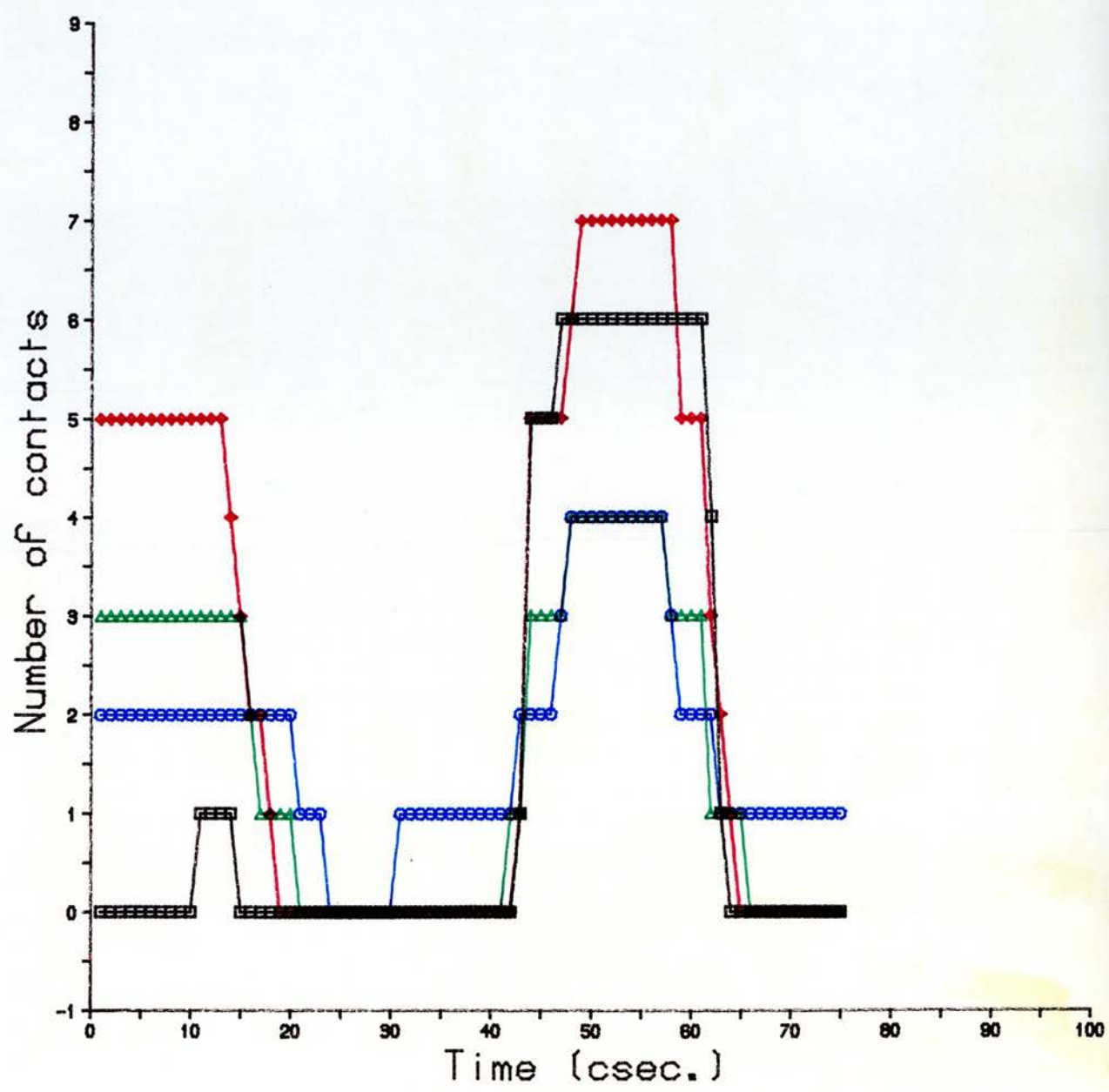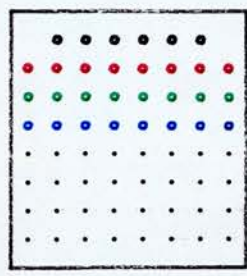
Figure   3.3.9.c

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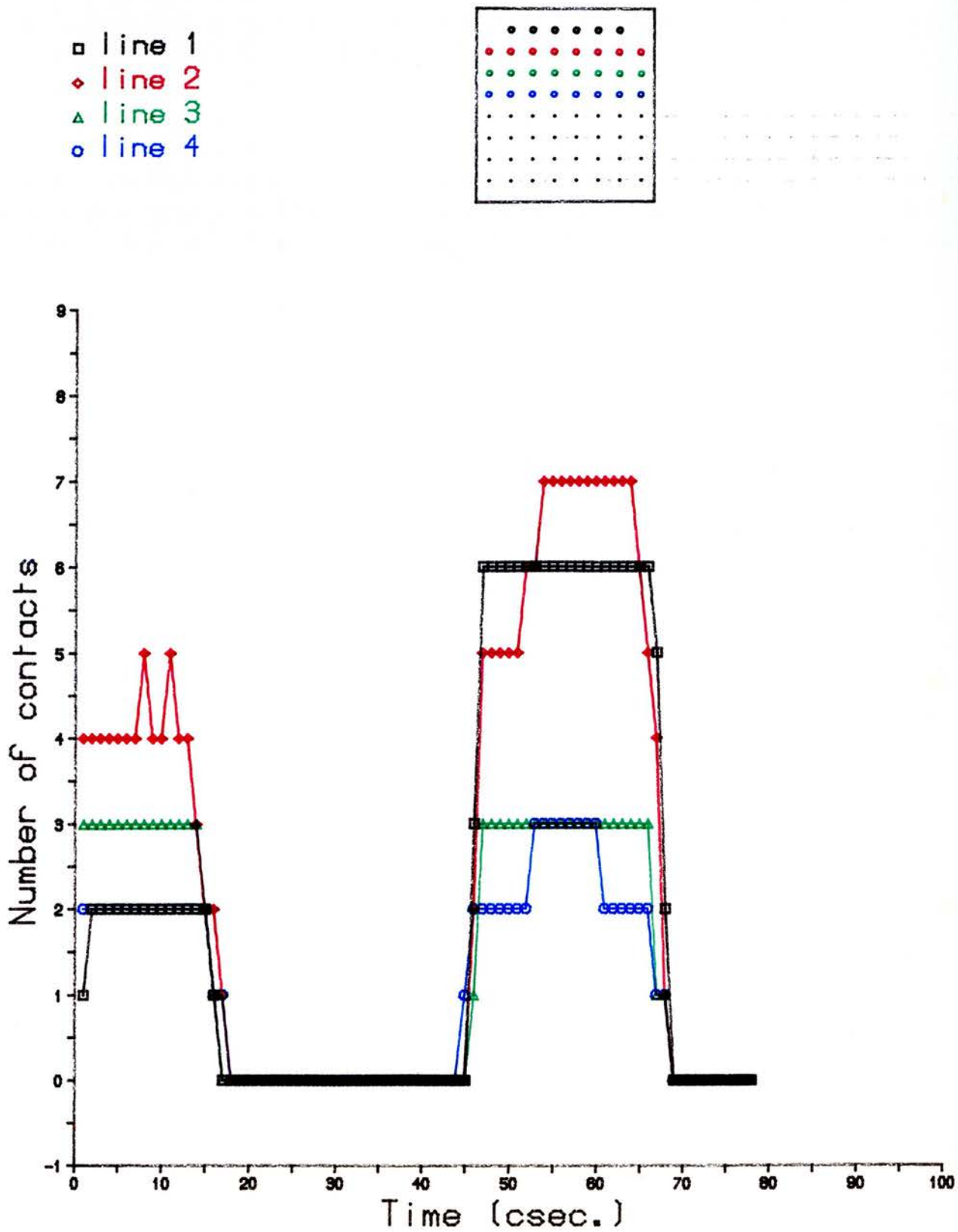
Figure 3.3.9.d

/sa:matla/
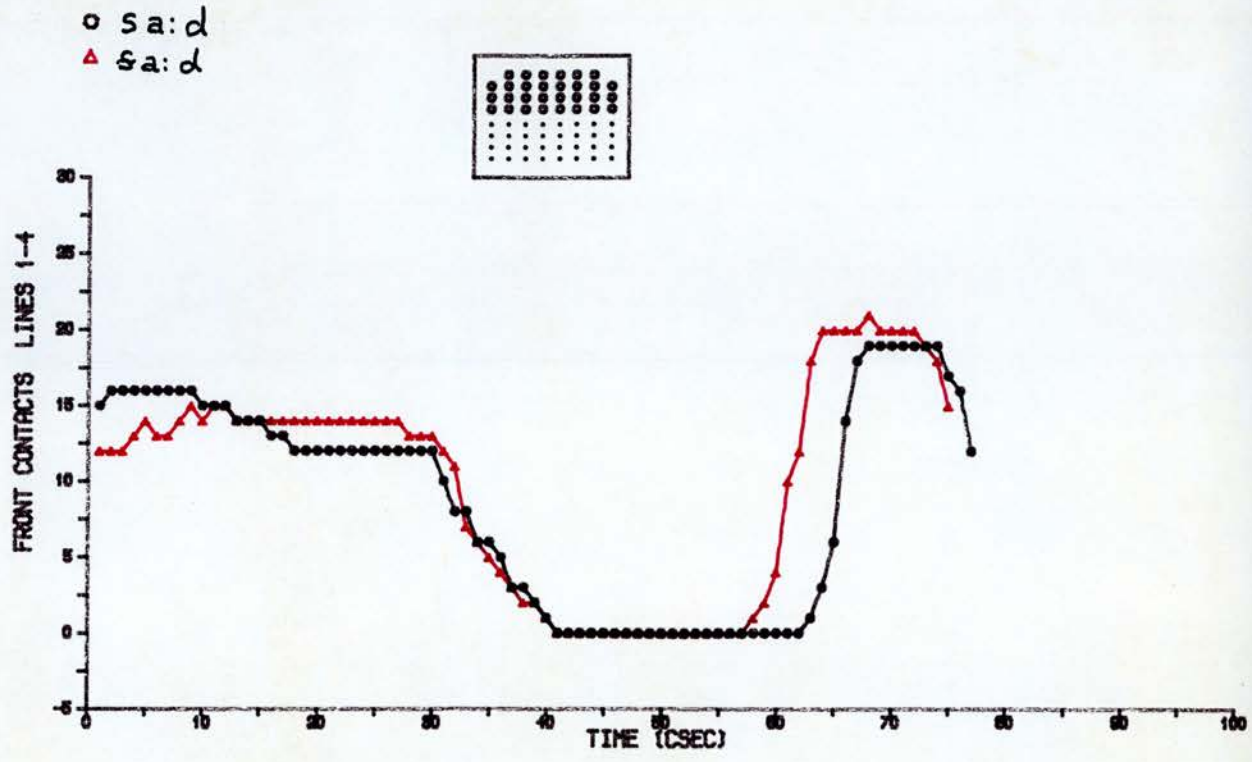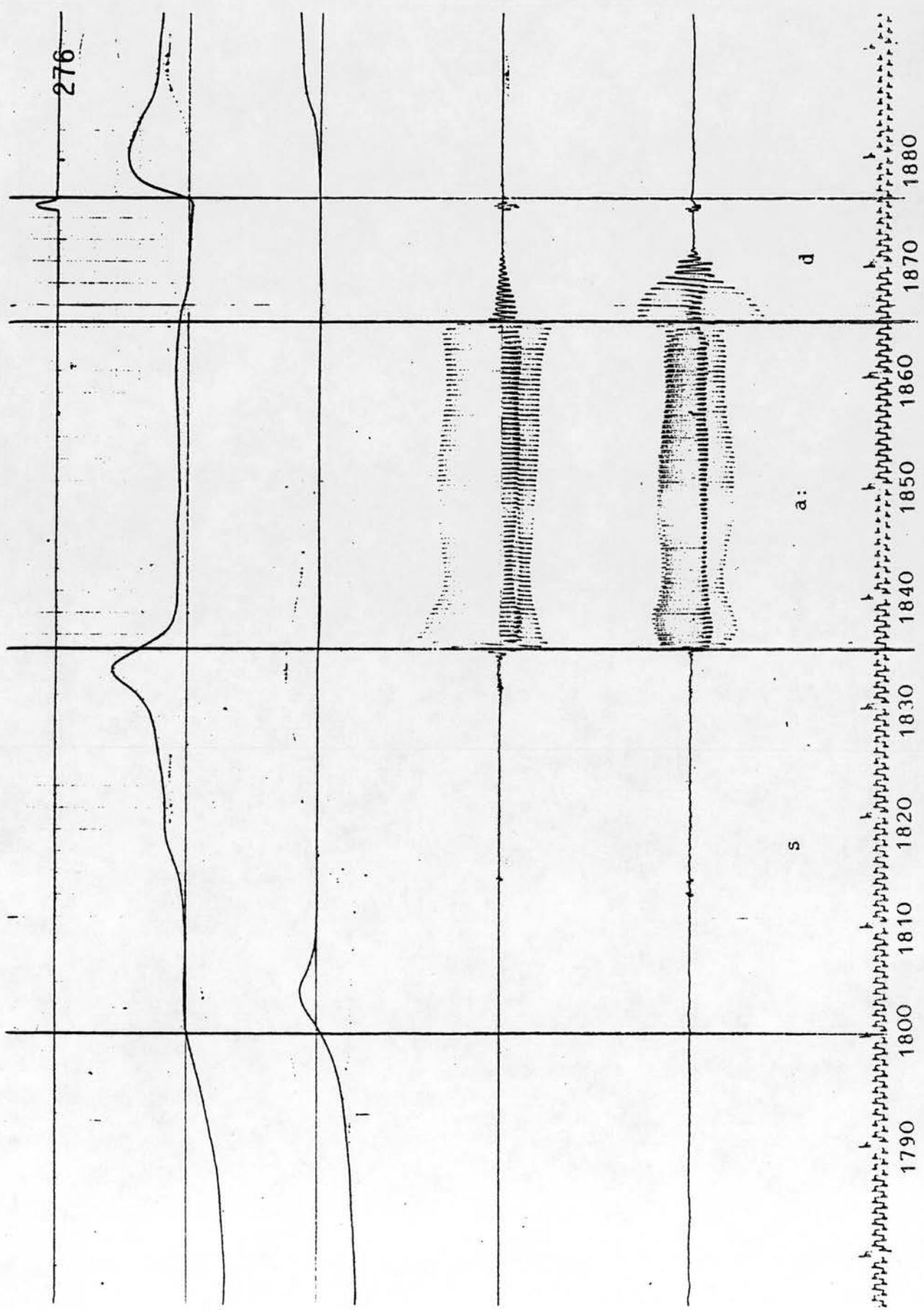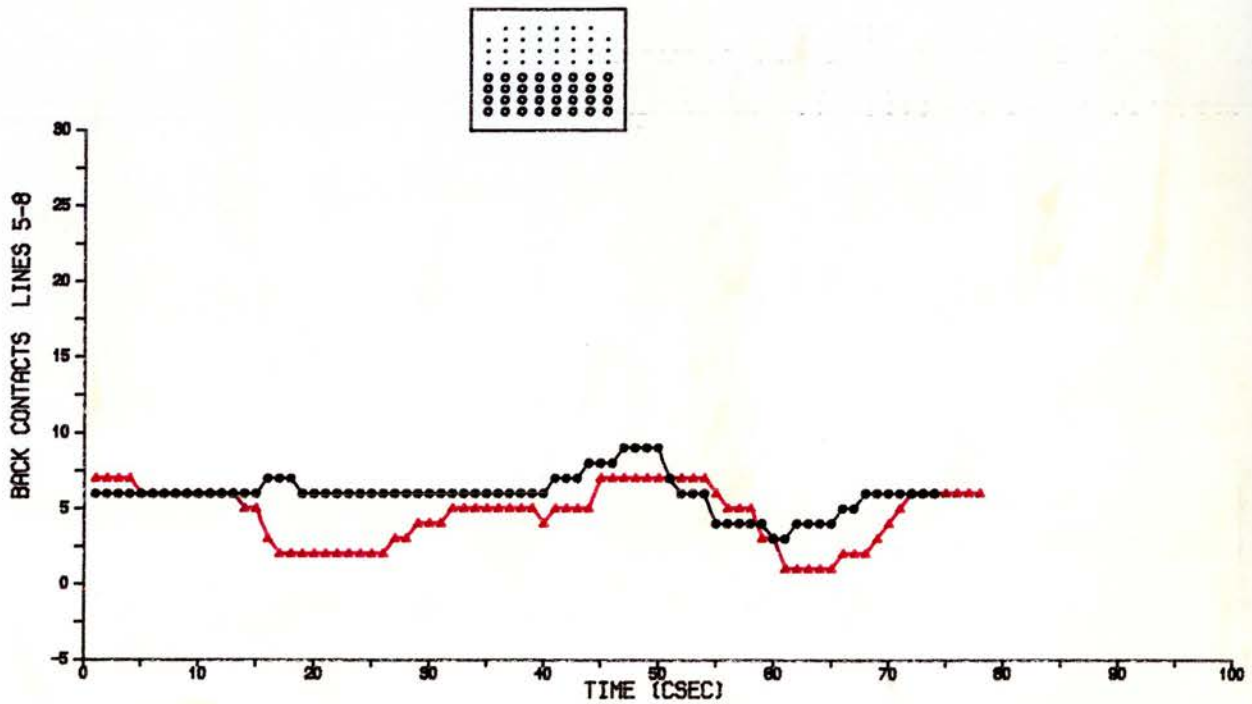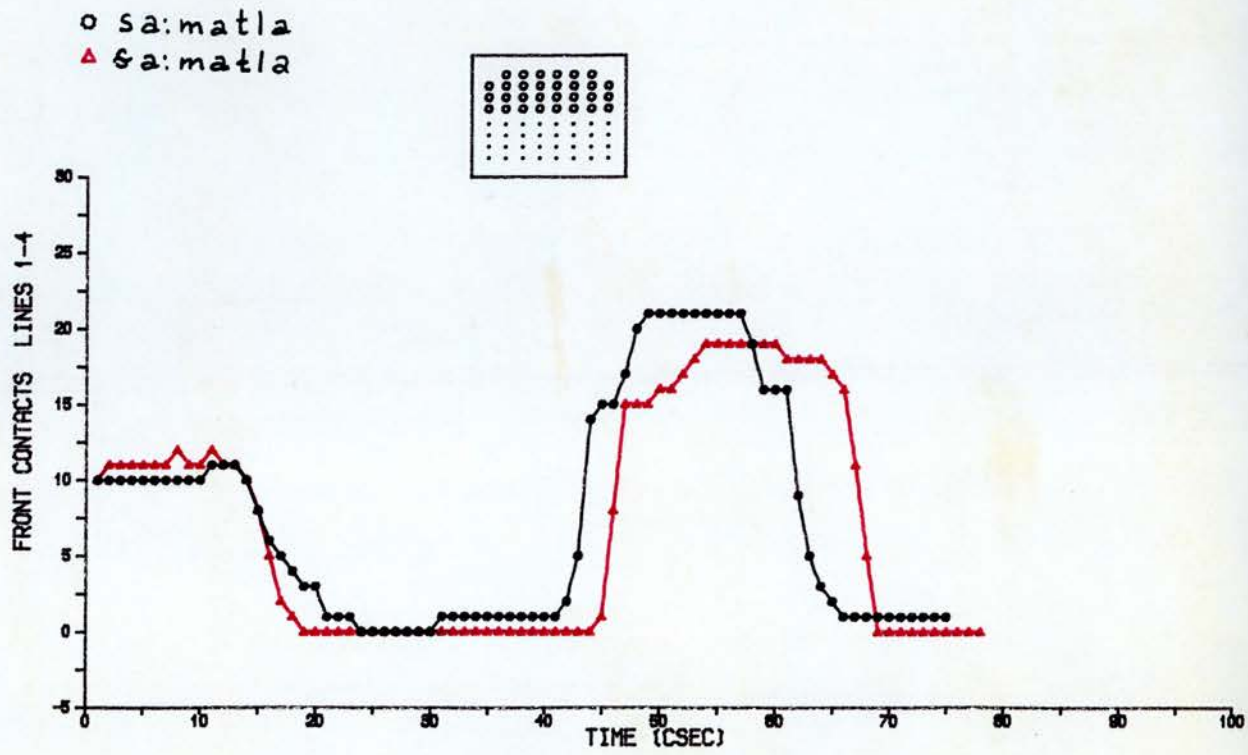
Figure 3.3.9.e

Figure   3.3.9.f
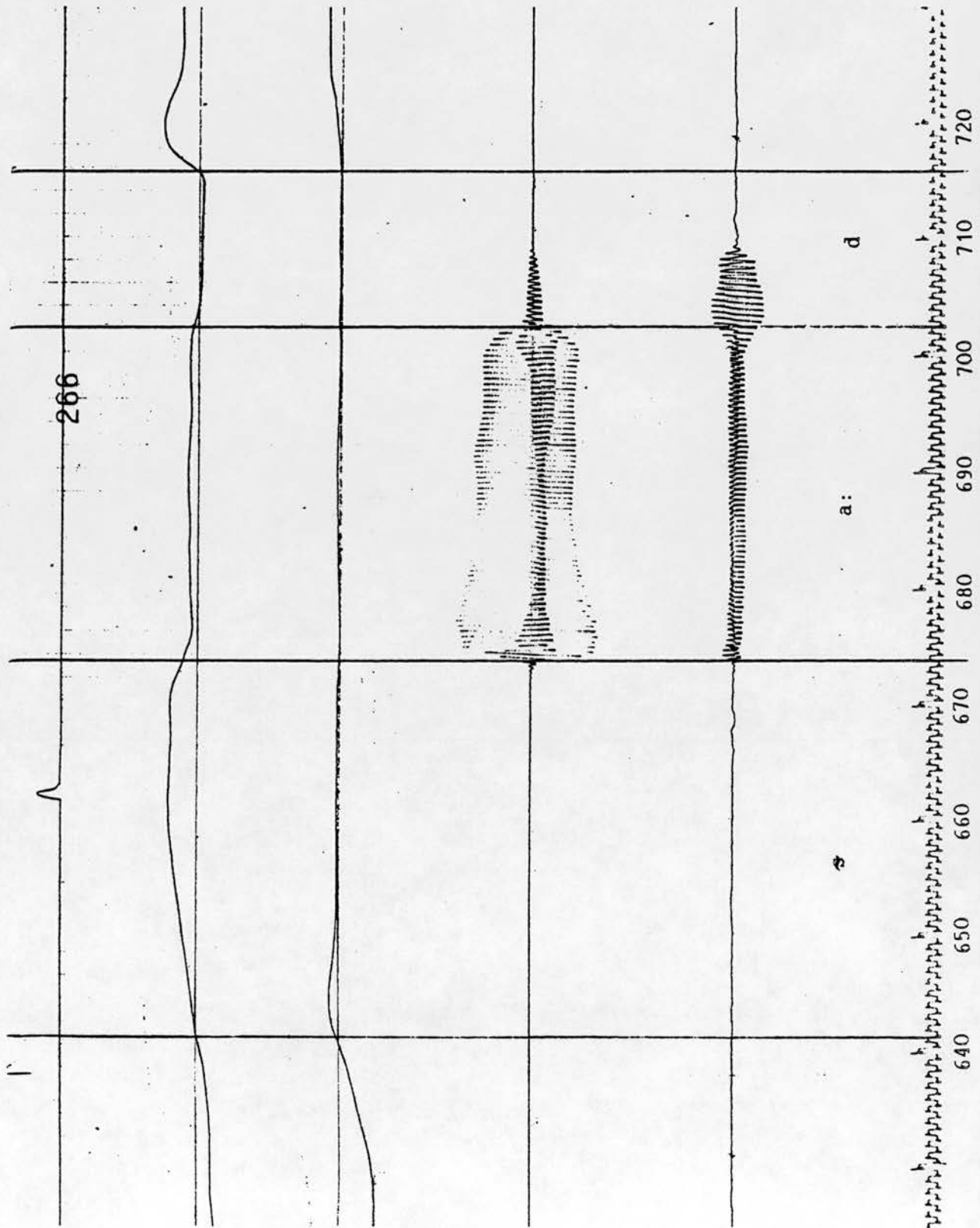
Figure 3.3.9.g

The EPG data, Figures 3.3.9.a,b (see appendix F), and the graphic representation of the data, Figures 3.3.9.c,d,e, for the two words show that /s/ has more contacts in the alveolar region indication a firmer constriction; but contrary to our expectation, /s/ is more retracted than /s/. In the emphatic environment /a/ has fewer contacts in the back region of the palate, /m/ has fewer touched electrodes both in the alveolar and palatal regions, /t/ and /l/ exhibit less contacts in the front and back regions of the palate, and /a/ has zero contacts in the alveolar region.

Figures 3.3.9.f,g show that there are no major differences in the airflow pattern for the two words; but they exhibit differences in duration. In the emphatic context, /s/ is about 10 msec longer, /a/ is 20 msec longer /m/ is 30 msec shorter, /a/ is 40 msec longer, /l/ is 30 msec longer and /a/ 20 msec shorter.

3.3.10   /nisi:b/ & /nisi:b/

The EPG data in Figures 3.3.10.a,b (see appendix F) and the graphic representation of the data in Figures 3.3.10.c,d,e show that in the emphatic context, /n/ has a much more retracted place of articulation as the main area of constriction is on the third row while it is on the first row in the non-emphatic context. It also has
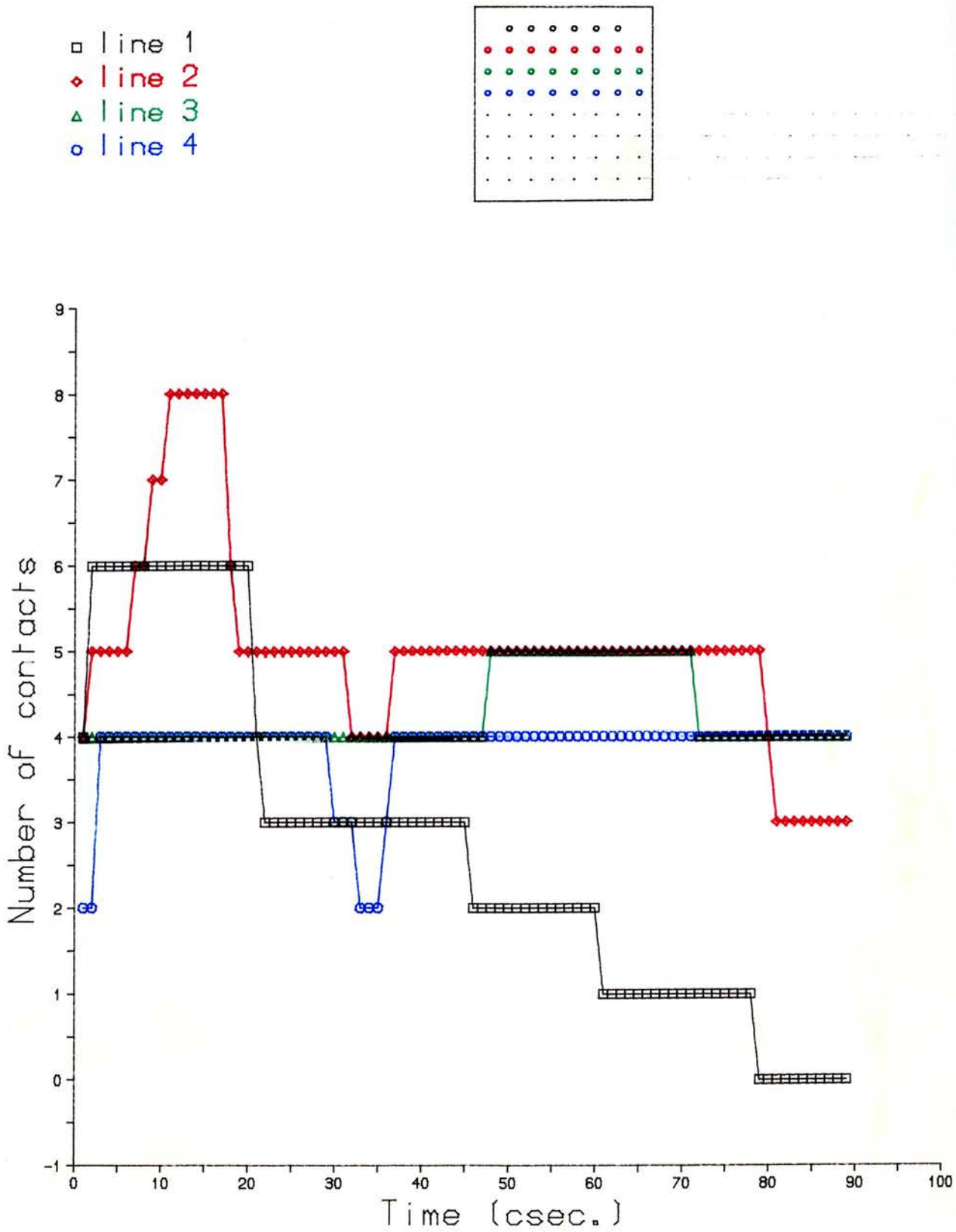
Figure 3.3.10.c

/nisi:b/
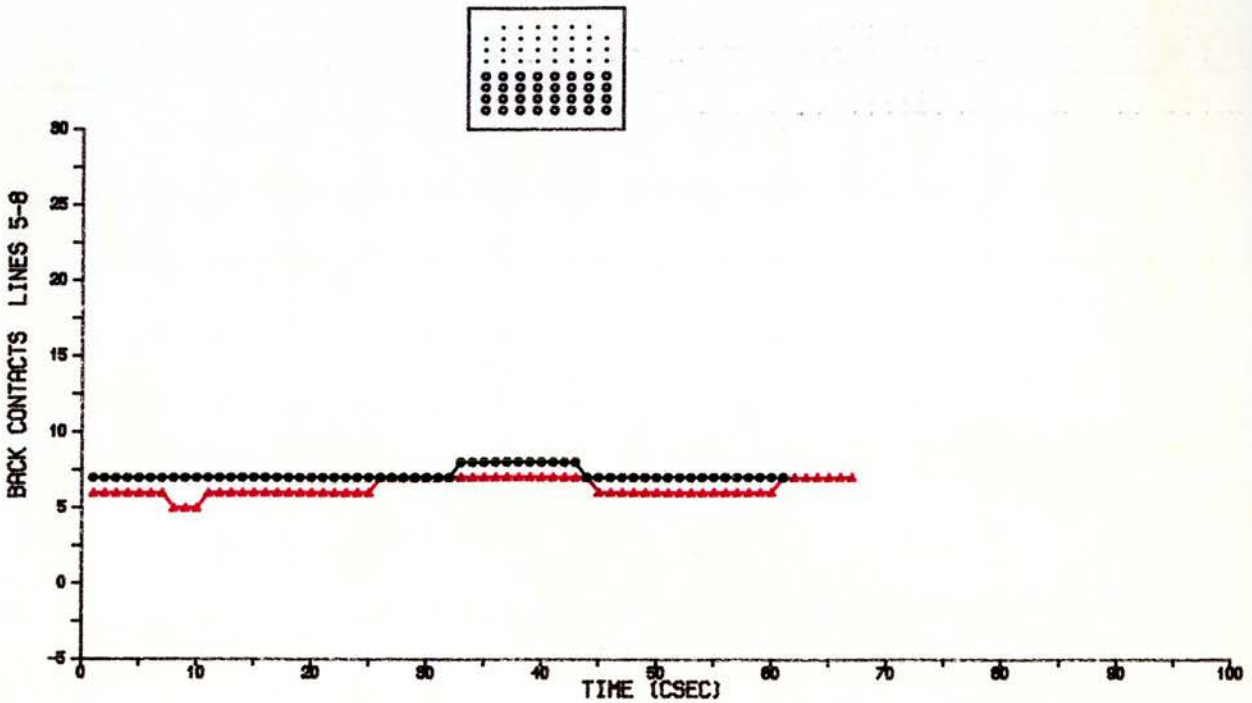
Figure   3.3.10.d
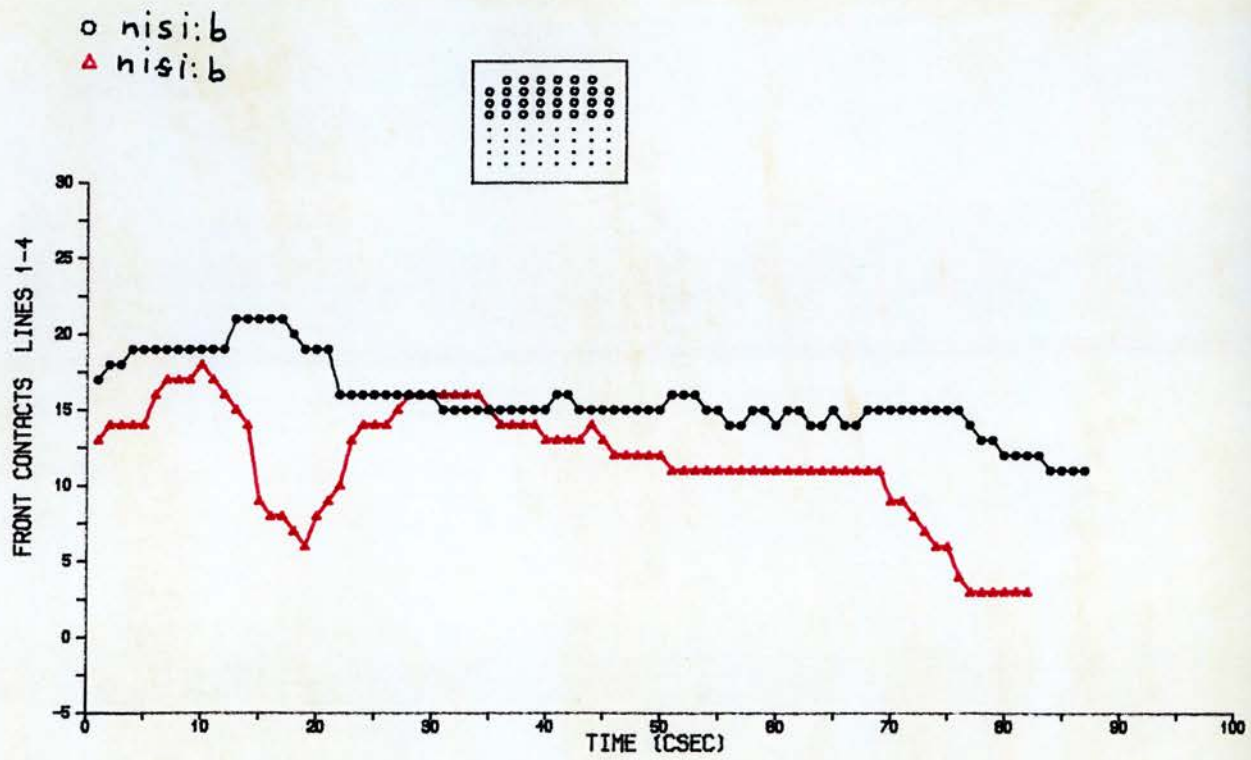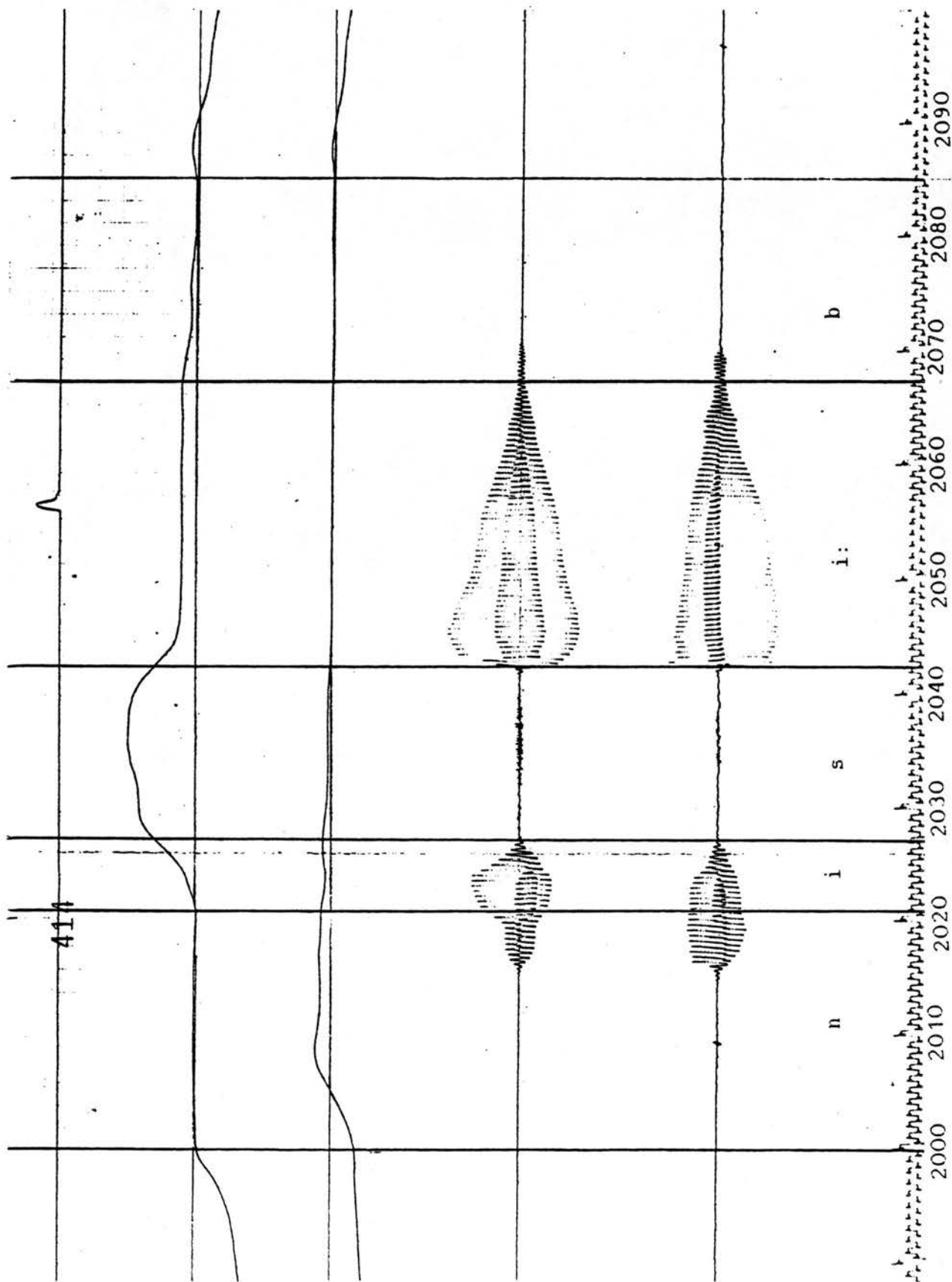
Figure   3.3.10.e

Figure   3.3.10.f
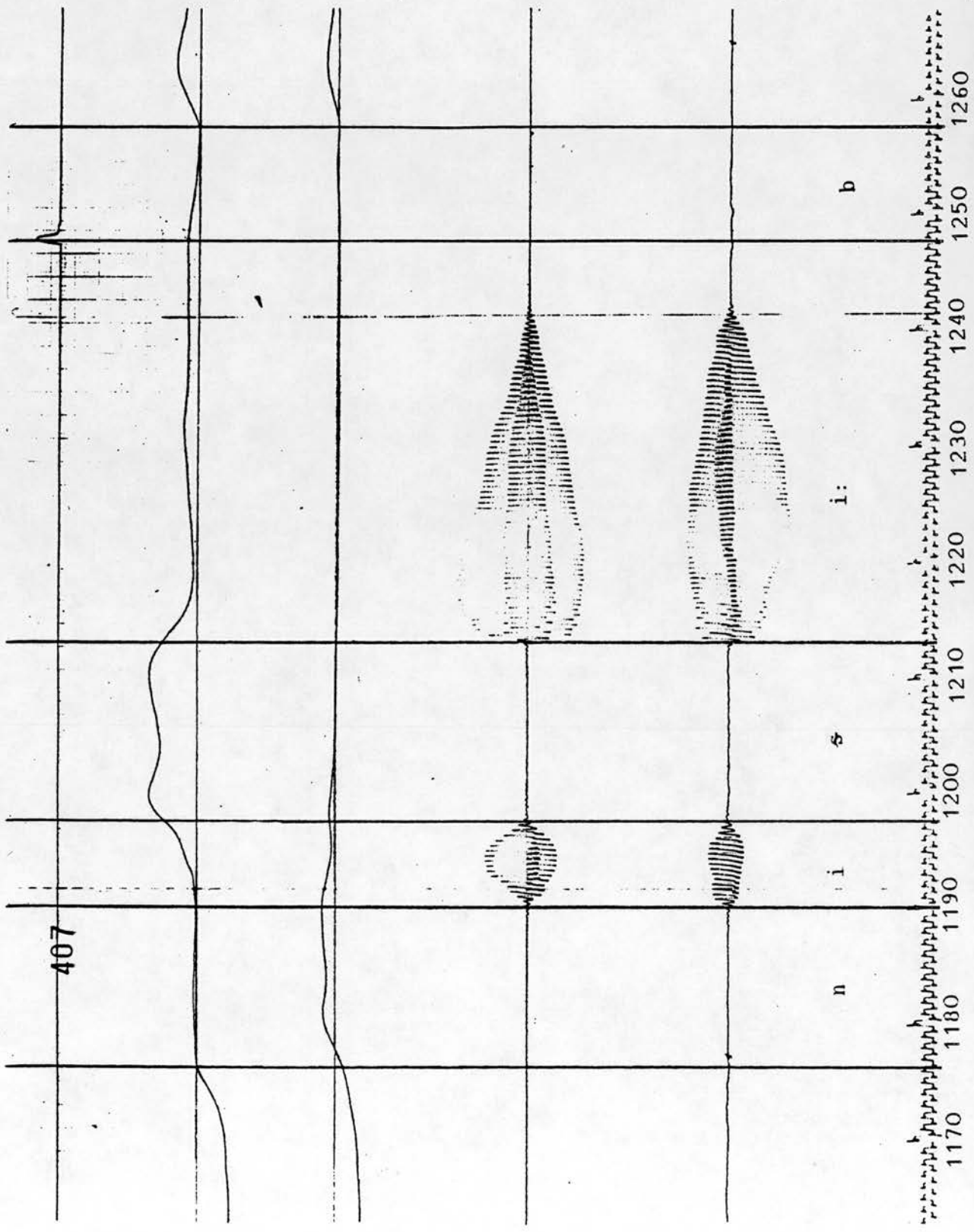
Figure   3.3.10.g

less lingual-palatal contacts in the palatal region. /i/ has a retracted place of articulation and a wider untouched central area and a fewer contacts in the posterior area of the palate. /ʂ/ is retracted to the second line and has a firmer contact leaving a narrower central groove in the alveolar region than /s/. The front vowel /i:/ has less contacts in the anterior region of the palate and is retracted. /b/ also exhibits signs of pharyngealization as it has much less lingual-palatal contacts both in the anterior and posterior regions.

The airflow records in Figures 3.3.10.f,g show a slightly less airflow rate for the word containing the emphatic segment. In the emphatic context, /n/ is 80 msec shorter, /i/ is 20 msec longer, /ʂ/ has more or less the same duration, /i:/ is 100 msec longer and /b/ is 90 msec shorter.

3.3.11   /Xalle:na:/ & /Xaɫɫe:na:/
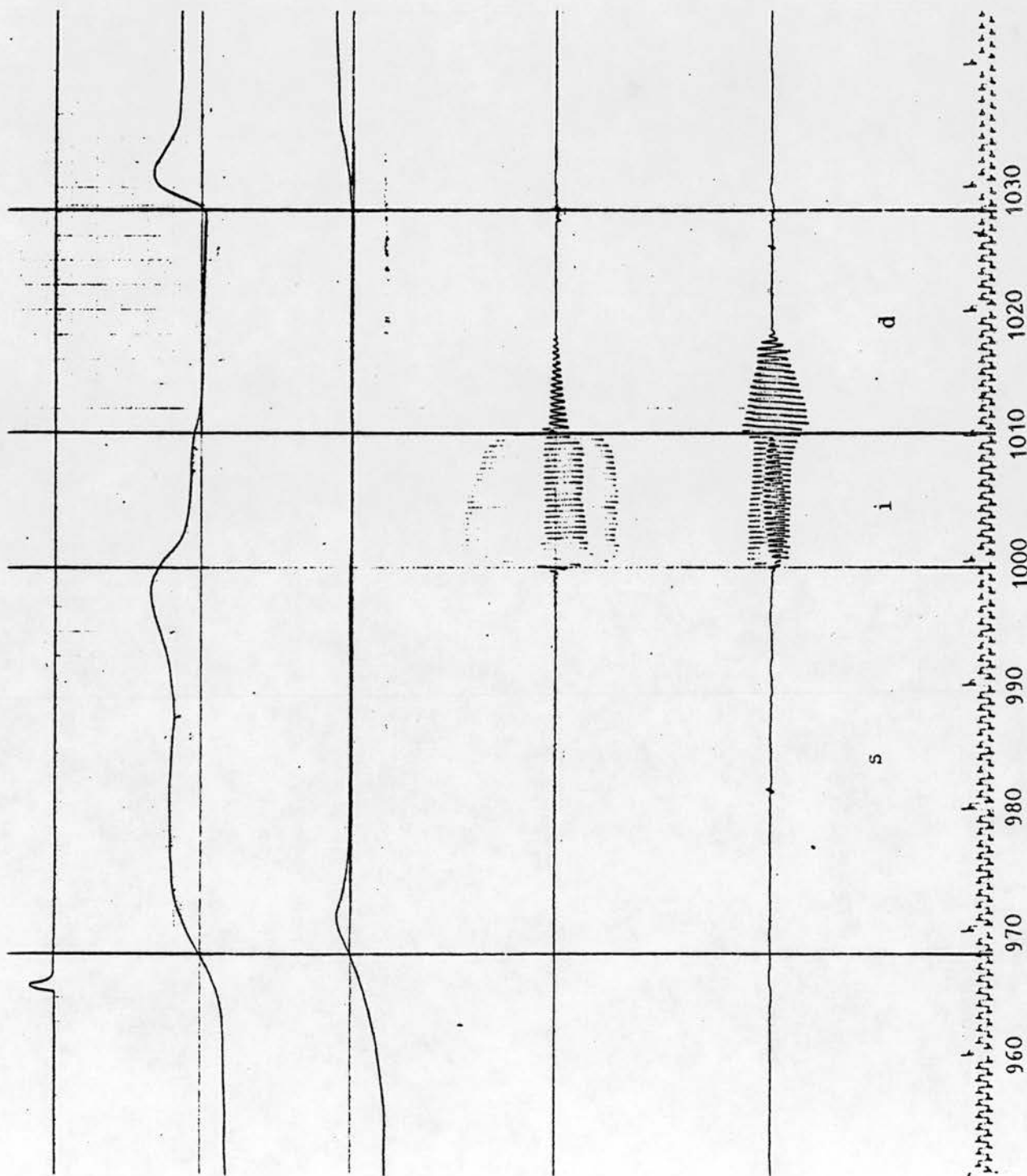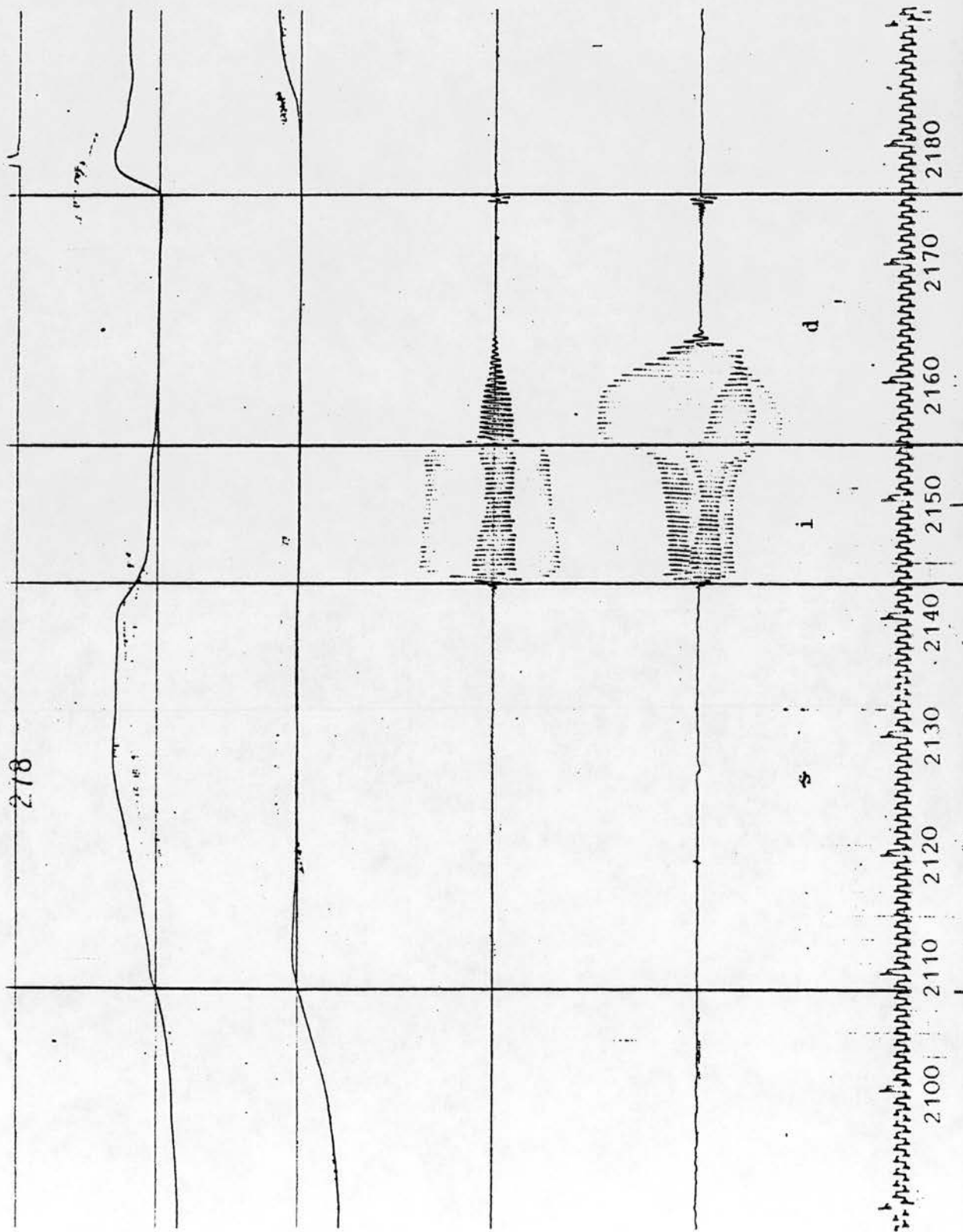
Comparing the EPG data, Figures 3.3.11.a,b (see appendix F), and the graphic representation of the data, Figures 3.3.11.c,d,e, we notice that /X/ in both words has more or less the same lingual-palatal contact pattern, this could be due to the fact that it is a back uvular sound where the effect of pharyngealization is minimum. In the emphatic context, /a/ exhibits less contacts in
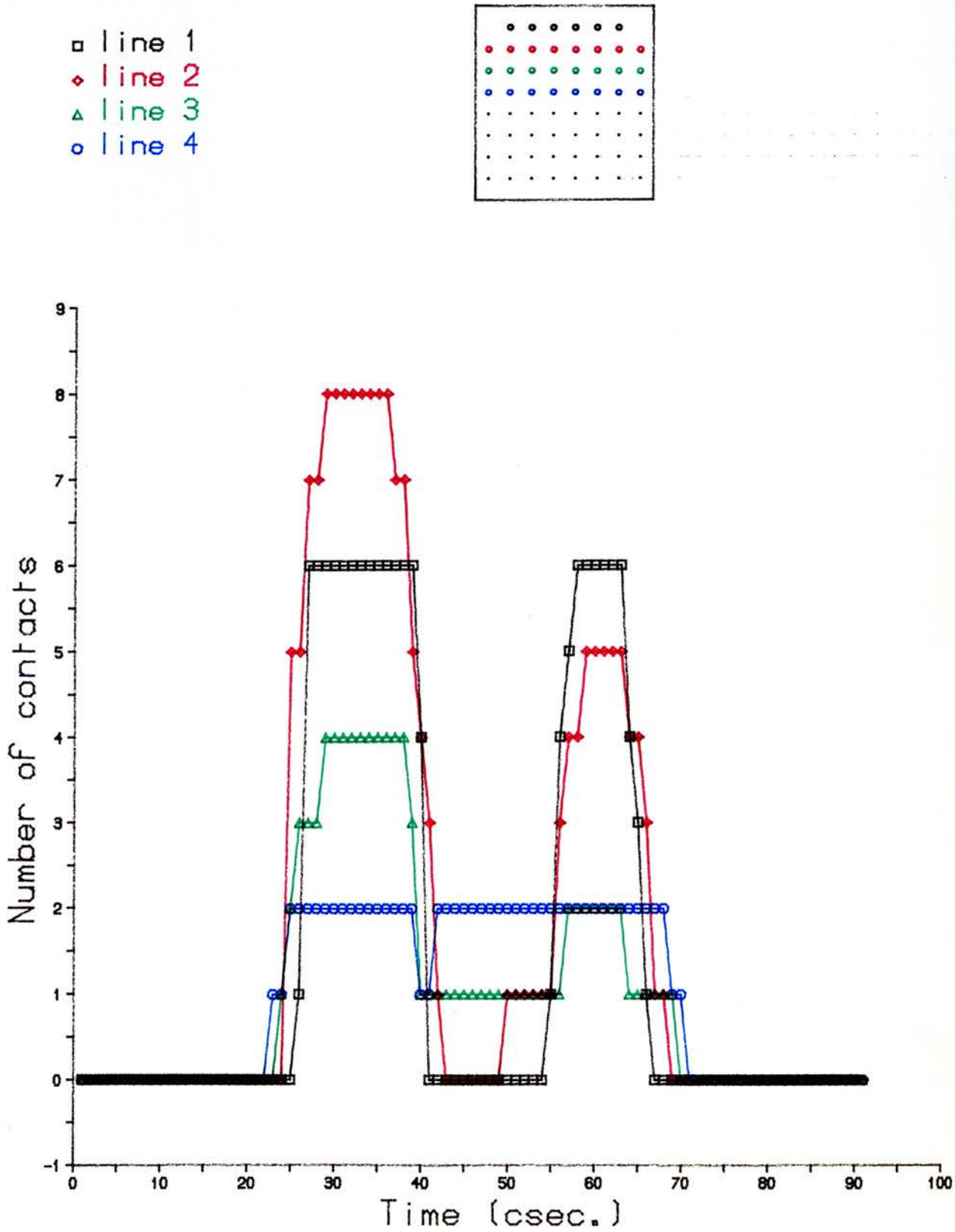
Figure 3.3.11.c

/Xalle:na:/

Figure 3.3.11.d

/Xałłe:na:/
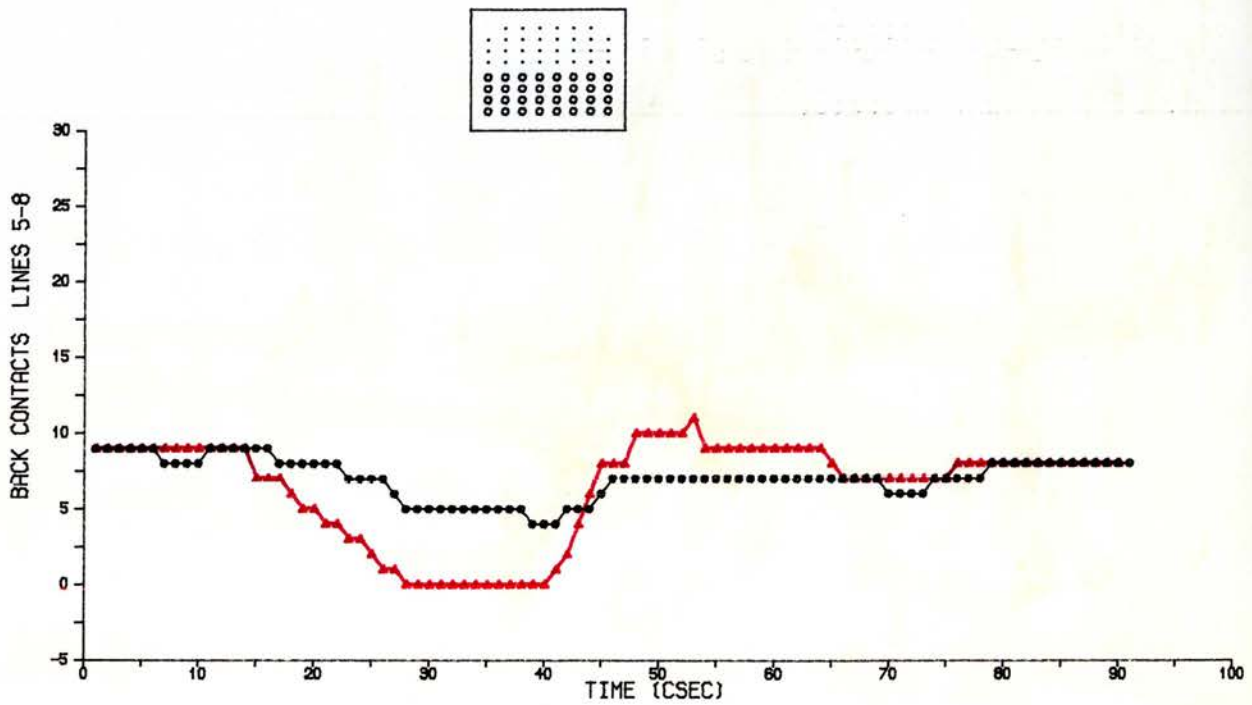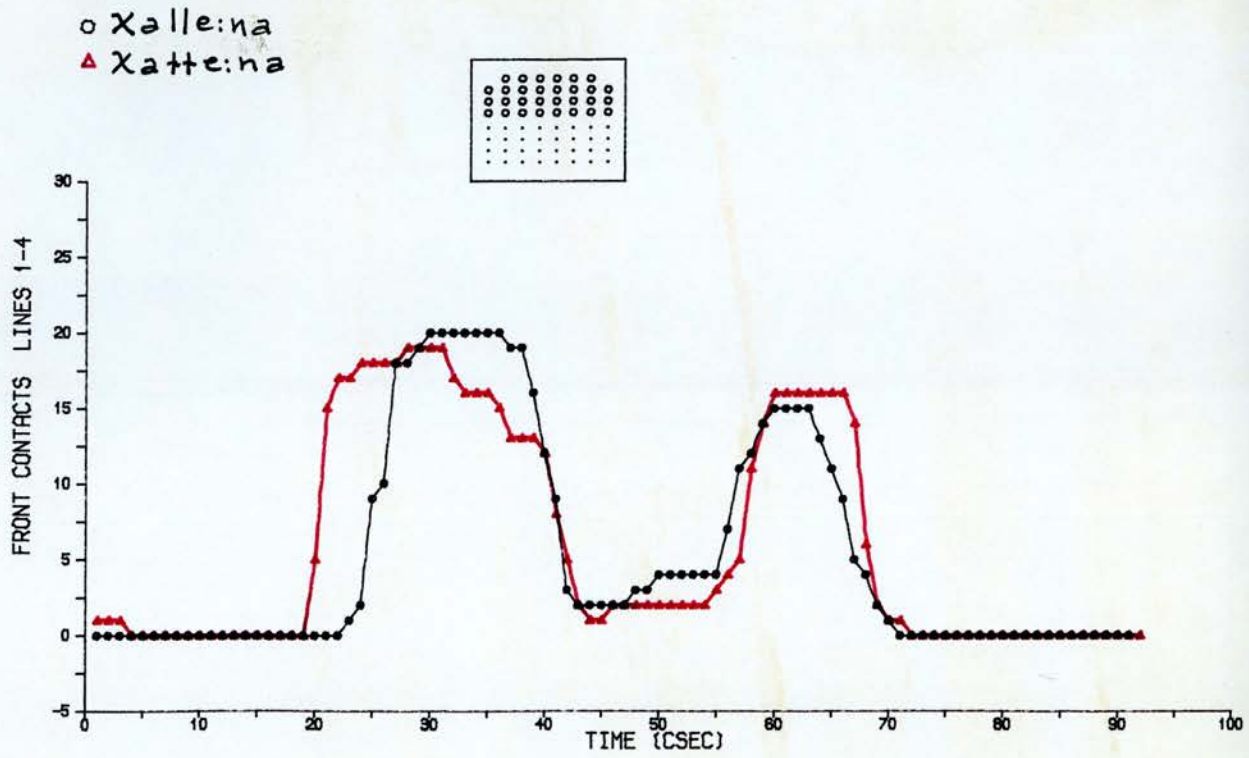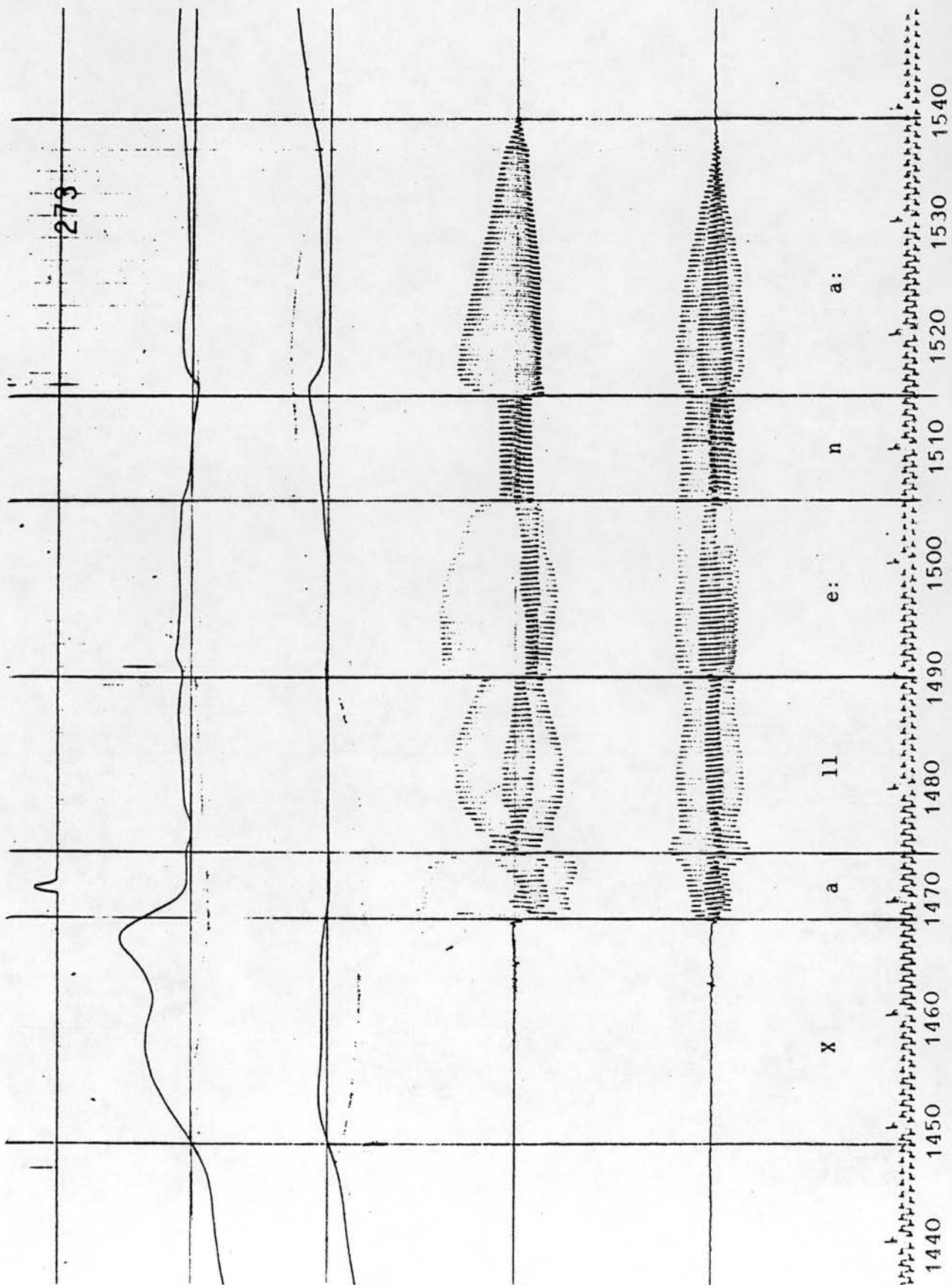
Figure 3.3.11.e

Figure 3.3.11.f
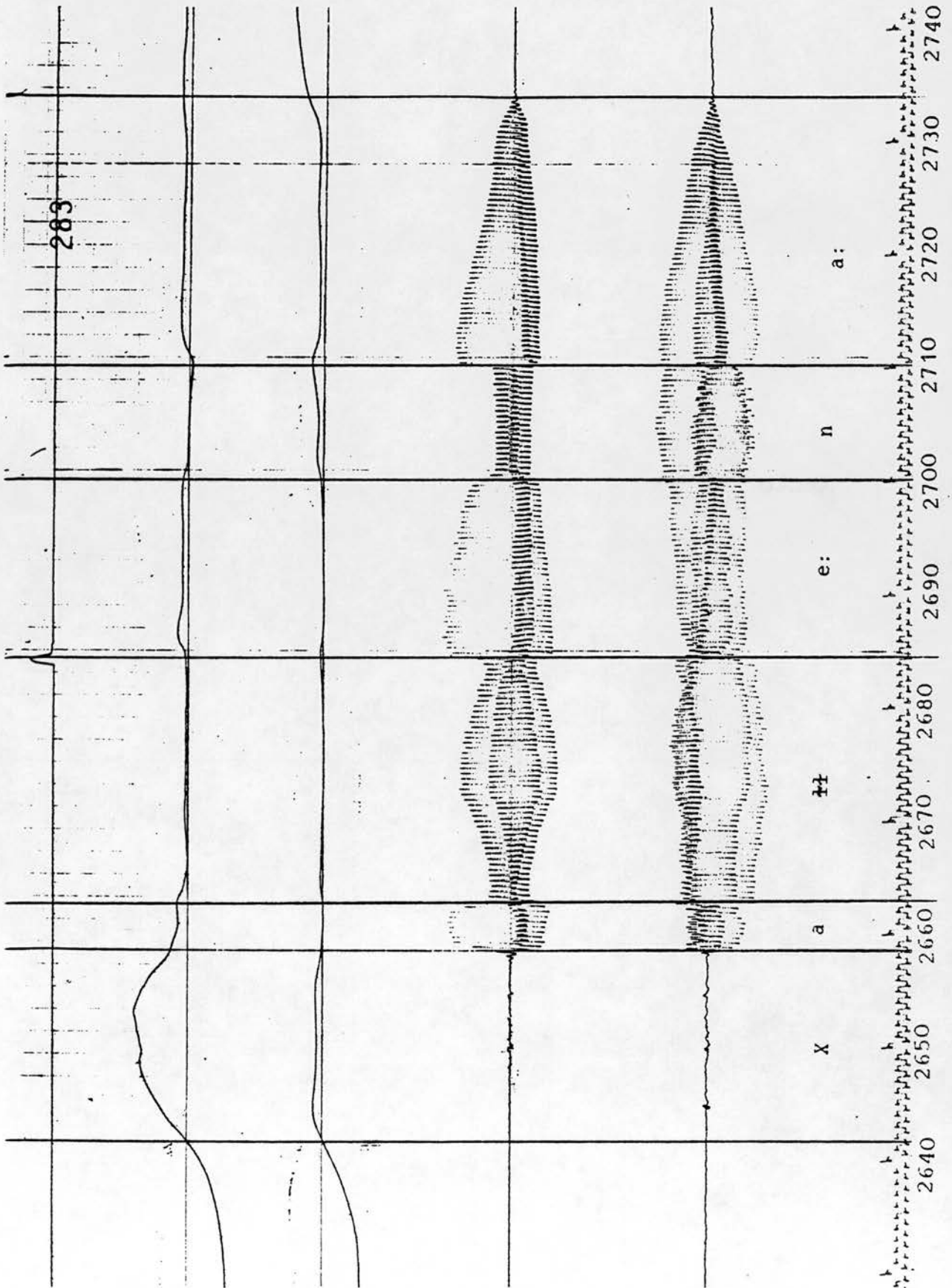
Figure 3.3.11.g

the posterior region of the palate. /ɭ/ has a retracted place of articulation as the lingual-palatal contact covers the second and the third rows while it covers the first and second rows for /ll/. Also we notice that the sides of the palate are free from any contacts indicating a lateral retroflex. It also has zero-contacts in the palatal region as a result of tongue concavity and retraction. /e:/ exhibits fewer contacts in the front region of the palate and slightly more contacts in the back region. /n/ has a retracted place of articulation as the constriction takes place on line two, while it is on line one in the non-emphatic environment. And the increase in the contacts in the alveolar region indicates a firmer constriction. /a:/ in both words has the same lingual-palatal contact pattern, being a back vowel the effect of emphasis is less noticeable.

The airflow records in Figures 3.3.11.f,g show that /Xaɬe:na:/ has much less airflow rate than /Xalle:na:/ . In the emphatic environment, /X/ is 30 msec shorter, /a/ is 10 msec longer, /ɭ/ is 60 msec longer, /e:/ is about the same length, /n/ is 10 msec longer and /a:/ is 10 msec shorter.

3.3.12   /be:t ta:jir/ & /be:t ṭa:jir/

Comparing the EPG data, Figures 3.3.12.a,b (see
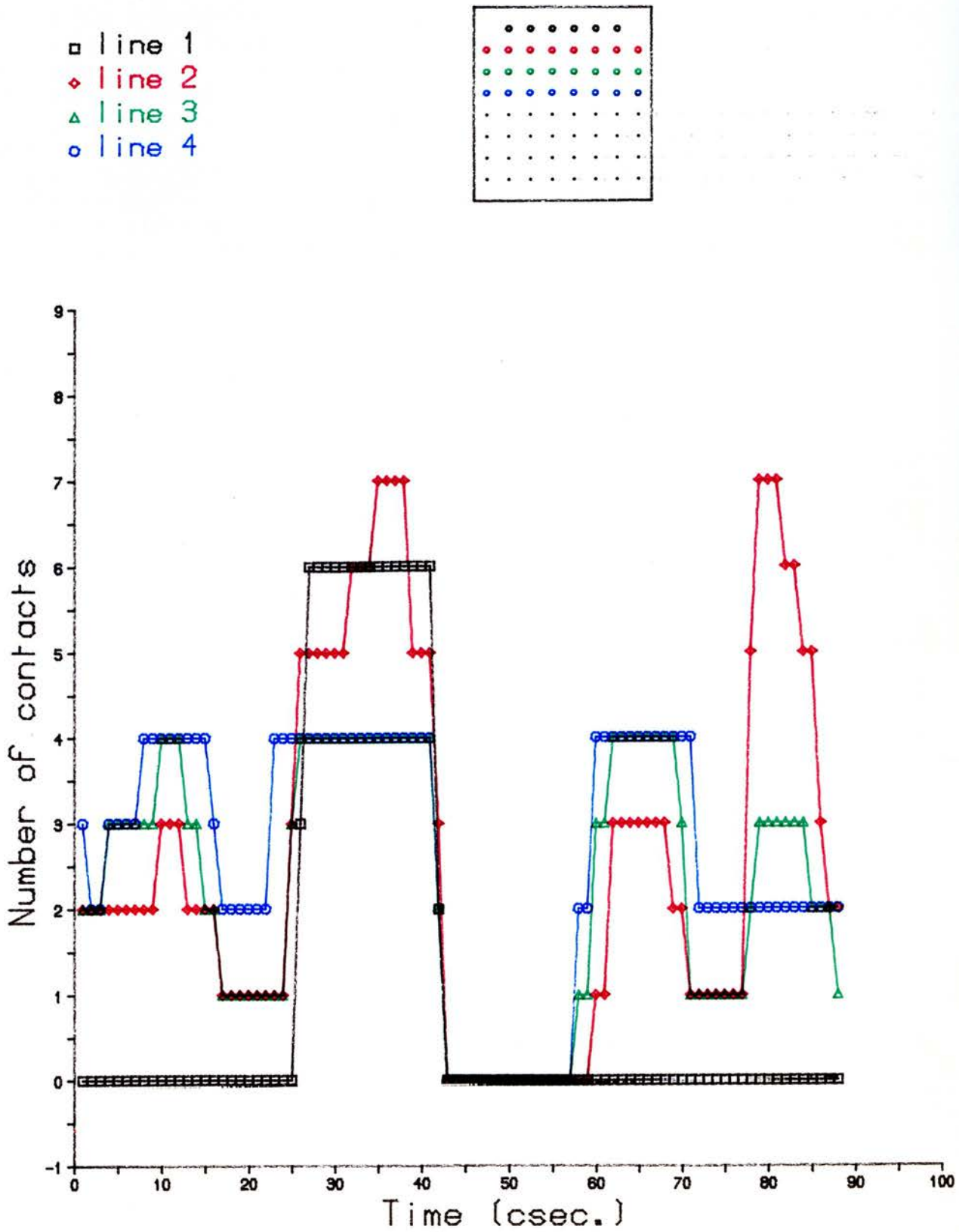
Figure   3.3.12.c

/be:t ta:jir/
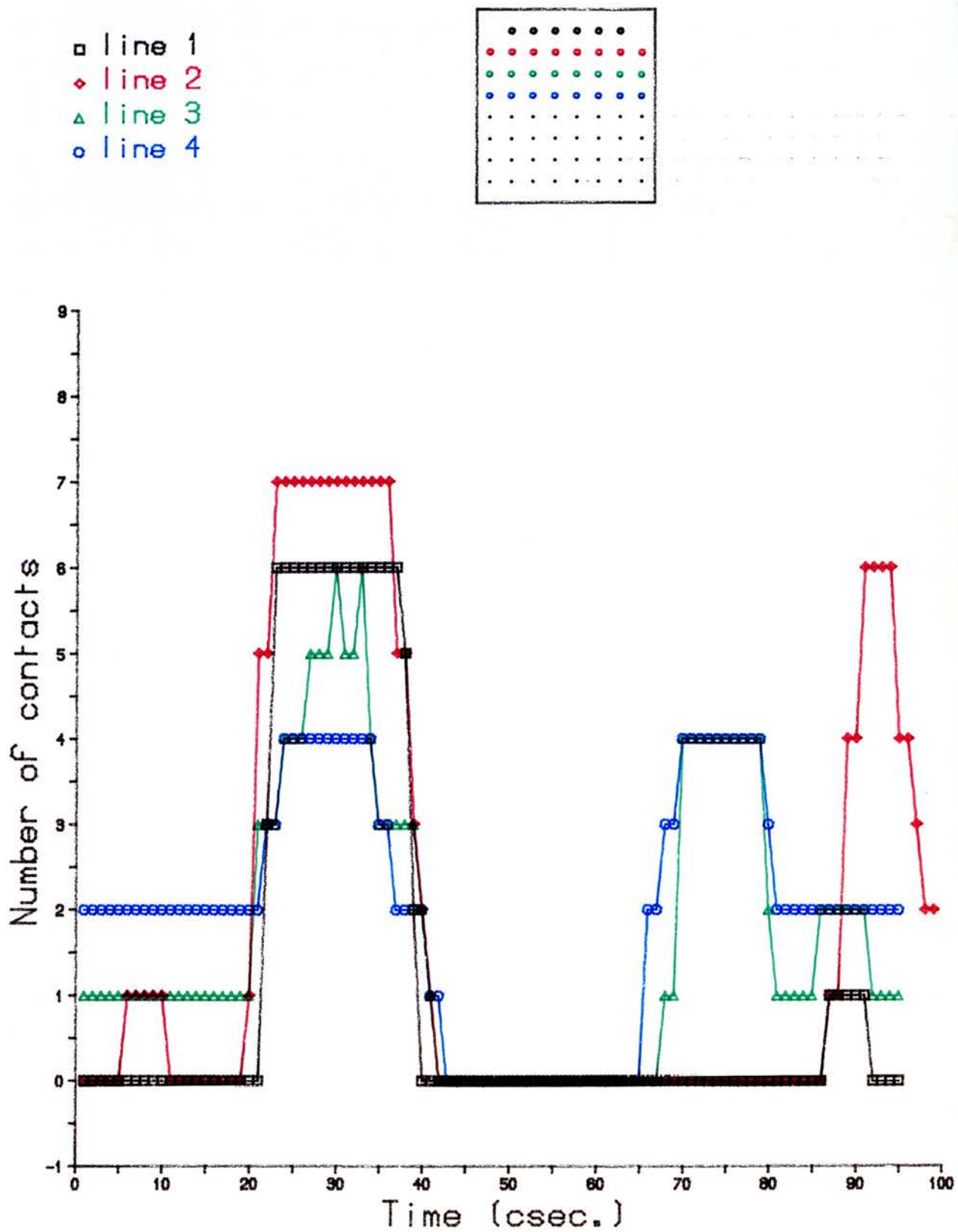
Figure 3.3.12.d

/be:t ɬa:jir/
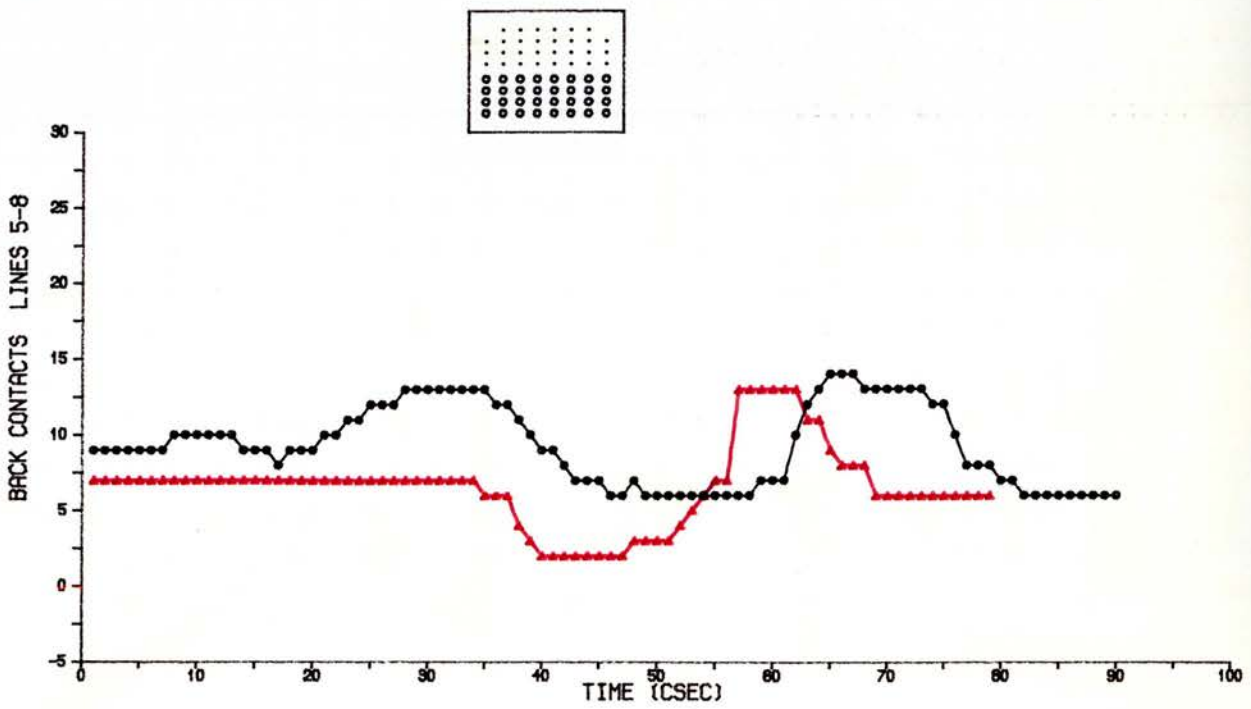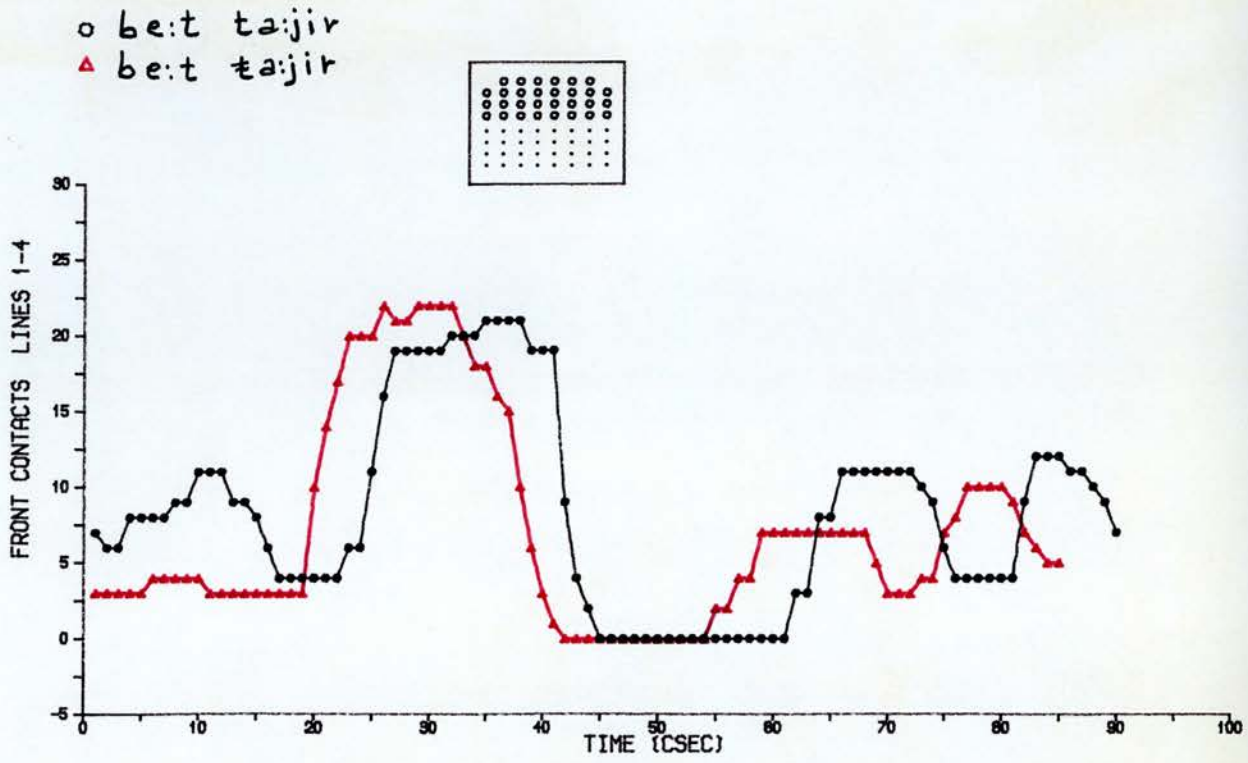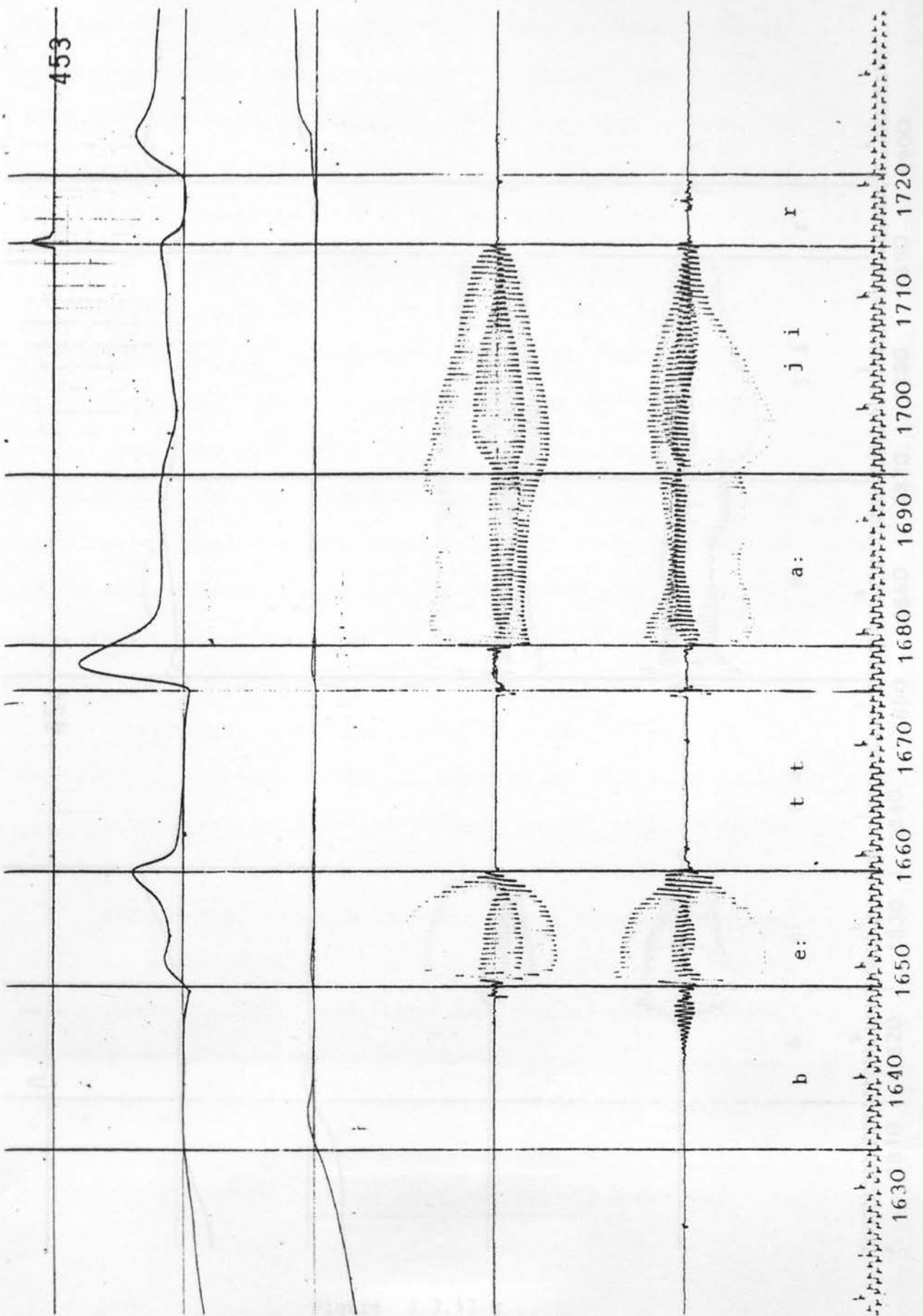
Figure 3.3.12.e

Figure 3.3.12.f
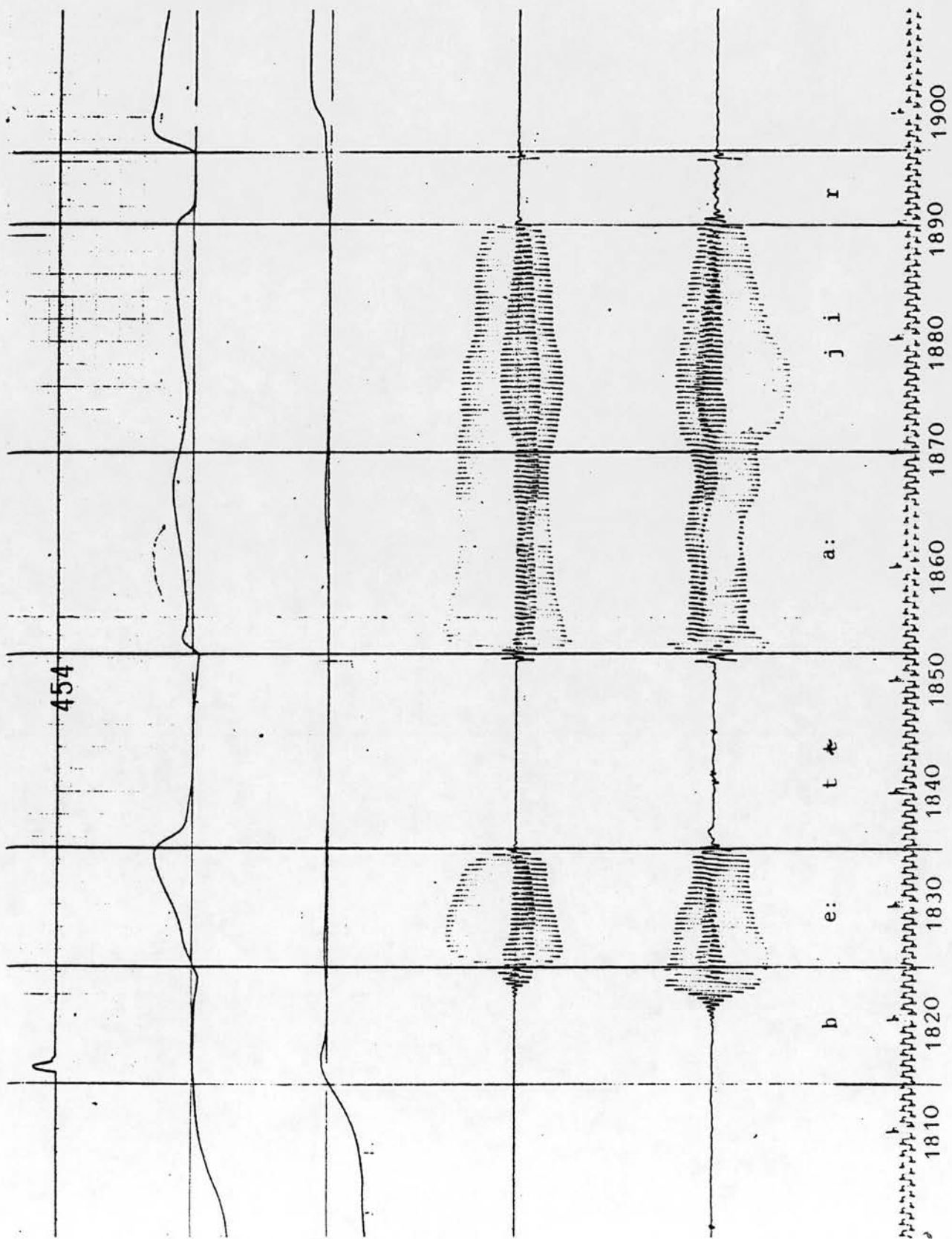
Figure 3.3.12.g

appendix F), and the graphic representation of the data Figures 3.3.12.c,d,e, one notices that in the emphatic context, /b/ has fewer touched electrodes both in the alveolar and palatal regions revealing the effect of pharyngealization inspite of the fact that it is followed by a front vowel and that the emphatic sound is three segments ahead. /e:/ also backed and retracted as it exhibits less contacts both in the front and back regions of the palate. /t/ is coarticulated with the homorganic /ŧ/. They both have a more contacts in the alveolar region and less contacts in the palatal region. /a:/ is more backed in the emphatic context as it has fewer contacts in lines 5-8. /ji/ are retracted from line two to three and have less contacts in the anterior region. /r/ has slightly less contacts in the front lines. In this phrase pharyngealization, which is characteristic of the initial consonant of the second word seems to be anticipated from the initial consonant of the first word and carried over to the end of the second word in spite of syllable and word boundaries.

The airflow records for the two phrases, Figures 3.3.12.f,g, show that on the whole the emphatic phrase has a lower airflow rate than the non-emphatic phrase. The release of /ŧ/ results in a lower peak of airflow and a zero VOT as the vocal folds start vibrating indicating the start of the following vowel. The release of /t/ results in a higher rate of airflow and 40 msec VOT. In

the emphatic context /b/ is 40 msec shorter, /e:/ has the same duration, /tʉ/ is 10 msec longer, /a:/ is 30 msec longer and /jir/ show no significant difference.

3.3.13 /bas isi:r/ & /bas iɬi:r/
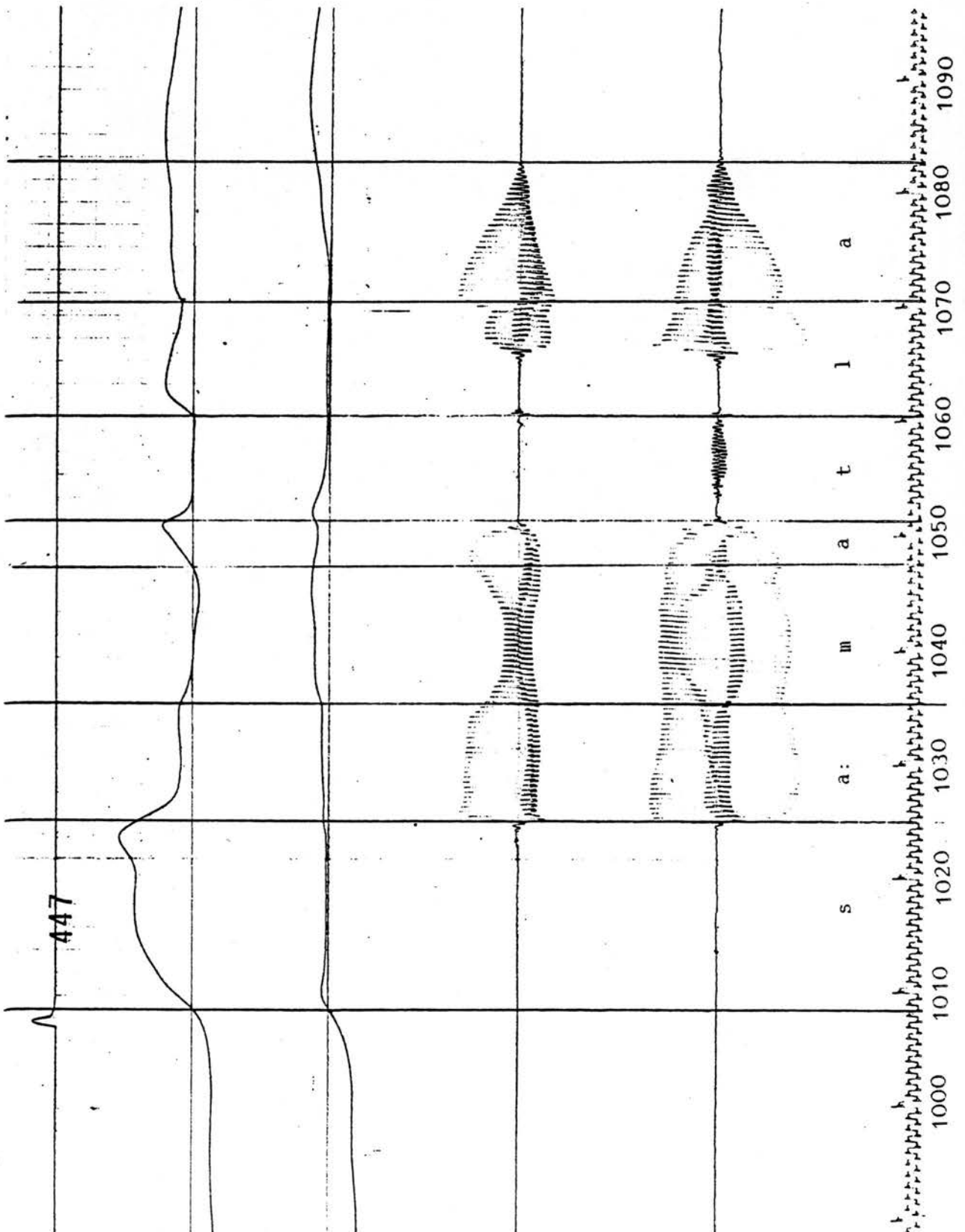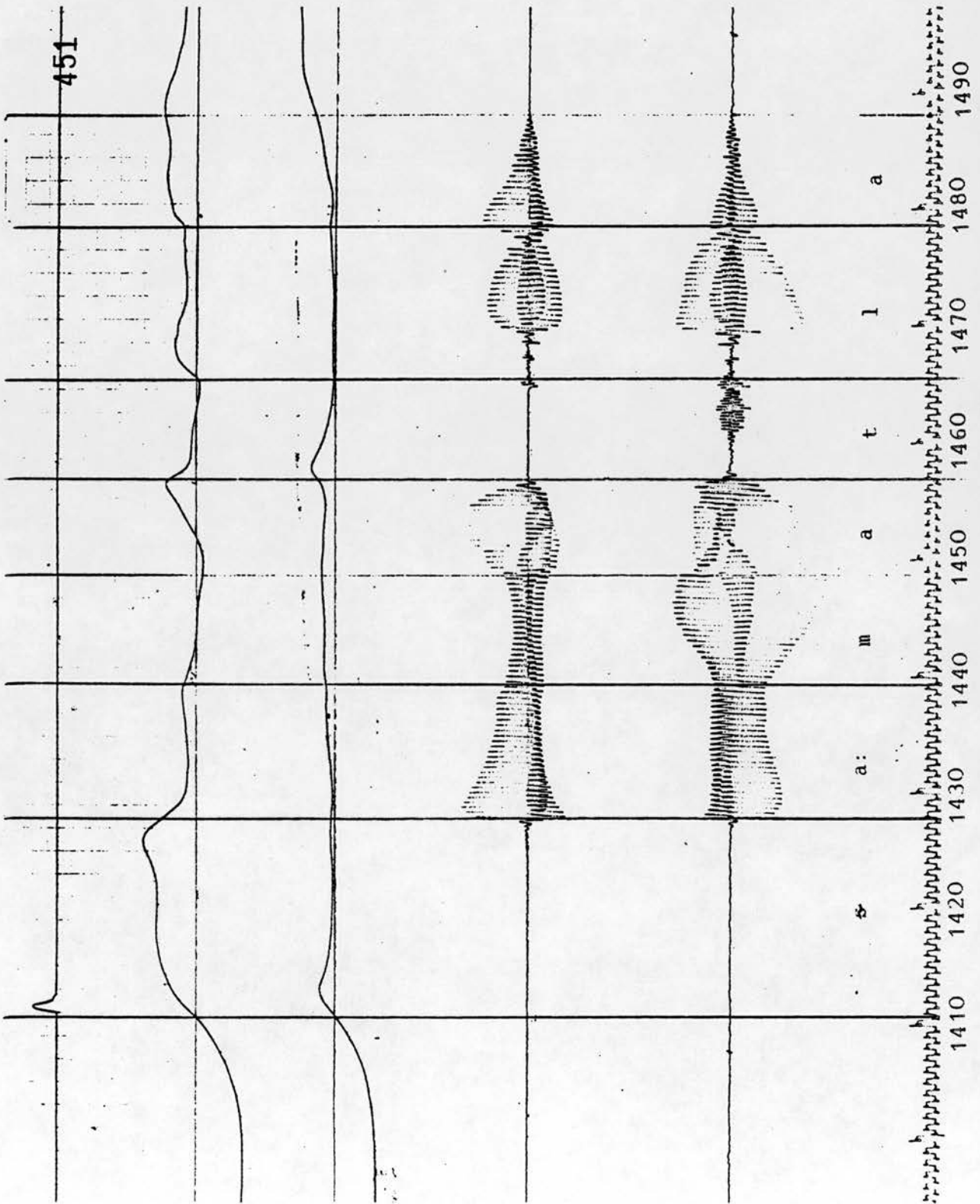

The EPG data, Figures 3.3.13.a,b (see appendix F), and the graphic representation of the data, Figures 3.3.13.c,d,e, show that the first word /bas/ of both phrases exhibits no difference in the lingual-palatal contact pattern. In the emphatic context, /i/ has fewer contacts in the back area, rows 5-8. /ɬ/ exhibits fewer contacts both in the alveolar and palatal regions. /i:/ also has fewer touched electrodes in the alveolar and palatal regions. /r/ has more or less the same number of contacts in the anterior part, and more contacts in the posterior part. The effect of emphasis does not seem to be very evident in the first word of the phrase, this could be due to the intervening front vowel /i/ between the two words, which may have weakened the effect of emphasis.

The airflow records, Figures 3.3.13.f,g, exhibit slightly a lower rate of airflow for the vowels in the emphatic context; and the two humps of the fricative are smoothed into one curve . In the emphatic context, /b/
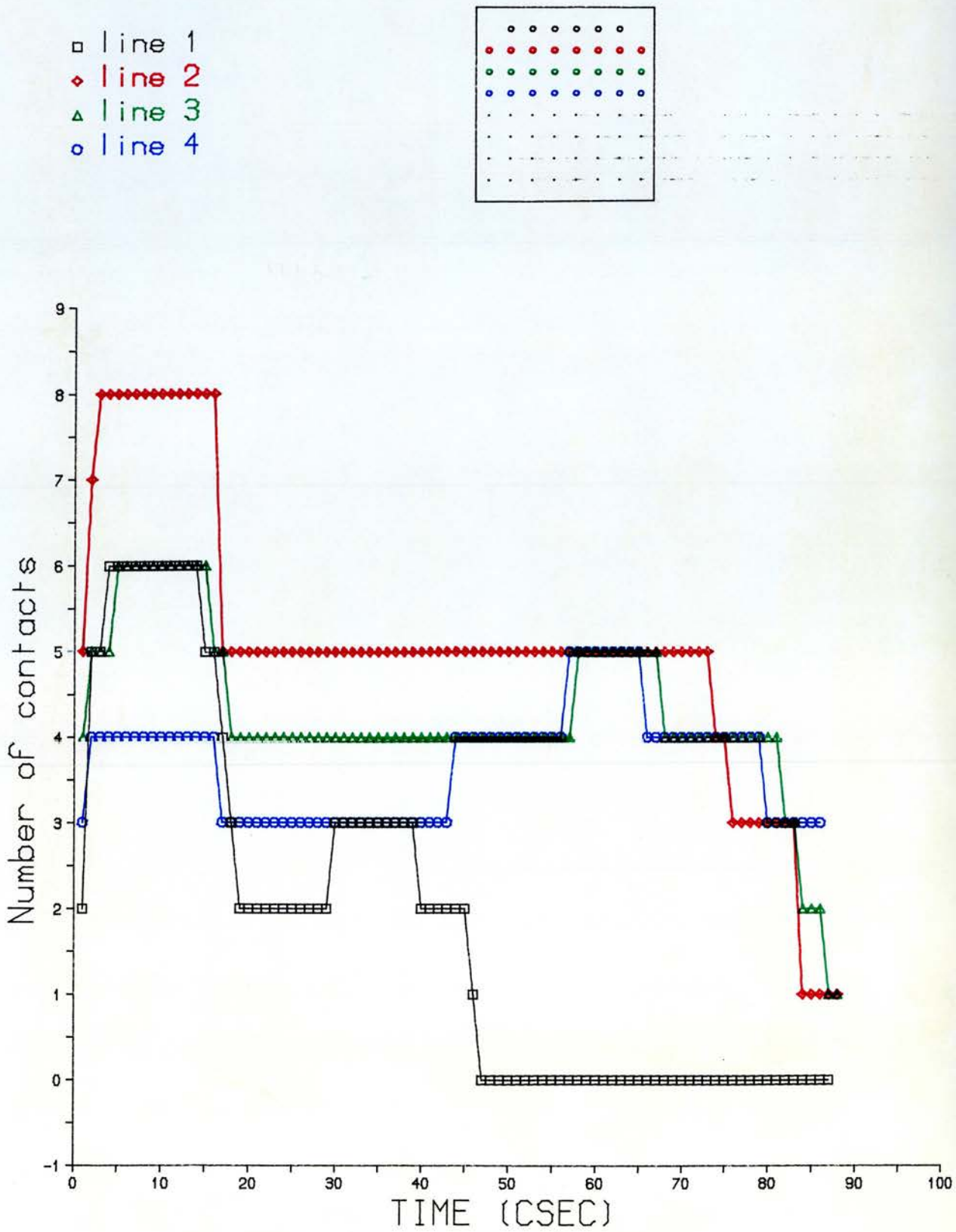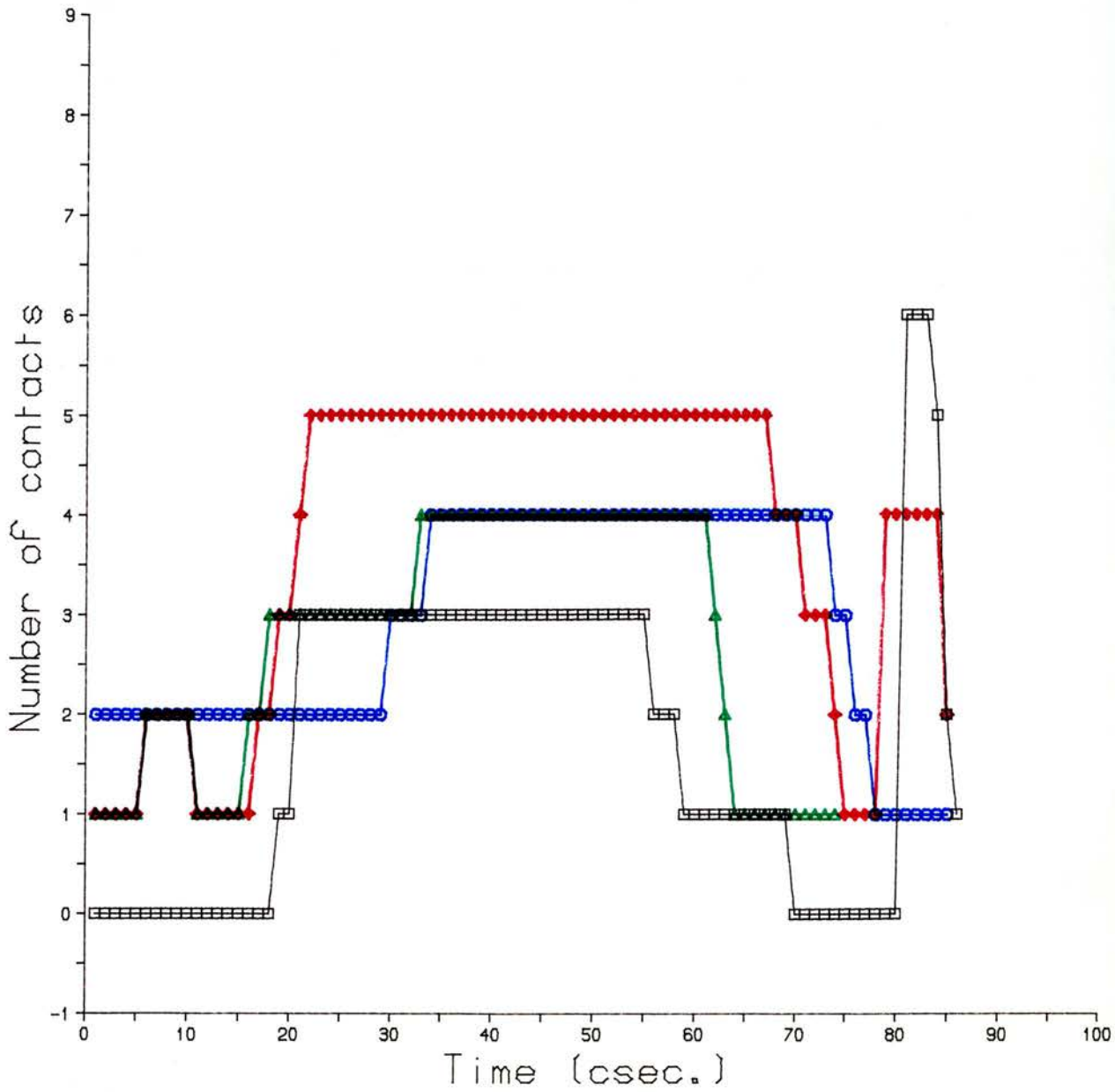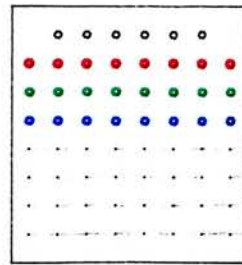
Figure 3.3.13.c

/bas isi:r/
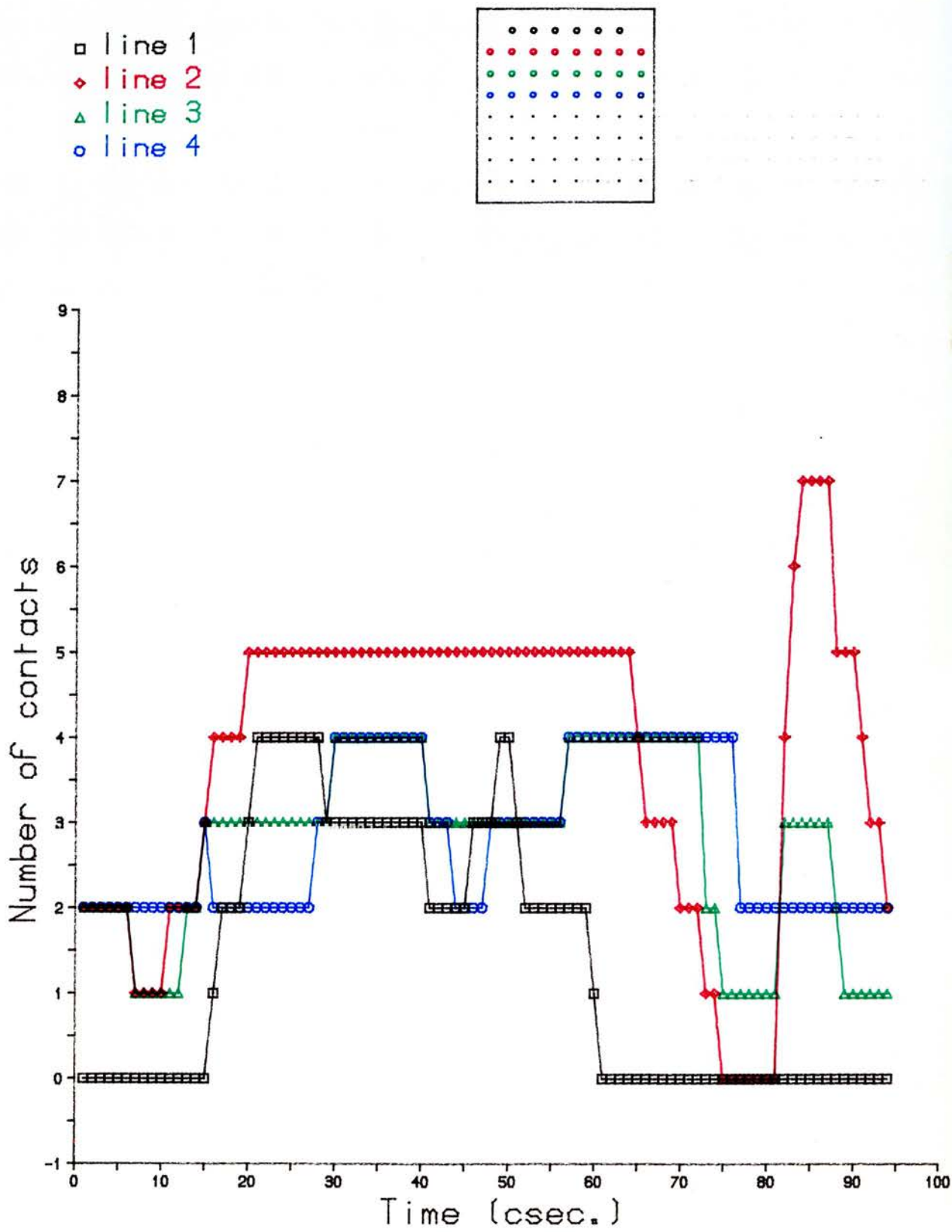
Figure 3.3.13.d

/bas isi:r/
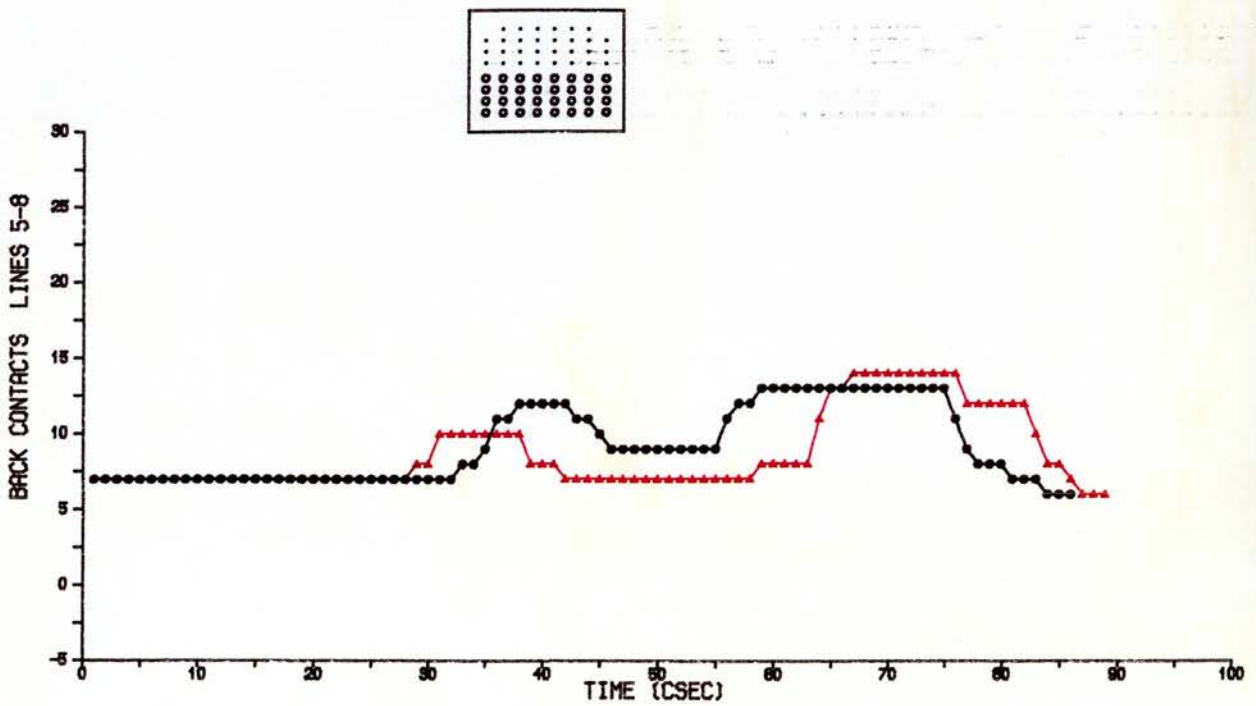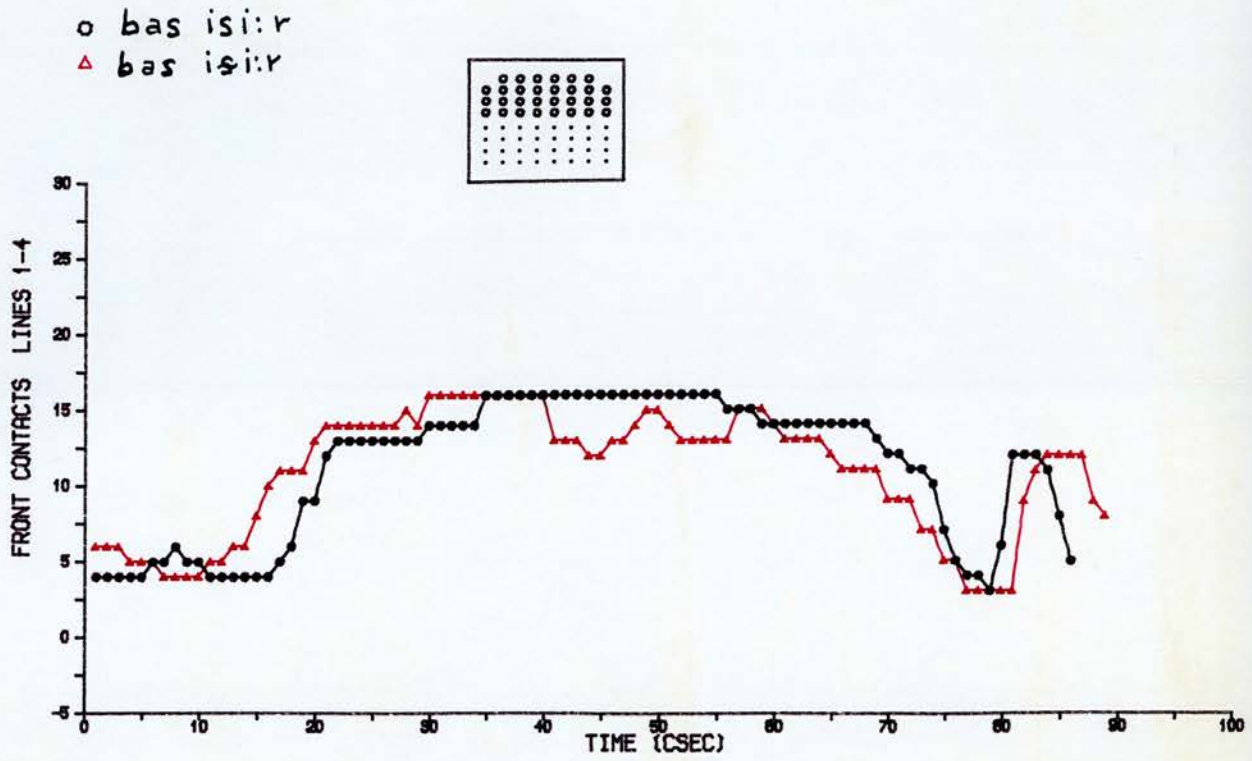
Figure 3.3.13.e
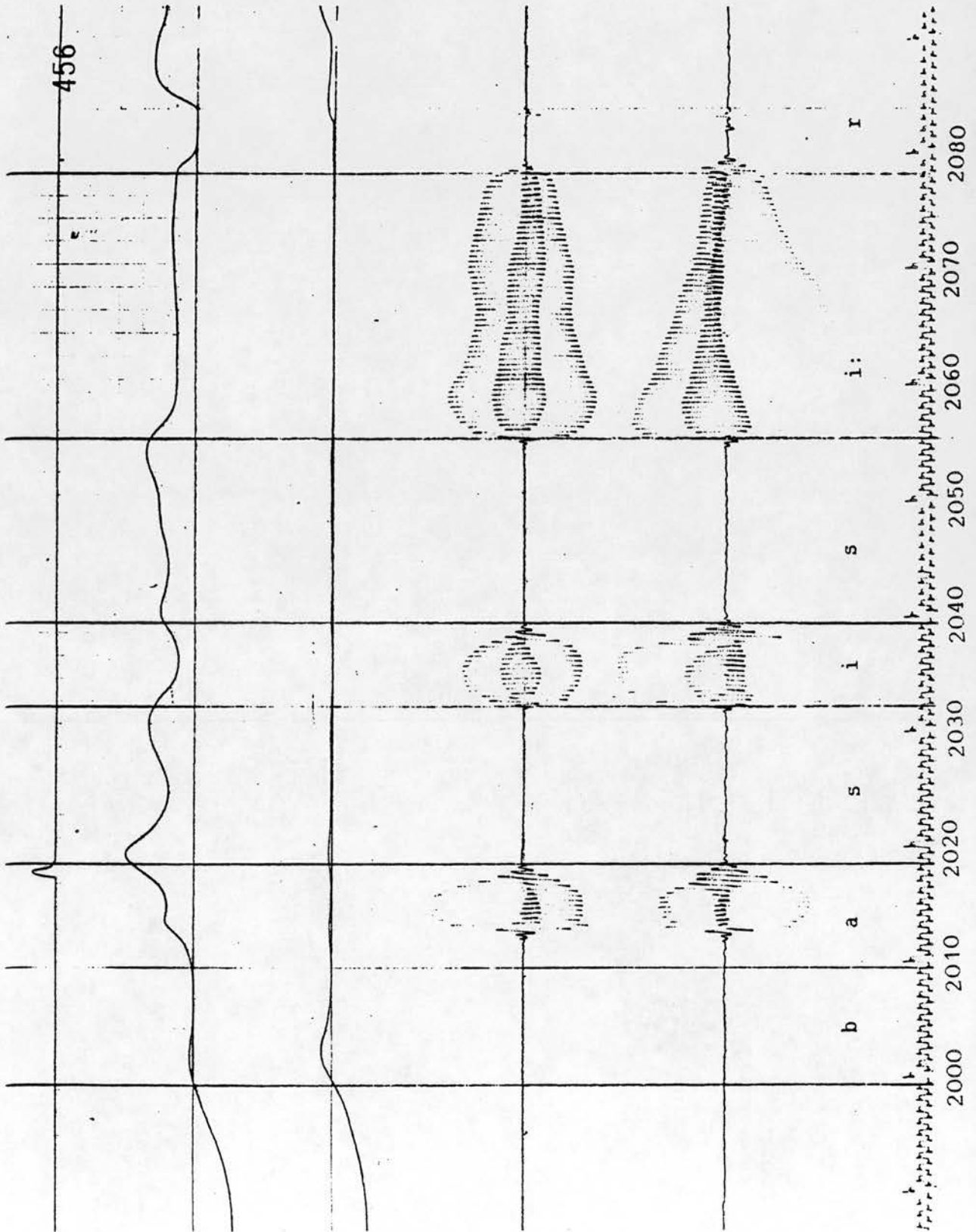
Figure   3.3.13.f

Figure 3.3.13.g

is 20 msec shorter, /a/ is 10 msec shorter, /s/, /i/ and /s/ are about the same length, /i:/ is 60 msec longer and /r/ is 10 msec longer.

3.3.14 /ħat ismi/ & /ħaṭ ismi/

The EPG data for the two phrases, Figures 3.3.14.a,b (see appendix F), and the graphic representation of the data, Figures 3.3.14.c,d,e, show that in the emphatic context, /ħ/ is more backed as it has fewer contacts in the palatal region; /a/ also has less contacts in the back region; /ṭ/ also exhibits fewer touched electrodes in lines 5-8; /i/ seems to be coarticulated with the following fricative /s/ which has more contacts in the alveolar region indicating a firmer constriction; the bilabial /m/ has tongue position of the preceding fricative and then moves towards the position of the following vowel; /i/ has fewer lingual-palatal contacts in the palatal region.

The airflow records, Figures 3.3.14.f,g, show that in the emphatic context /ħ/ has slightly lower oral airflow rate and is 30 msec shorter. /a/ rises up to a slightly lower airflow peak before the following plosive and is 10 msec longer. /ṭ/ has zero VOT and a lower airflow peak at its release, and contrary to our expectation, it is 50 msec shorter. /i/ is about 30 msec longer in duration. /s/ has a lower airflow rate and 10 msec shorter. /m/ has a
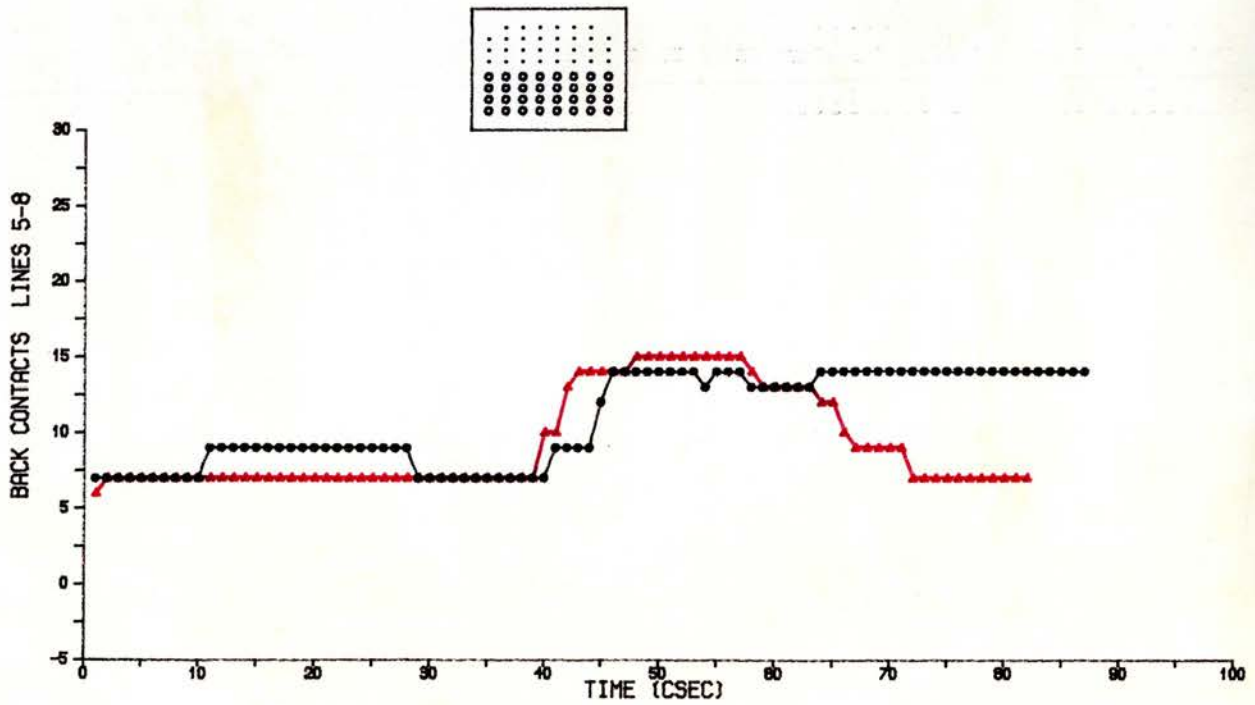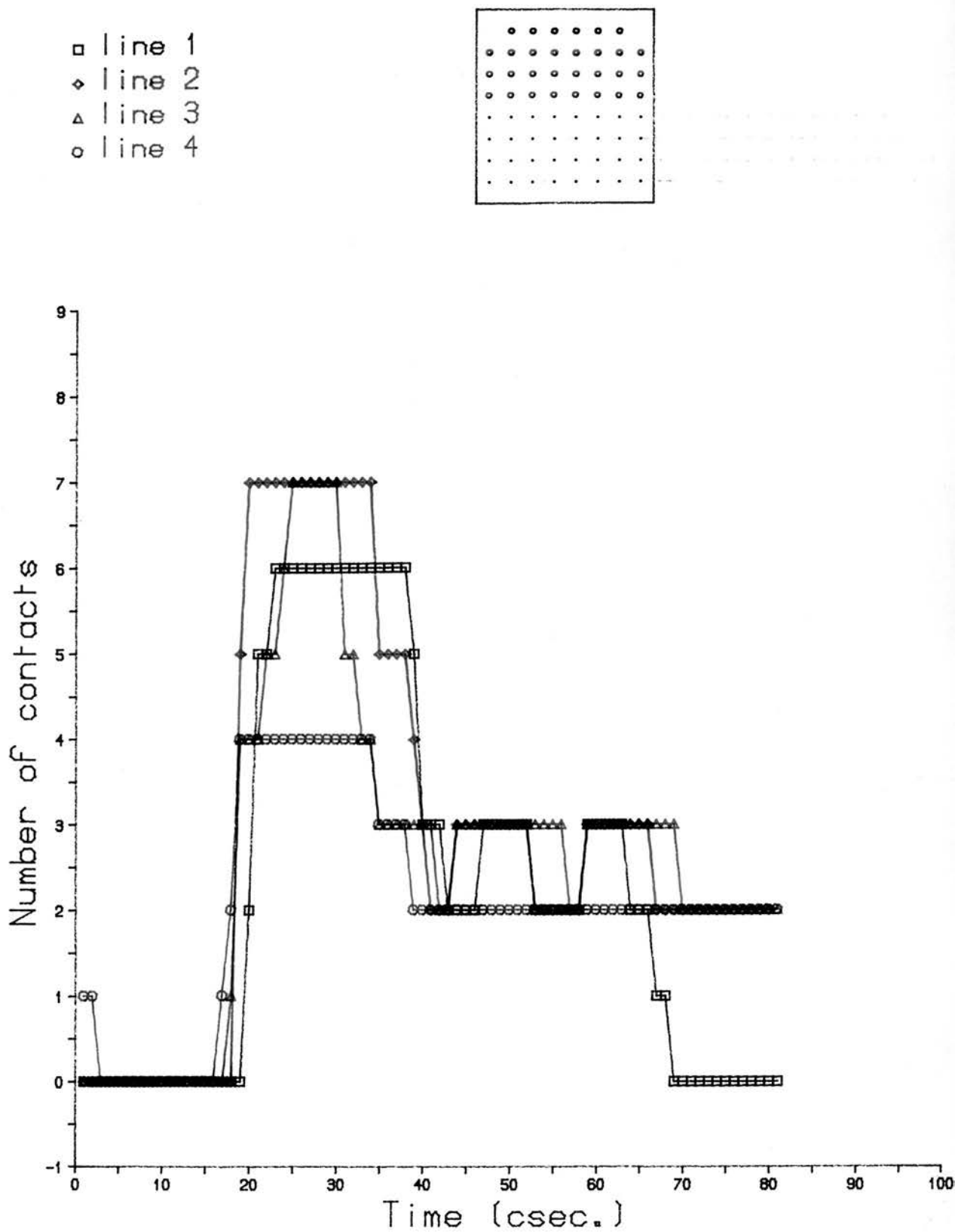
Figure   3.3.14.c
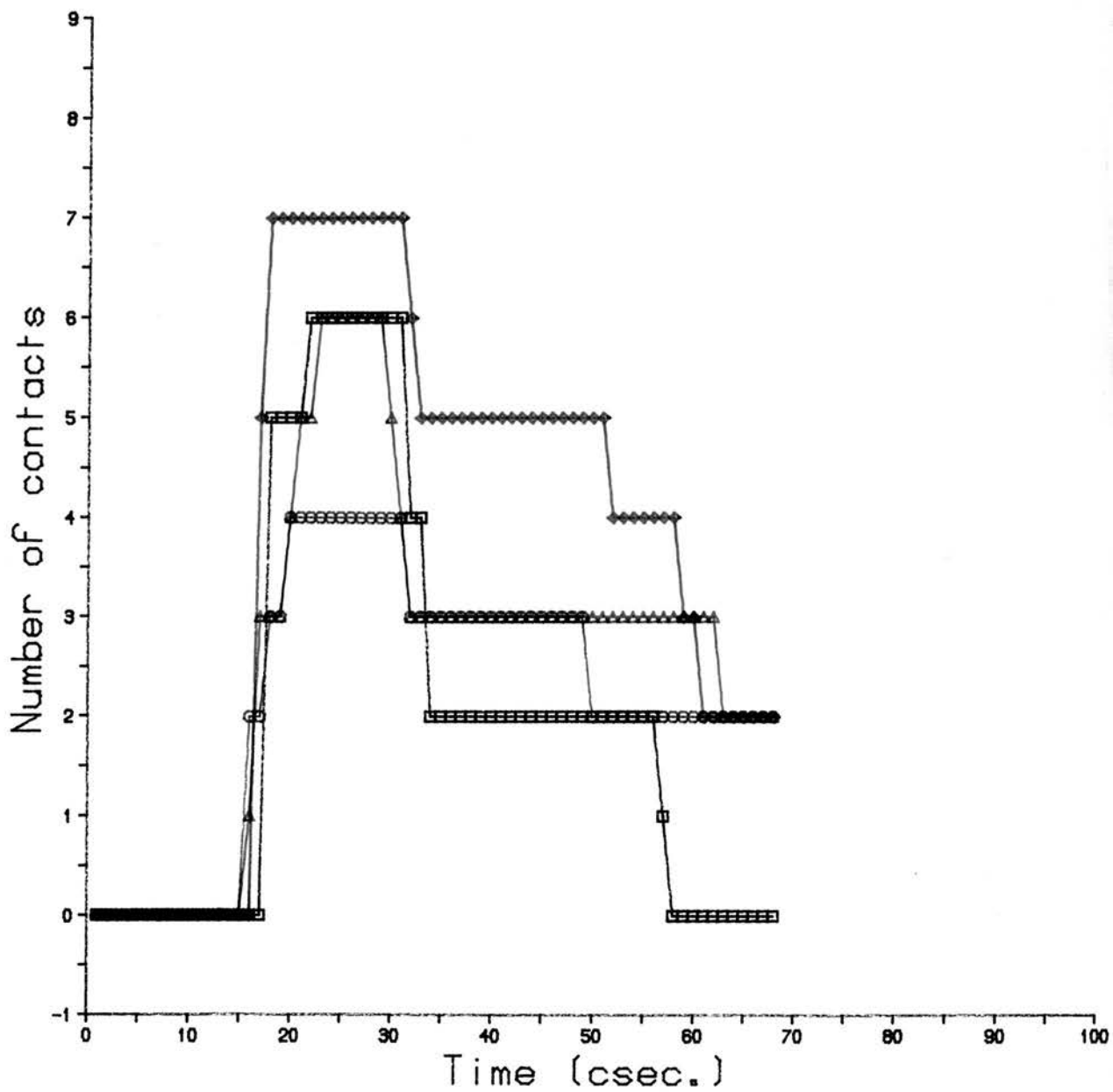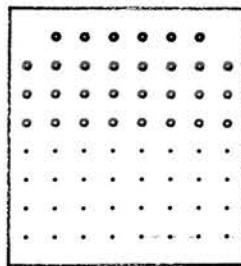
/ħat ismi/

Figure 3.3.14.d

/ħaɨ ismi/
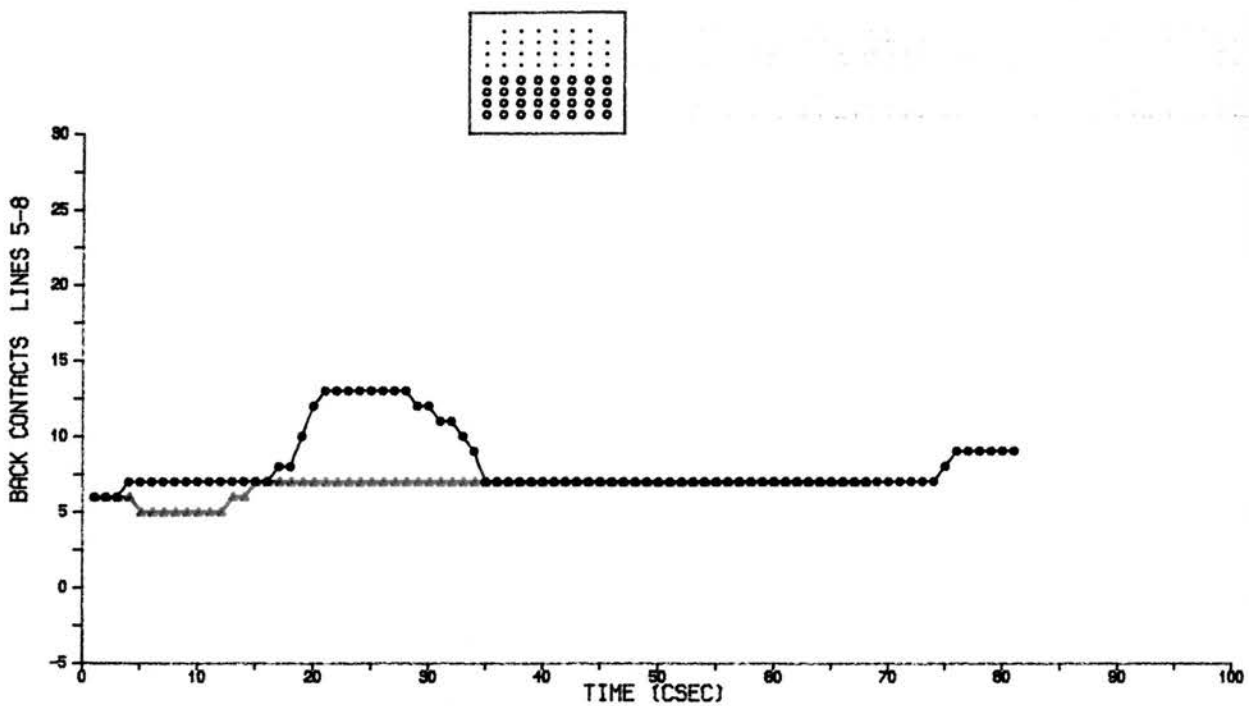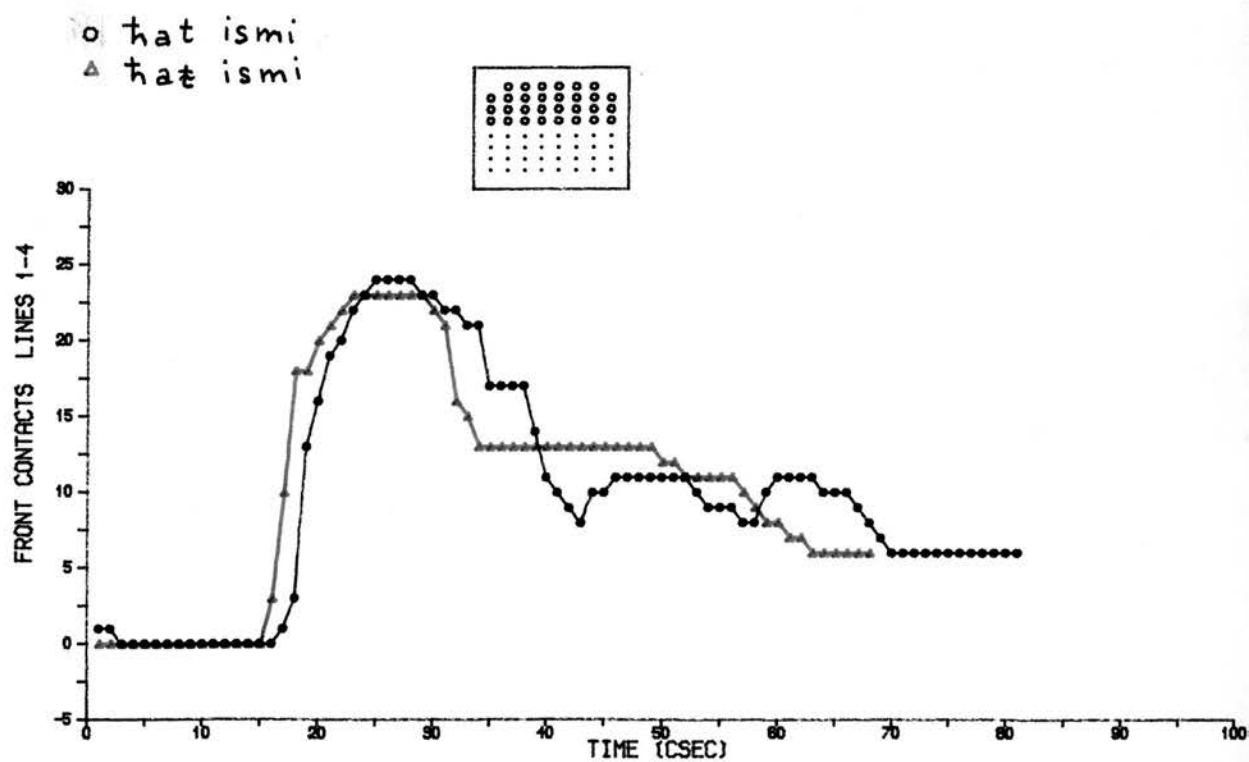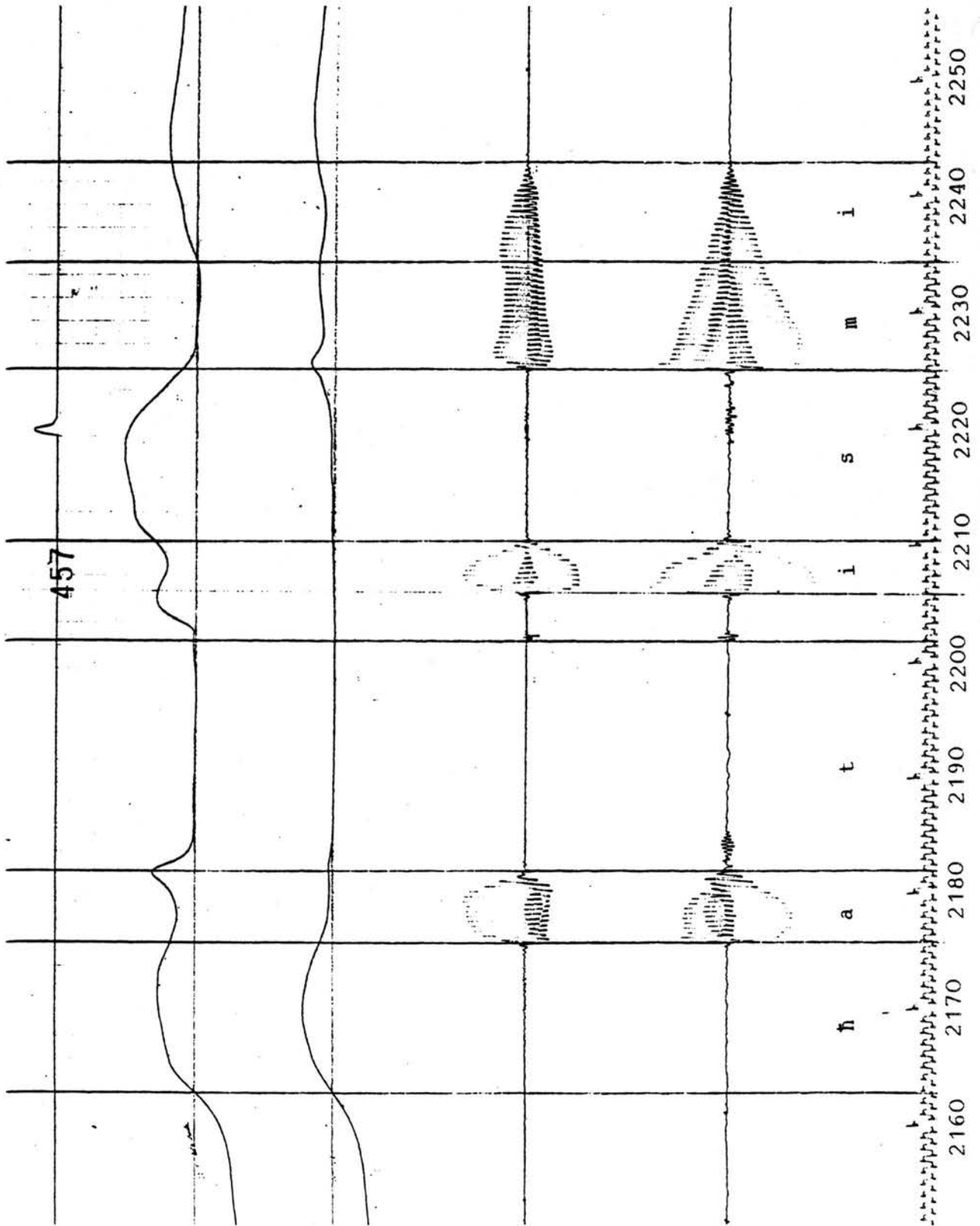
Figure 3.3.14.e

Figure 3.3.14.f
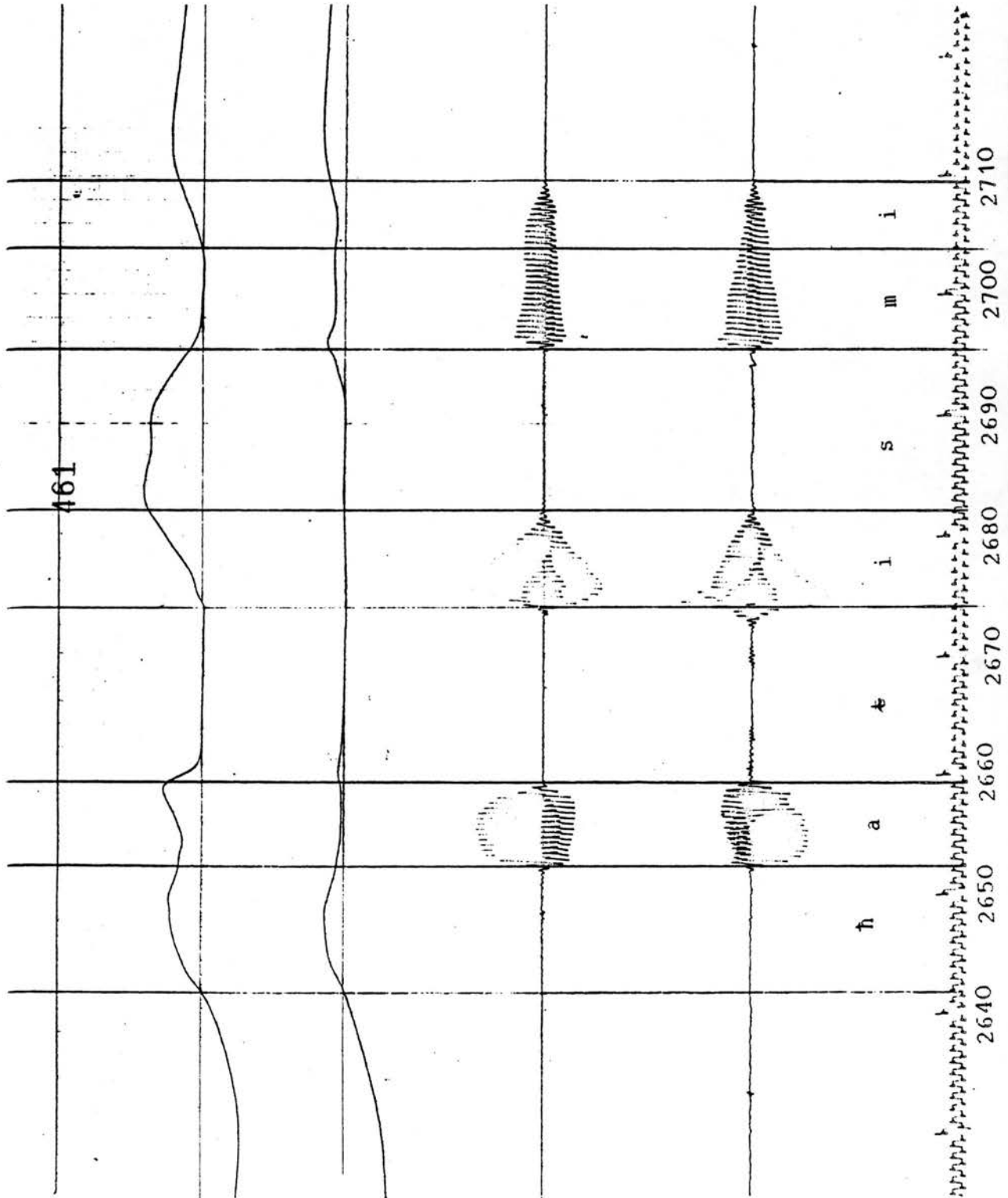
Figure   3.3.14.g

slightly lower nasal airflow rate and is 10 msec shorter. /i/ has slightly lower airflow rate and is 20 msec shorter.

From the above analysis we may summarize that the pharyngealized or emphatic sounds exhibit the following articulatory characteristics in contrast to their non-emphatic counterparts: (1) retraction in the primary place of articulation; (2) a larger area of lingual-palatal contacts in the alveolar region; (3) a smaller area of lingual-palatal contacts in the palatal region; (4) a wider untouched area in the centre line of the palate; (5) zero VOT for the emphatic voiceless plosive; (6) a longer duration.

The retraction in the place of articulation, that is tongue tip and blade retraction during the production of ·the alveolar emphatic sounds is a result of the retraction of the body of the tongue towards the upper pharyngeal wall, a movement required in achieving emphasis. This supports the impressionistic claim made in the literature that emphatic sounds involve tongue tip and blade retraction (Harrell 1957). The extensive area of lingual-palatal contacts in the alveolar region is possibly a result of the increased tension felt during the production of the emphatic sounds, causing a firmer

constriction between the alveolar ridge and the tip and/or blade of the tongue. This also supports the impressionistic claim made in the literature, (Harrell 1957, Lehn 1963), that pharyngealized sounds are more fortis than non-pharyngealized sounds as they are produced with "increased tension of the entire oral and pharyngeal musculature" (Lehn 1963, p.30). The smaller number of lingual-palatal contacts in the palatal region for the pharyngealized sounds exhibited in the EPG data is a consequence of lowering the front of the tongue and retracting its back and root towards the posterior wall of the pharynx. The wider untouched central area associated with the emphatic sounds is a result of lateral spreading and tongue depressing or hollowing. The generally slightly lower airflow rate associated with the pharyngealized segments could be interpreted as a result of a larger oral cavity created by tongue lowering and retraction.

3.4. Coarticulatory Effects:

In this section the effect of emphatic consonants on neighbouring non-emphatic vowels and consonants will be examined. This will be mainly inferred from the lingual-palatal contact patterns observed in the EPG data during their production.

3.4.1 Effect of emphatic consonants on vowels

Generally all vowels are backed in the neighbourhood of pharyngealized consonants. The front close and half-close vowels, /i:/, /i/ and /e:/, all exhibited a smaller number of touched electrodes in the anterior region of the palate when they were next to emphatic sounds as a result of the rearward movement of the tongue. So the front vowels become central and the close vowels become more open. /i/ becomes [ə], /i:/ becomes [ɨ:] and /e:/ becomes [ë:].

The front open vowel /a/, the back open vowel /a:/ and the back half close vowel /o:/ all exhibited fewer contacts in the posterior region of the palate next to emphatic consonants, indicating a backing effect. /a/ becomes an open back vowel [ɒ], /o:/ becomes lowered [ǫ:] and /a:/ becomes more backed [ɑ:].

3.4.2
Effect of emphatic consonants on neighbouring
non-emphatic consonants

In general, all consonants exhibited less lingual-palatal contacts in the environment of pharyngealization. The labials /b/ and /m/ showed less contacts both in the alveolar and palatal regions. The alveolars /n/, /l/, /r/, /s/, /t/ and /d/ have a retracted

primary place of articulation and many fewer lingual-palatal contacts in the palatal region. The palatals /ʃ/ and /j/ were also backed as they have fewer touched electrodes both in the anterior and posterior regions. The uvular /X/ does not seem to be affected by pharyngealization as it is a back sound itself. The pharyngeal /ħ/ exhibited fewer contacts in the back lines of the palate, so it is backed in the neighbourhood of emphatic consonants.

3.5   The scope of emphatic coarticulation

In the following sections, the scope and magnitude of emphatic coarticulation as exhibited in the EPG data will be discussed.

3.5.1   Anticipatory Coarticulation:

It is evident from the above analysis that the effect of an emphatic consonant can potentially spread over an entire word regardless of the quality or duration of the neighbouring segments. /ŧ/ in /ʃ o:ŧ/ induces backing and retraction on the preceding segments though their production requires an antagonistic forward

movement by the anterior part of the tongue. Also /s/ in /ris/ affects the preceding vowel /i/ where its place of articulation is retracted resulting in a central instead of front vowel. /r/ also is affected as it becomes a tense instead of a lax segment by exhibiting a firmer constriction. The effect of the final /ŧ/ in /naʃi:ŧ/ spreads backwards to cover the four preceding segments in spite of the fact that the first two neighbouring segments /ʃ/ and /i:/ are palatal, they did not block or prevent the spread of pharyngealization to the first syllable of the word /na/. The effect of emphasis is bidirectional, that is to say it affects the preceding as well as the following segments. In the word /nisi:b/ though /s/ is sandwiched between two front vowels, this did not prevent the spread of emphasis to cover the whole word. In /Xalle:na:/ the effect of the emphatic geminate /ll/ spreads to cover the entire word, causing retraction to all the segments.

3.5.2 Perseverative Coarticulation

The effect of the emphatic consonants in the words /ŧi:n/, /si:n/ /sa:d/, /sid/, /ŧal/ and /sa:matla/, spreads perseveratively to cover the entire words.

In the case of /sa:matla/ it extends over 6 segments. Syllable boundary does not seem to block or weaken the

spread of emphasis in either the backward or forward direction.

3.5.3 The effect of word-boundary on emphatic coarticulation

In the phrase /be:t ƭa:jir/ the effect of the emphatic /ƭ/ which is the initial consonant of the second word spreads backwards to cover the entire first word where the presence of the front vowel /e:/ did not prevent its spreading, and it spreads forward to cover the entire scond word. This is contrary to the findings of Ghazeli (1977) where his results for Tunisian Arabic showed that the effect of pharyngealized consonants does not cross a word boundary, "a backing gesture can extend over an entire word (400 to 600 msec), it will not extend over 15 msec across a word boundary" (p.183). It is also contrary to Laradi's (1984) findings for Libyan Arabic where she confirmed that "the influence of retraction never extends across word boundary, but it may extend over the entire word" (p.321).

Although the effect of /ƽ/ in the phrase /bas iƽi:r/ did not seem to have influence on the preceding word in the EPG data, it did exhibit a strong influence on both the preceding and following vowels in the acoustic data as the F2 value of /a/ in the first word drops from 1500

Hz to 1250 Hz (see Chapter 4). The effect of emphasis thus crosses the word boundary from right-to-left in spite of the intervening front vowel /i/.

In the phrase /ħaŧ ismi/, the effect of the final emphatic segment /ŧ/ in the first word extends backward to cover the entire word. But its effect on the following word is not very strong. /s/ seems to be pharyngealized as it has a larger area of contact in the alveolar region. The final /i/ also seems to be affected by emphasis as it exhibits fewer contacts in the palatal region. The initial /i/ does not show any sign of pharyngealization in the EPG data, but the airflow record shows that it is 30 msec longer in duration which is one of the characteristics of emphatic sounds, that is having a longer duration than the non-emphatic counterparts.

In summary, the above electropalatographic experiment has shown that emphasis can spread from the phonologically emphatic consonants to affect neighbouring consonants and vowels regardless of the quality or duration of the segments and regardless of syllable or word boundaries to about 600 msec (or 6 segments). Also it has been shown that the perseverative effect has approximately the same magnitude as the anticipatory effect.

CHAPTER   FOUR

THE ACOUSTIC PROPERTY OF EMPHASIS

4. Acoustic Characteristics of Emphatic-Consonants

The most important acoustic cue of the presence of pharyngealization is the lowering of the second formant frequency of the adjacent vowel, as there is some correlation between the degree of tongue backing and the value of the second formant "there is a direct relation between back-and-up tongue retracting and F2 frequency lowering; the more the tongue is retracted, the more the frequencey of F2 is lowered" (Delattre 1951, p.872). This acoustic fact about emphasis has been confirmed by several acoustic studies of different dialects of Arabic: Jakobson 1957 on Northern Palestinian, Obrecht 1968 on Lebanese and Egyptian, Coady 1967 on Iraqi, Saudi Arabian, Egyptian and Tunisian, Odisho 1973 on Iraqi, Ghazeli 1977 on Tunisian, Ahmed 1979 on Egyptian, Giannini and Pettorino 1982 on Iraqi, and Card 1983 on Palestinian.

Obrecht, 1968, found that "acoustically, emphasis is detectable as a lowering of the second formant in the speech segment" (p.22), and that the lowering of F2 locus or F2 transition in the CV context is what distinguishes emphatic consonants from the non-emphatic ones. Coady's 1967 study confirms Obrecht's results as he finds that the locus of the emphatic consonant is always

significantly lower in frequency than that of the plain
and that the minimum difference between the locus of
the plain and that of the emphatic is 200 Hz with the
emphatic being lower. Odisho's 1973 study reveals that
the most characteristic acoustic feature of emphasis is
the "proximity of F1 and F2 which appear as a single
dark band on the spectrogram" (p.47). As we will see
later, this statement is only true of the open vowels.
Odisho gives the following table which represents the F2
values of the emphatic and non-emphatic consonants in a
nonsense disyllabic minimal pairs:

t	1800	ŧ	1100
s	1750	ş	1100
d	1700	đ	1100
ð	1600	ð̣	1000
l	1600	ł	1100
r	1450	ṛ	1100
b	1250	ḅ	900
m	1150	ṃ	900

Ghazeli (1977), in his acoustic investigation of
pharyngealization in six dialects of Arabic (Tunisian,
Libyan, Algerian, Egyptian, Jordanian and Iraqi), writes
that "the acoustic cue most indicative of the presence of
Pharyngealization in all the dialects investigated is the
low onset (or end) of the second formant of vowels

adjacent to pharyngealized consonants" (p.77). He gives
the following table, which represents the average values
of onsets of the second formant of vowels adjacent to
the emphatic and non-emphatic consonants:

	s	ṣ	t	ṭ	
i	2100	1500	2100	1300	
u	1300	900	1100	900	
æ	1600	-	1800	-	
a	-	1200	-	1300	(p.78)

Giannini and Pettorino (1982) report that the "general
trend obtained from the spectrographic data shows F1
aproaching F2 in the environment of an   'emphatic'
consonant" (p.23). Card's 1983 study also confirms that
"the main acoustic cue for emphasis is a lowered second
formant" (p.49).

This lowering of the second formant is a
powerful cue in the perception of pharyngealization which
leads to the impressionistic perceptual description of the
emphatic sounds as being 'low pitched', 'thick', 'fat', 'dark'
'corpulent', 'heavy', and 'magnified' ; and to the
acoustically based features [+Flat] (Jakobson 1957), and
[+F2 drop] (Card 1983) which are proposed to represent
emphasis in the phonology of Arabic.
In the following sections we will report the
spectrographic experiment conducted for this study.

4.1 Acoustic Investigation of Emphasis

The aim of this experiment is to delineate the acoustic characteristics and correlates of the emphatic consonants in Q.A. and the influence they exert on the neighbouring sounds and the scope of their influence.

4.1.1 Technique

The Kay Digital Sona-Graph, model 7800, with its accompanying printer, model 7900, is used in this experiment.

The Digital Sona-Graph is a powerful acoustic analyzer which analyzes and displays complex signals in the 0-16 KHz range in terms of their frequency, duration and intensity componants. It consists of a high speed spectrograph, an audio waveform printer, an audio spectrum analyzer and an electric signal splicer. Its memory can store the incoming signals through a connected microphone or a tape recorder of the length of 64k 'words' or data points. The stored signals can then be analyzed in six different modes: 1. the three dimensional analysis of the signals into their frequency, amplitude and duration with a choice of five different analysis filter bandwidths; 2. amplitude versus time

analysis; 3. amplitude versus frequency analysis; 4. fundamental frequency versus time analysis; 5. display of the amplitude envelope of the signal ; and 6. a contour type analysis which can display intensity in 6 dB steps in 8 distinct shades of grey

Thus spectrography gives us information on many parameters of speech and enables us to carry out an acoustic analysis of both segmental and suprasegmental features.

For the purpose of our study the first mode of analysis is used with a wide filter bandwidth of 300 Hz and a range of 8000 Hz. Permanent record of the analysis is produced by the printer which was connected to the Sona-Graph by a cable, on a B/65 paper type. Frequency (pitch) is represented on the vertical axis of the spectrogram and covers the speech range from 0 to 8000 Hz; duration (time) is represented on the horizontal axis and covers 2.56 sec. on a paper of 32.5 cm. long (thus 1 mm= 7.87 msec.); intensity (loudness) is represented by the degree of darkness of the marks on the paper. The black lines across the spectrograms are the calibration lines which are to be taken as the centre of the calibration frequencies and spaced out every 500 Hz. Formant value is delimited by the middle part of the formant.

4.1.2 Subjects

Two male adults native speakers of Q.A. read the acoustic data.

4.1.3 Data

A list of meaningful test words and phrases (see appendix G) were read three times at a normal conversational rate by each of the two subjects and recorded in a soundproof recording studio. The recorded data were then played on a tape recorder which was connected to the spectrograph and spectrograms were made of the first two repetitions of each word and phrase.

4.2 Emphatic consonants versus non-emphatic consonants

The acoustic characteristics of the pharyngealized consonants and their non-pharyngealized counterparts will be considered in this section.

/t/ versus /ŧ/

Both /t/ and /ŧ/, (see Figures 4.2.a-b), are characterized by a blank gap on the spectrograms,

/æa:b/
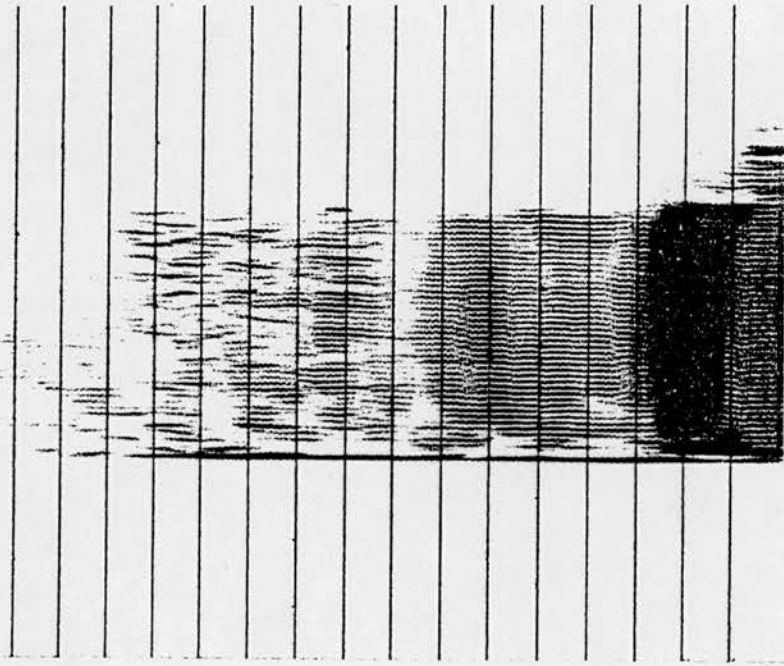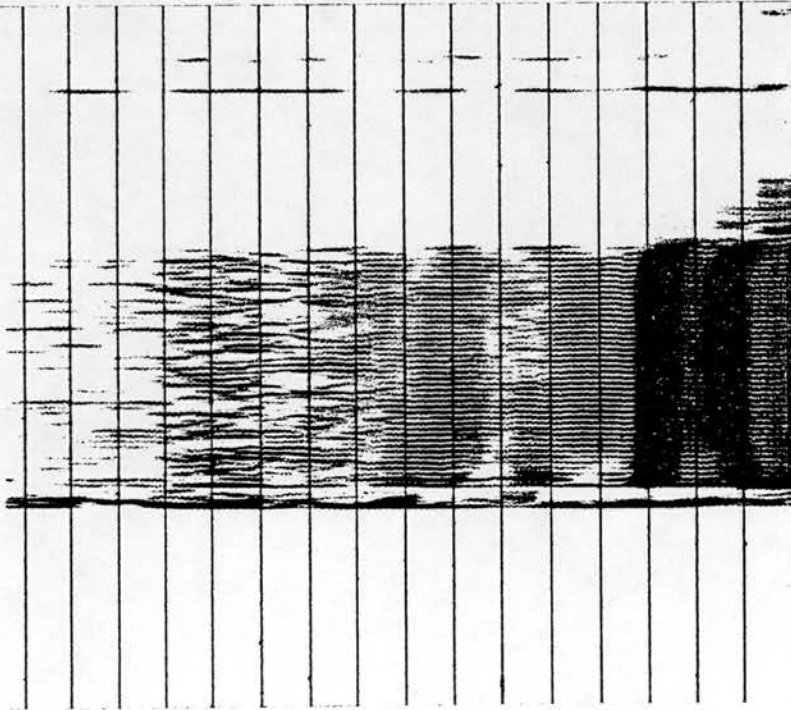
Figure 4.2.b

/ta:b/

Figure 4.2.a

representing the closure period. This blank gap is followed by an energy burst visible as a strong vertical spike extending from 0 Hz to 8000 Hz. But when they are followed by a vowel, the gap between the release of /ṭ/ and the onset of the vowel is much shorter than the gap between the release of /t/ and the onset of the vowel; it is 0-15 msec in the case of /ṭ/ and 30-50 msec in the case of /t/. This difference in the VOT represents the aspiration which is present in /t/ and lacking in /ṭ/.

Also one notices that the closure period for /ṭ/ is longer in most cases than /t/. This may be due to the kinesthetically felt tense articulation; according to Chomsky and Halle (1968) "in tense sounds, both vowels and consonants, the period during which the articulatory organs maintain appropriate configuration is relatively long" (p.424). This firm and tense articulation of the pharyngealized consonant enables the tip and blade of the tongue not to lose contact under the pressure of tongue lowering and backing.

/s/ versus /ṣ/

The spectra for both /s/ and /ṣ/ (Figures 4.2.c-d) are very similar. They both exhibit a random noise with a concentration of energy from around 3000 Hz and up. This energy is even visible from 0 Hz in some cases. Thus there is no clear cut difference between the acoustic spectra of /s/ and /ṣ/ as they both demonstrate the
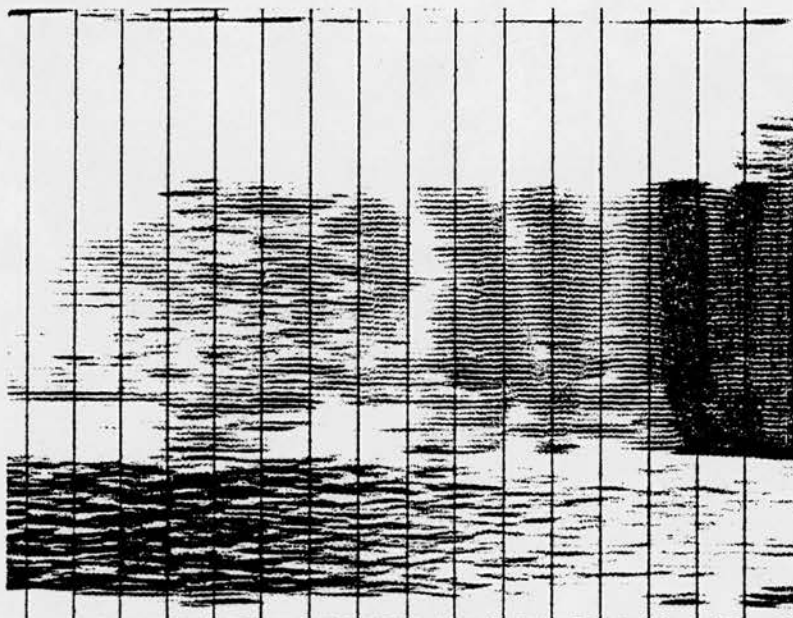
/sa:d/

Figure 4.2.d
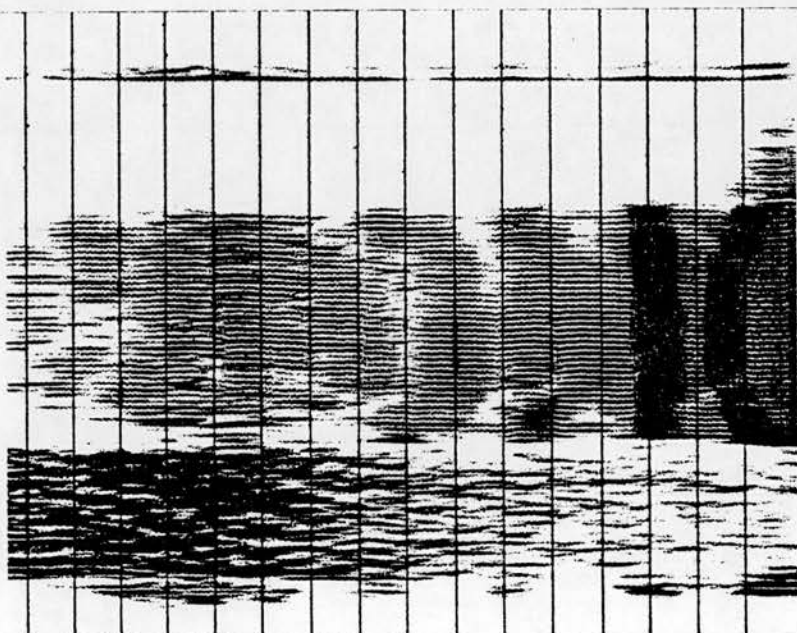
/sa:d/

Figure 4.2.c

characteristics of voiceless alveolar fricatives. This is due to the fact the acoustic spectra for these sounds are generally determined by the posture of the vocal tract at and anterior to the primary place of articulation. Both /s/ and /ʂ/ have similar vocal tract configuration at the primary stricture except for a slight retraction in the case of /ʂ/ which does not seem to have any noticeable acoustic consequences. /ʂ/ demonstrates, in most instances, a longer duration than /s/ indicating a greater intensity.

/ʒ/ versus /ʐ/

Both /ʒ/ and /ʐ/ (see Figures 4.2.e-f) exhibit vowel-like formant frequencies on the spectrograms. But /ʐ/ displays a much lower second formant frequency than /ʒ/. The average F2 value for /ʐ/ next to /i:/ is 1000 Hz, next to /a:/ is 850 Hz and next to /u:/ is 750 Hz. While the average F2 value for /ʒ/ next to /i:/ is 1500 Hz, next to /a:/ 1300 Hz and next to /u:/ is 1300 Hz. In general, /ʐ/ displays less friction than /ʒ/. This could be a result of a firmer partial contact of the tip of the tongue against the back of the upper teeth which reduces the velocity of air and consequently reduces friction.

/ɣil/
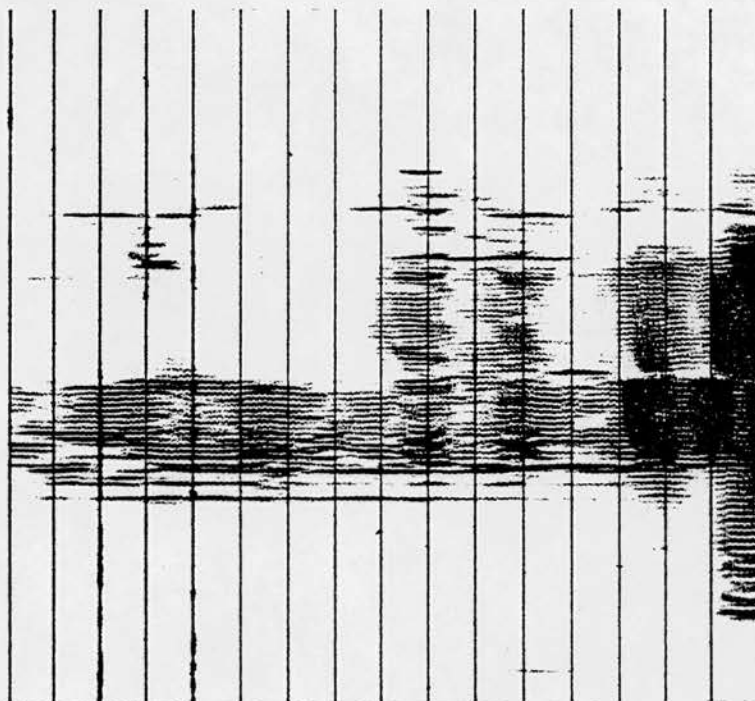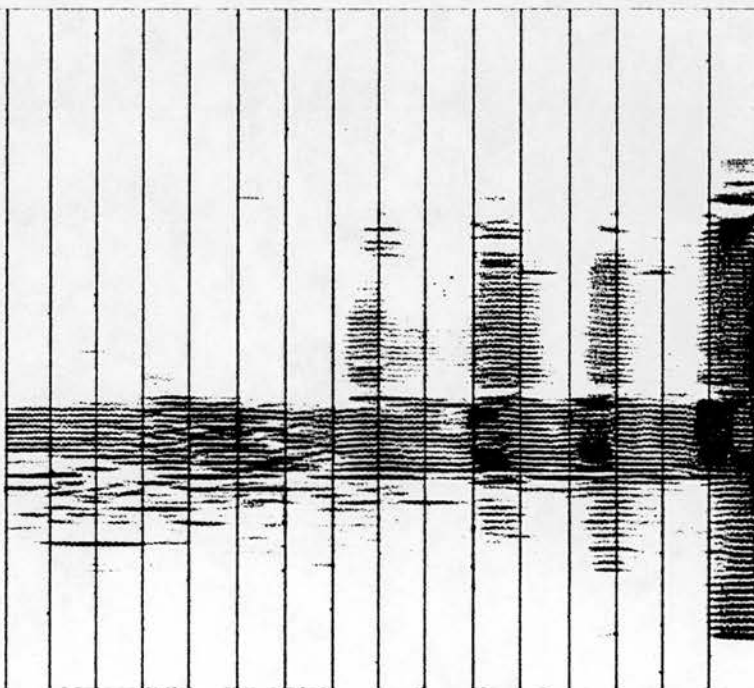
Figure 4.2.f

/ɣil/

Figure 4.2.e

/l/ versus /ɫ/

Both /l/ and /ɫ/ (see Figures 4.2.g-h) exhibit
vowel-like formant frequencies and can be easily
distinguished by their second formant value, which is
much lower in the case of /ɫ/. The pharyngealized
lateral displays an average F2 value of 1000 Hz and the
non-pharyngealized lateral displays an average F2 value of
1500 Hz.

4.3   The acoustic effect of emphasis on
the neighbouring vowels

The most important acoustic effect of the
emphatic consonants on the adjacent vowels is the
lowering of the onset or offset of their second formant
frequency.   Inspecting the following tables and graphs
(Figures 4.3.1-6), we notice that they have the most
dramatic effect on the onset of the long palatal vowels.
/i:/ shows a displacement of 850 Hz next to /ðˤ/ as
compared to /ð/. /i:/ and /e:/ exhibit the following
displacement next to /sˤ/ as compared to /s/: 1000 Hz and
850 Hz respectively.   They exhibit the following
displacement when adjacent to /tˤ/ as compared to /t/:
1150 Hz and 975 Hz respectively.   The spectrograms in
Figures 4.3.7-10 reveal that both /i:/ and /e:/ have a
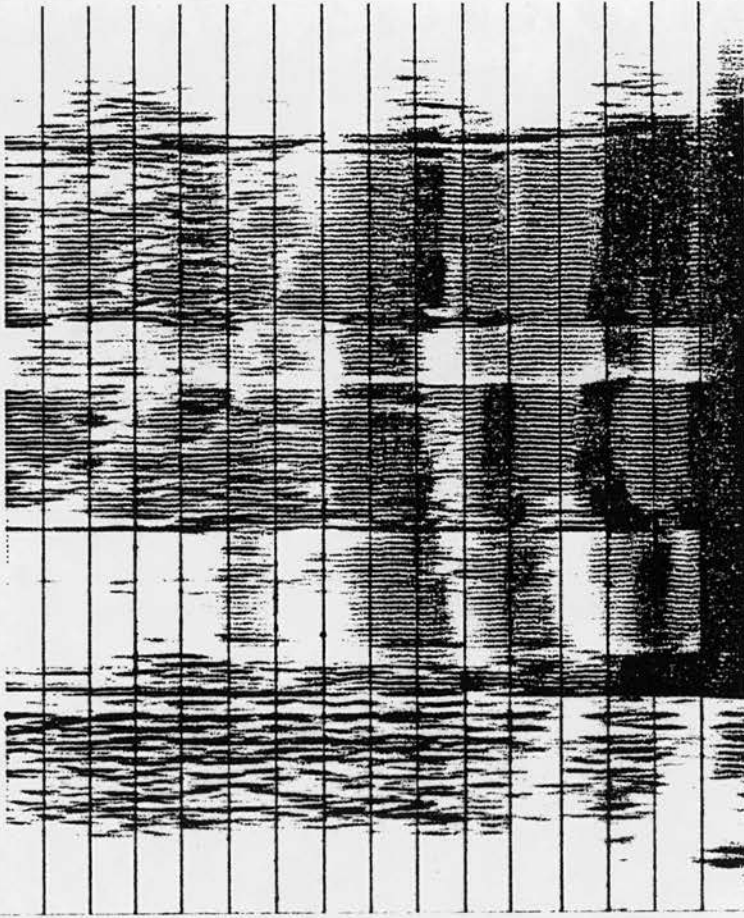
/Xaɬe:na:/
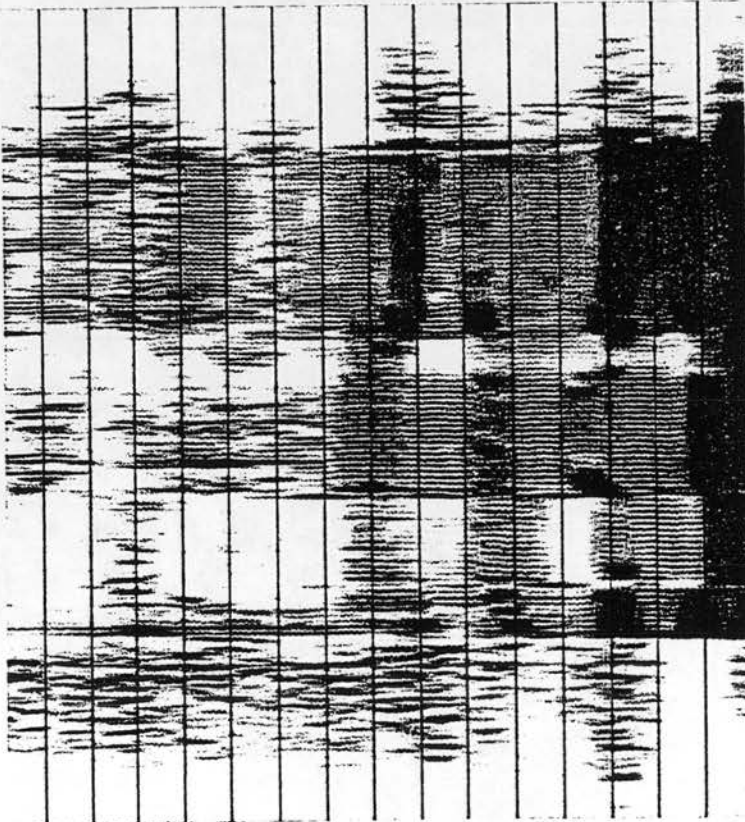
Figure 4.2.h

/Xalle:na:/

Figure 4.2.g

Vowels	/ə/	/ᵊ/	extent of displacement
/i/	1750	1100	650
/i:/	1850	1000	850
/e:/	–	1100	–
/a/	1500	1100	400
/a:/	1400	1000	400
/u/	–	–	–
/o:/	–	–	–
/u:/	1500	750	750

F2 onset values in Hz

Figure 4.3.1

Vowels	/s/	/ʃ/	extent of displacement
/i/	1700	1025	675
/i:/	2000	1000	1000
/e:/	1850	1000	850
/a/	1750	1150	600
/a:/	1500	1100	400
/u/	-	1000	-
/o:/	1400	1000	400
/u:/	1500	750	750

F2 onset values in Hz

Figure 4.3.2

Vowels	/t/	/ɛ/	extent of displacement
/i/	1850	1100	720
/i:/	2250	1100	1150
/e:/	2000	1025	975
/a/	1700	1100	600
/a:/	1300	1100	200
/u/	1500	1000	500
/o:/	1500	1075	425
/u:/	1450	750	700

F2 onset values in Hz

Figure 4.3.3

Graph showing the average value of onsets of
the second formant of the vowels /i/,/i:/,/e:/,/a/,
/a:/,/o/,/o:/,/u:/ adjacent to the emphatic consonant
/ð̣/ and its non-emphatic counterpart /ð/.
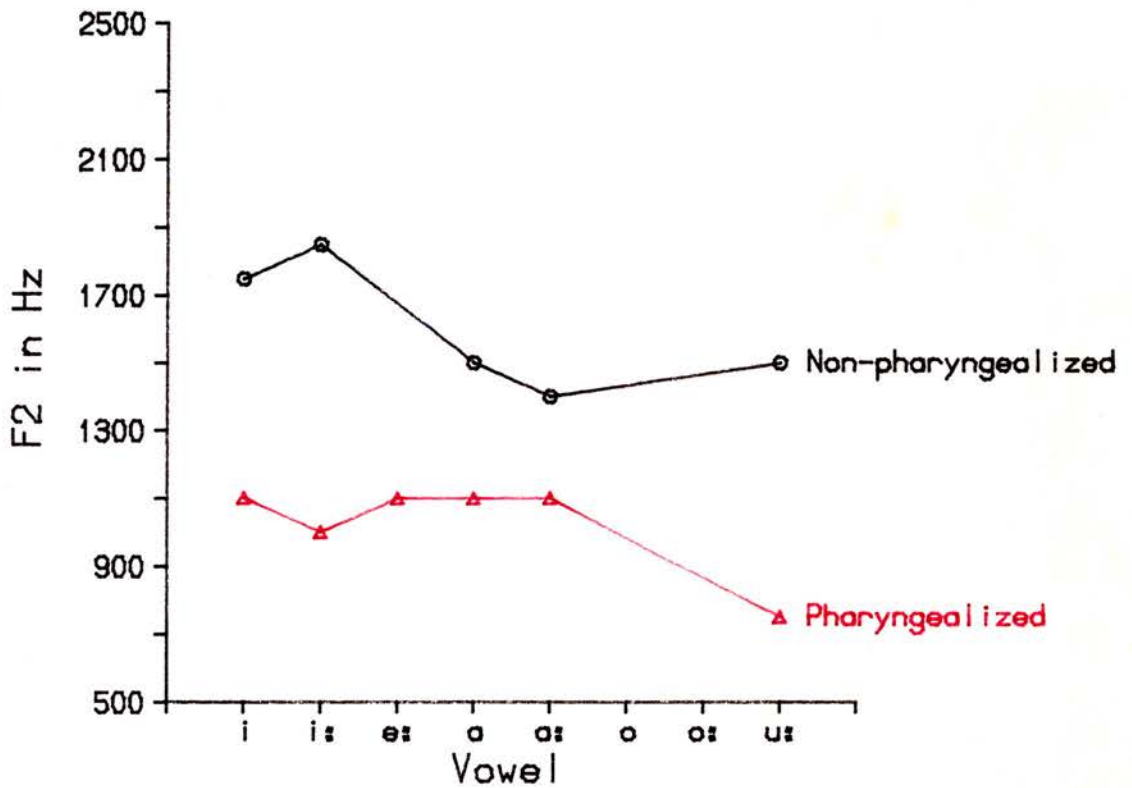
Figure 4.3.4

Graph showing the average value of onsets of
the second formant of the vowels /i/,/i:/,/e:/,/a/,
/a:/,/o/,/o:/,/u:/ adjacent to the emphatic consonant
/S/ and its non-emphatic counterpart /S/.
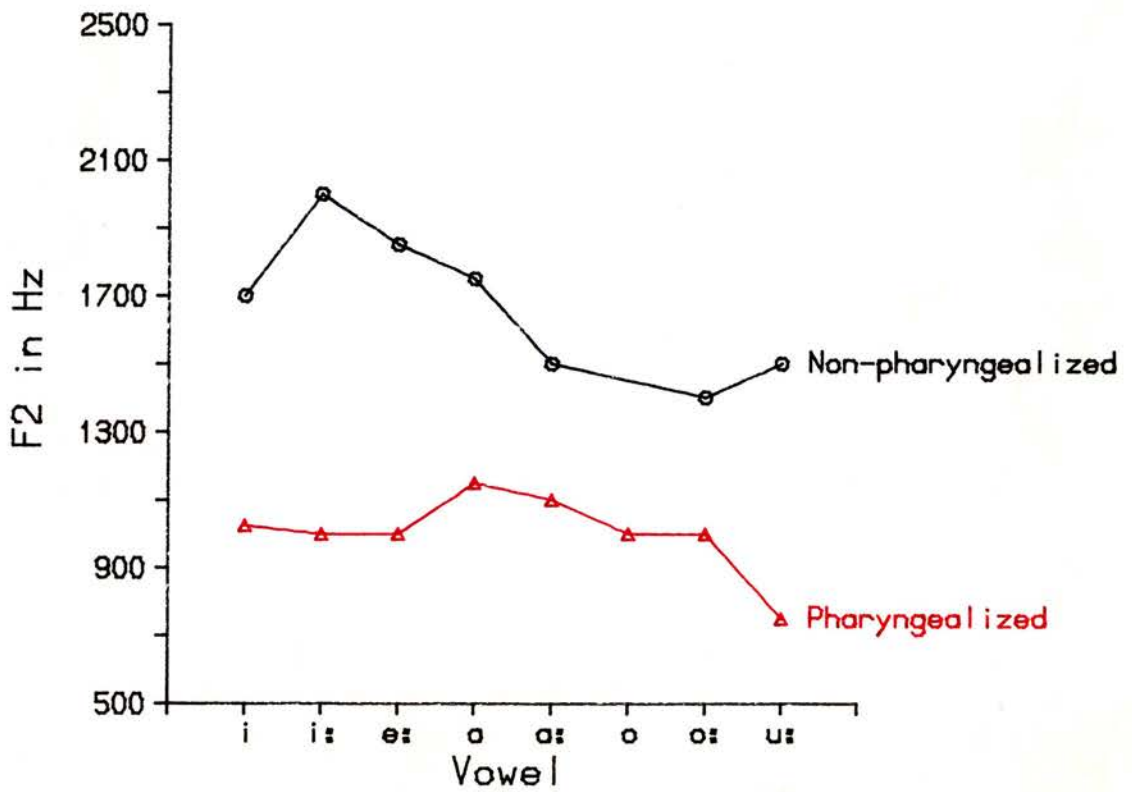
Figure   4.3.5

Graph showing the average value of onsets of
the second formant of the vowels /i/,/iː/,/eː/,/a/,
/aː/,/o/,/oː/,/uː/ adjacent to the emphatic consonant
/t̪/ and its non-emphatic counterpart /t/.

Figure 4.3.6

/ti:n/

Figure 4.3.7

/ɬi:n/
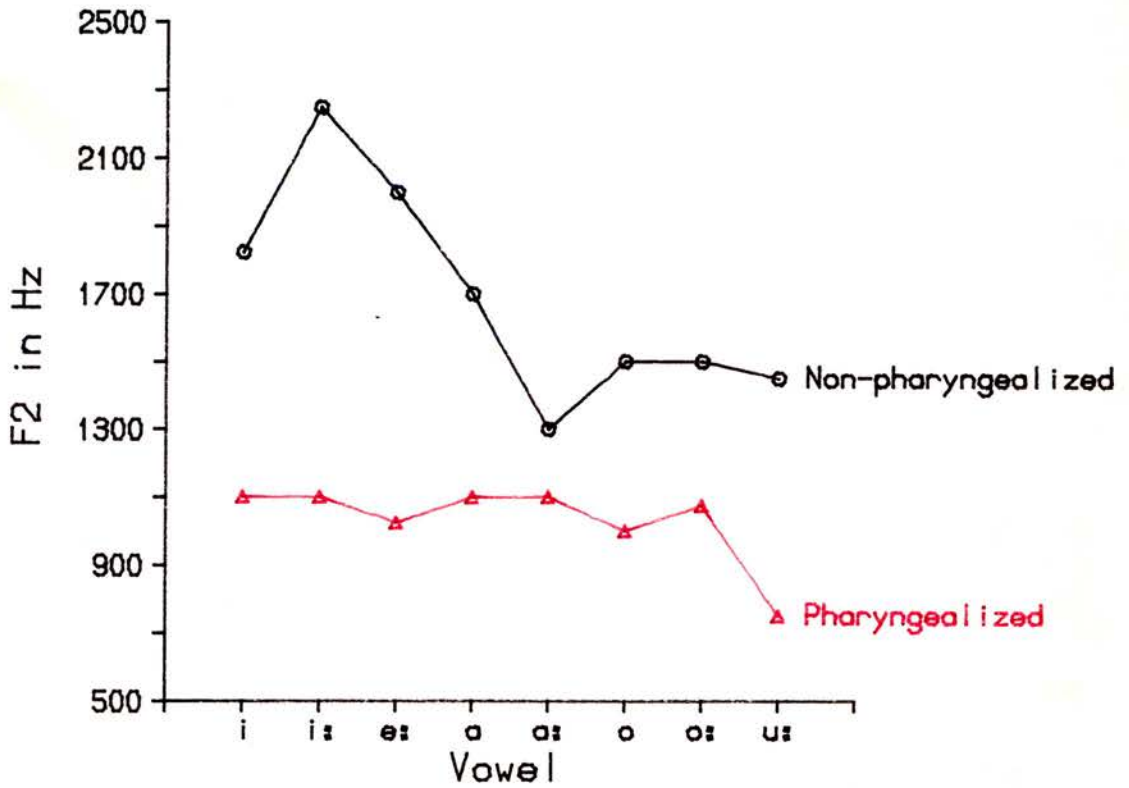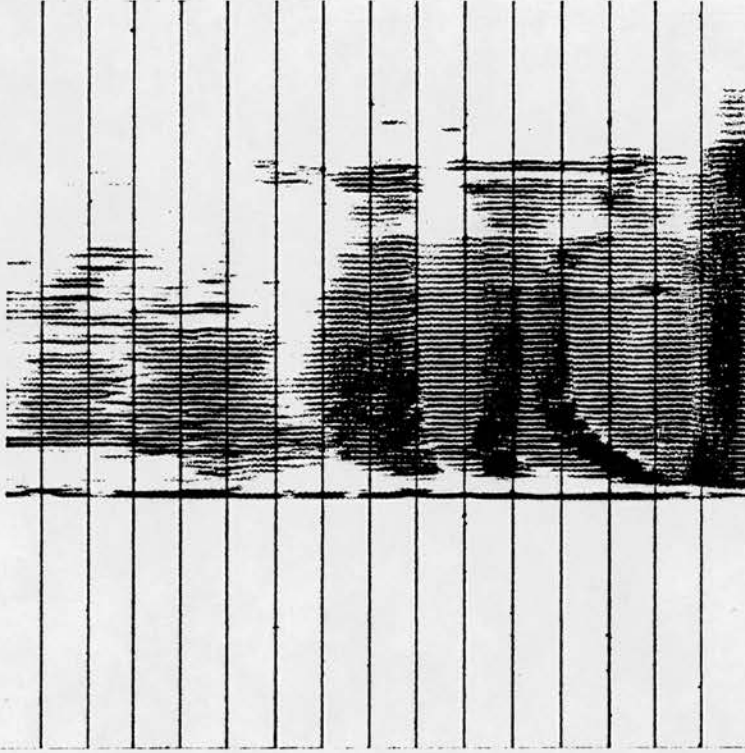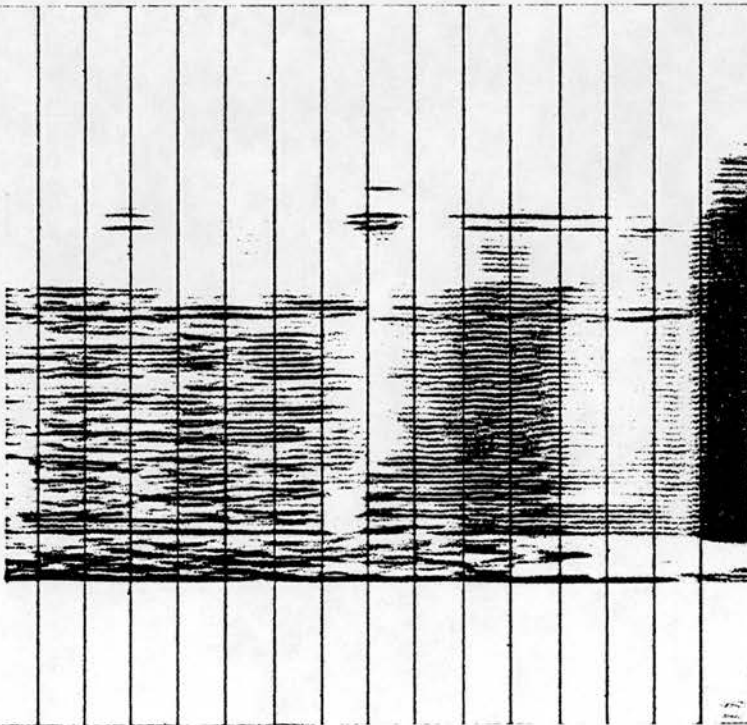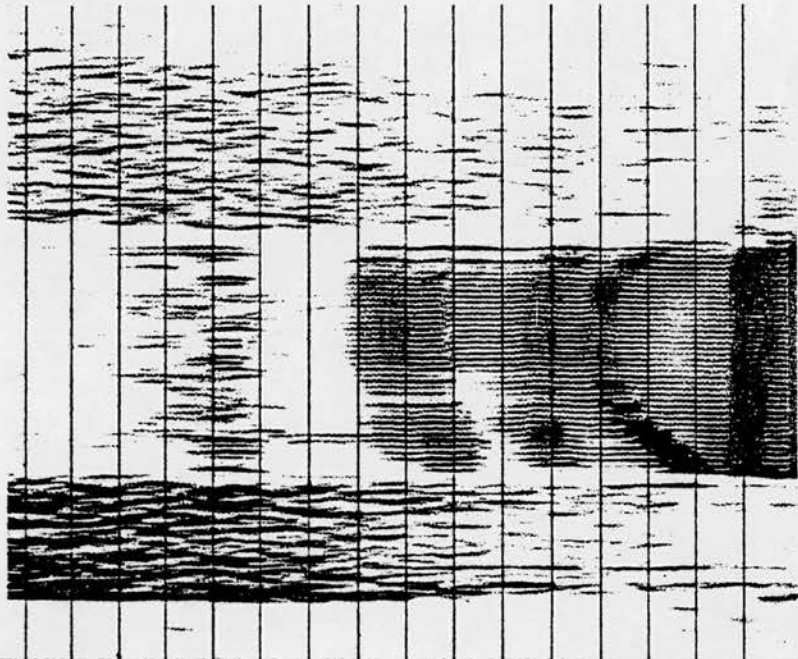
Figure 4.3.8

/se:f/
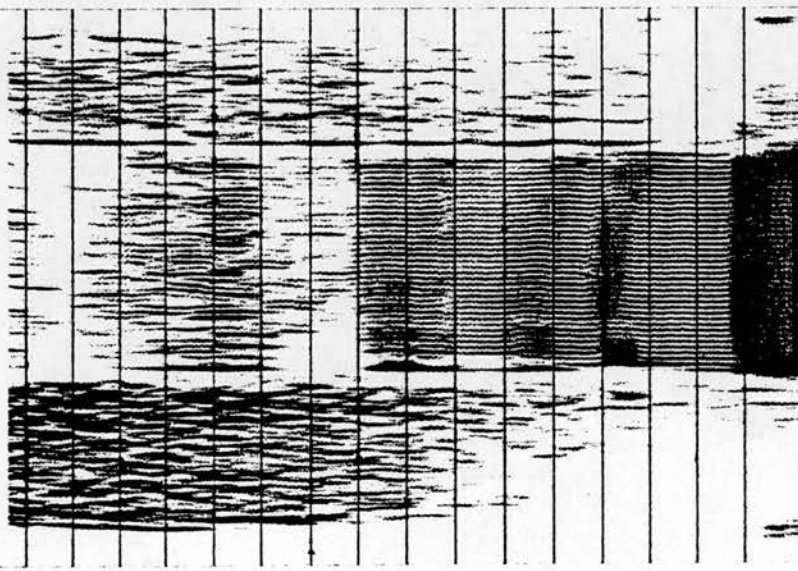
Figure 4.3.10

/se:f/

Figure 4.3.9

long F2 transition (about one third of their duration)
when adjacent to pharyngealized consonants before they
reach their steady state value which is 2000-2250 Hz for
/i:/ and 1850-2000 Hz for /e:/. This low onset or offset
of the front close vowels and their long transition when
adjacent to an emphatic consonant reflect the changes in
the vocal tract configurations in moving to and away
from an emphatic consonant. As we found out in the last
chapter, the most important articulatory feature of
pharyngealization is the lowering of the body of the
tongue and the rearward movement of the back of the
tongue towards the pharyngeal cavity causing a large
oral cavity. This large oral volume results acoustically
in a low second formant. As the massive back of the
tongue is not as briskly mobile as the tip or blade of
the tongue, it takes a relatively   longer time for the
back of the tongue to achieve or break away from the
posture required for pharyngealization. Hence when a
high front vowel follows a pharyngealized consonant, upon
the release of the primary stricture of the emphatic
consonant, the oral cavity is still holding the secondary
stricture with a large oral cavity causing the onset of
F2 of the following vowel to be very low; but then
gradually the back of the tongue moves forward and
upward to achieve the required posture for the front
high vowel; thus decreasing the volume of the oral cavity
and increasing the value of F2.

This gradual and long movement of the posterior part of the tongue results in a longer transition for /i:/ and /e:/ when adjacent to a pharyngealized consonant than when adjacent to a non-pharyngealized consonant, as the distance over which the tongue has to travel from /C̰/ to /i:/ and /e:/ is longer than from /C/ position to /i:/ or /e:/. This results in a rising transition when a front high vowel follows an emphatic consonant and a falling transition when it precedes an emphatic consonant. /i/ being a short vowel, is pharyngealized all the way through as its F2 lowered from 1750 Hz to 1250 Hz next to a pharyngealized consonant (see Figures 4.2.e-f) resulting in a schwa-like central vowel. In most cases /i/ does not exhibit any transition and the whole vowel is lowered; but there are few cases where the whole vowel is just a transition without a steady state.

When the vowel /u:/ follows a pharyngealized consonant (see Figures 4.3.11-12) we find that it exhibits a pattern opposit to that of /i:/. There is no transition between /C̰/ and /u:/ as all of F2 consists of a steady state at 750 Hz. While there is a transition between /C/ and /u:/ as F2 starts at a value of 1200 Hz and then gradually falls down to reach its steady state value of 750 Hz. This acoustic characteristic of the pharyngealized consonants in relation to /u:/ reflects the physiological articulatory relationship. As the tongue is already retracted or backed for the emphatic consonant, the

/ʒu:g/
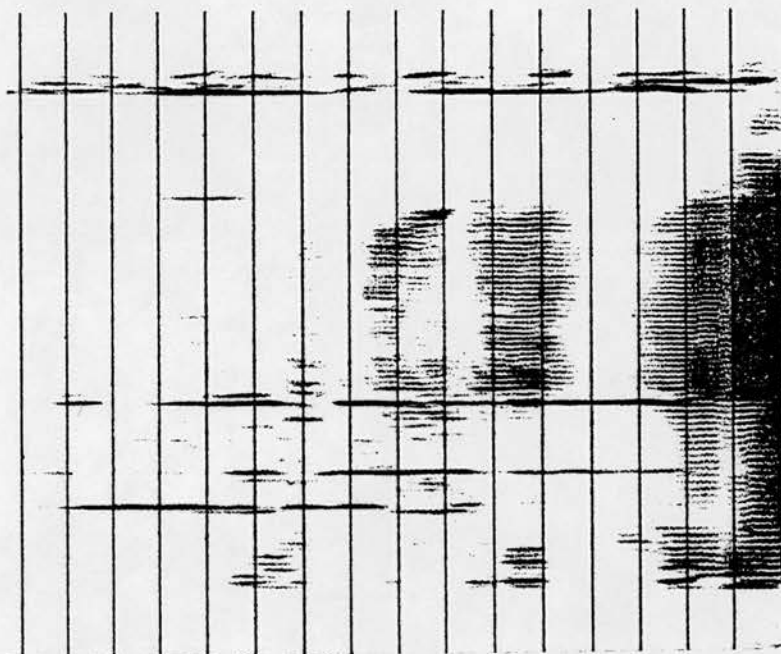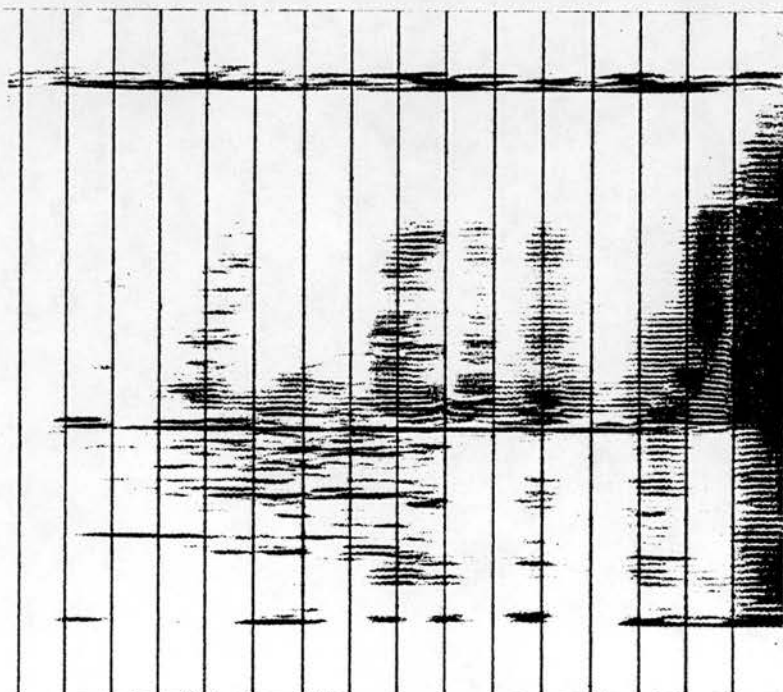
Figure 4.3.12

/ʒu:g/

Figure 4.3.11

distance it has to travel to achieve the required configuration for the back vowel is very small, hence there is no transition. While for the non-emphatic alveolar consonant, the tongue is not retracted or backed, hence upon its release the back of the tongue has to travel a longer distance backward to achieve the posture required for the back vowel. Thus, resulting in a falling F2 transition when it follows a non-emphatic consonant and a rising transition when it precedes a non-emphatic consonant.

Similarly, the vowel /o:/ (Figures 4.3.13-14) exhibits no transition next to a /€/, with F2 having a value of 1000 Hz. While it displays a transition next to the non-emphatic counterpart, as F2 exhibits a value of 1250 Hz, then falls to a steady state value of 1000 Hz. As for the short vowel /u/, it shows no transition next to an emphatic consonant, having a low F2 value of 900 Hz, but it exhibits a falling transition next to a non-emphatic consonant from 1500 Hz to 1000 Hz. In fact the whole vowel consists of just a falling transition (see Figures 4.3.15-16).

. The low central vowel /a:/ does not display any transition whether it is adjacent to /€/ or /C/. But when it is adjacent to /€/ the whole vowel has a lower F2 value and a slightly higher F1 value, causing the two formants to approximate each other and form a single thick formant on the spectrogram. In the example given

/ʃoːʈ/

Figure 4.3.14

/ʃoːt/
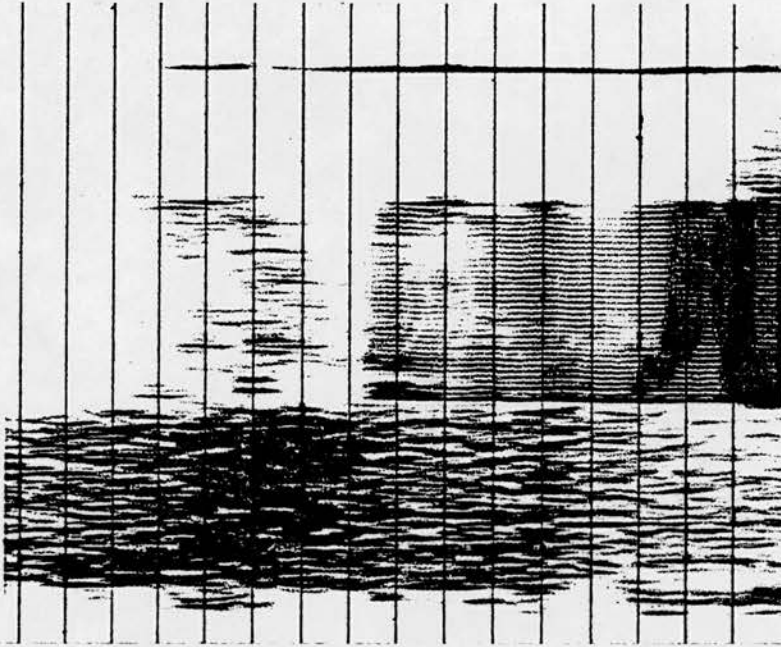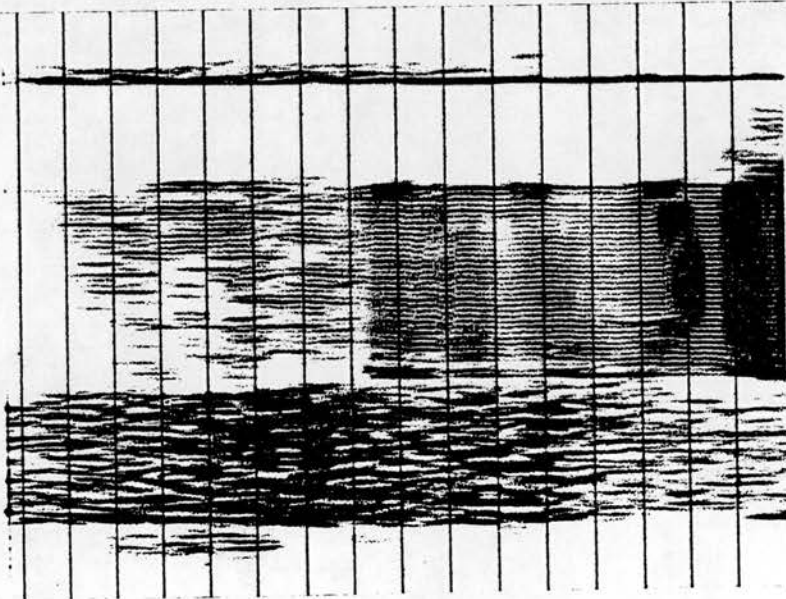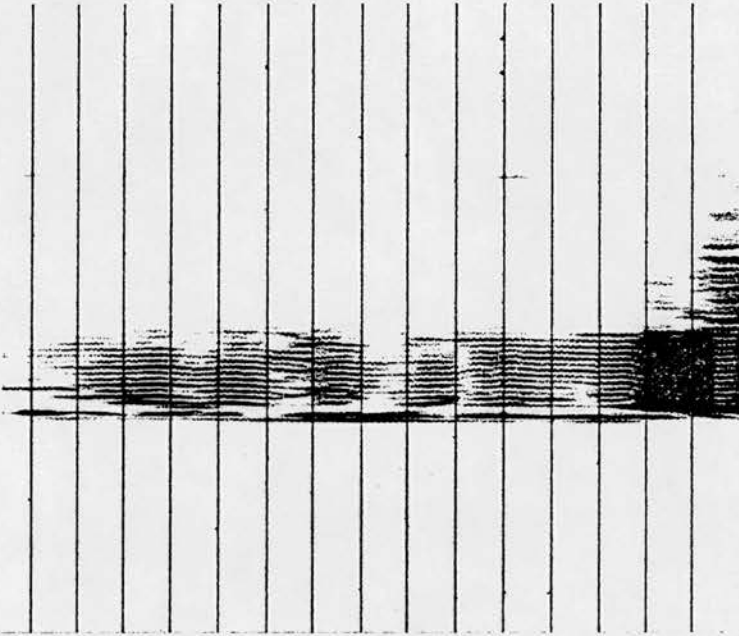
Figure 4.3.13

/ʧub/
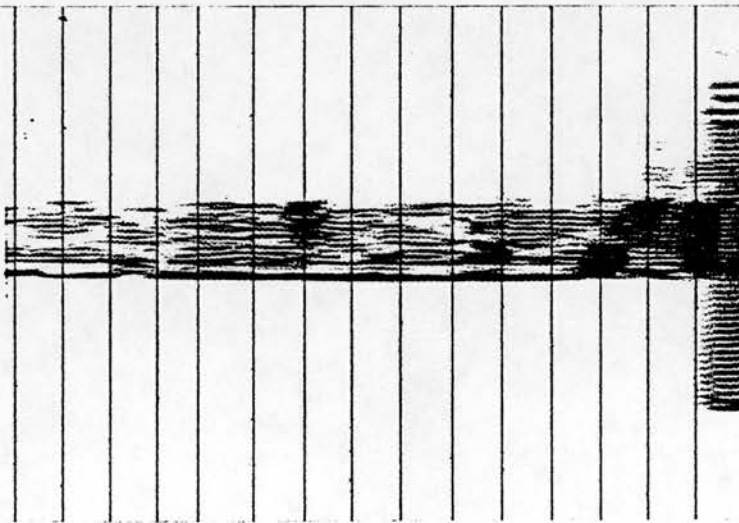
Figure 4.3.16

/dub/

Figure 4.3.15

in Figures 4.2.a-b F2 of /ẗa:b/ falls from 1400 Hz to 1200 Hz and F1 rises from 700 Hz to 800 Hz. This difference in F2 value and F1 value reflects the fact that upon the release of /ẗ/, the tongue keeps its secondary stricture for the vowel /a:/ as it requires a posture similar to that of the pharyngealized consonant but of a lesser degree, being a low and almost back sound itself. This slight more lowering and backing configuration for /a:/ causes the lowering of F2 and slight raising of F1. Thus /a:/ is rendered [ɑ:]. Figures 4.3.17-18 shows that /a/ displays similar acoustic feature as /a:/ when adjacent to a pharyngealized consonant as it is rendered lower and backer, F2 is lowered from 1500 Hz to 1000 Hz and F1 is raised from 500 Hz to 700 Hz without any transitions as emphasis runs through the whole vowel causing /a/ to become [ɑ]. Thus both [ɑ] and [ɑ:] signal the presence of pharyngealization.

In summary, acoustically, the presence of a pharyngealized consonant next to the open vowels /a/ and /a:/ causes their F2 to be lowered and their F1 to be slightly raised. The back vowels /u/, /o:/ and /u:/ exhibit a falling or a rising transition next to the non-emphatic consonants depending on whether they are preceding or following it. While they exhibit no transition next to the emphatic consonants. The front vowels /i:/ and /e:/ display a long rising or falling transition of F2 next to the pharyngealized consonants
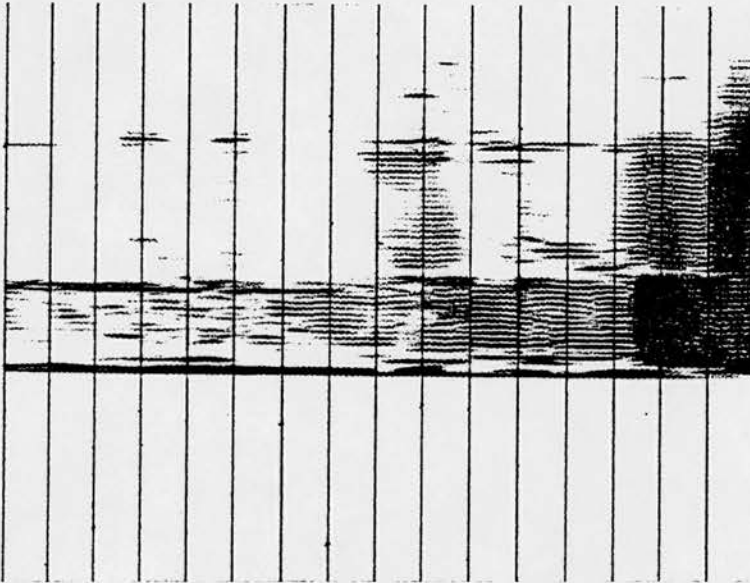
/æal/
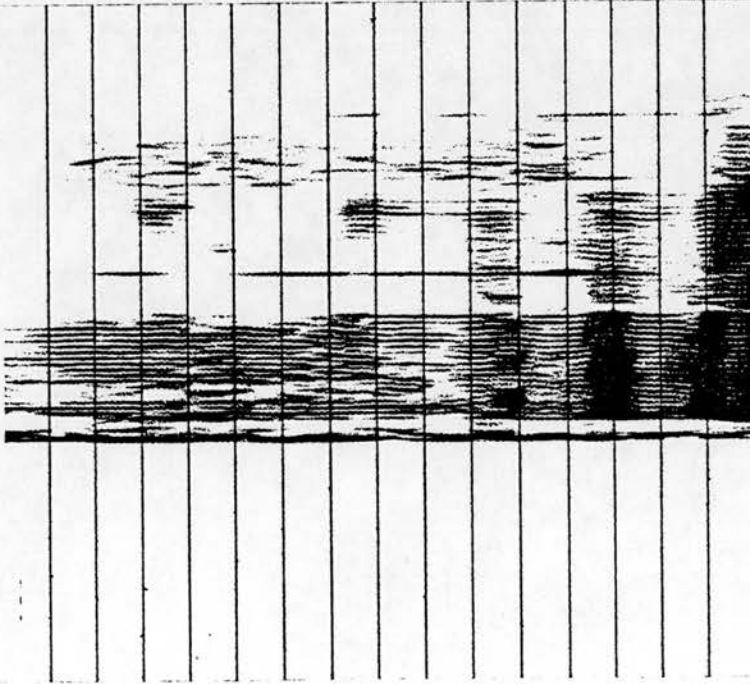
Figure 4.3.18

/tal/

Figure 4.3.17

while they do not show any transition next to the non-pharyngealized cognates.

4.4 Coarticulatory Effects

In this section the temporal scope and magnitude of anticipatory and perseverative emphatic coarticulation will be examined. This will be mainly inferred from the presence of certain acoustic cues exhibited in the spectra of segments neighbouring the phonologically emphatic consonants. As we found in the above section, vowels exhibit a low F2 value when adjacent to pharyngealized consonants. The effect of the emphatic consonants on neighbouring non-emphatic consonants is only directly evident in those consonants which have a vowel-like formant structure, that is to say nasals, liquids and voiced fricatives, as their second formant gets lowered under the influence of emphasis. But the effect of emphasis on the other consonants can only be inferred from the transitions of the vowels following or preceding them as they transmit the effect of pharyngealization to them.

4.4.1 Anticipatory Coarticulation

Spectrograms of the words /biːfiːd/ and /biːfiː%/ (Figures 4.4.1.a-b) show that the effect of emphasis can spread from right to left to cover the entire word. The first /iː/ has an F2 value which is 200 Hz lower in the emphatic word without exhibiting any transition. This is probably due to the fact that it is in an unstressed position, hence it has a much shorter duration than the second /iː/ (102 msec as opposed to 212 msec). The second /iː/ starts at a steady state F2 value of 2250 Hz for about two-thirds of its duration, then it falls to 1500 Hz before /%/. Thus, in spite of the high front vowels which require an antagonistic articulatory movement to that required for the pharyngealization, emphasis did spread backwards to engulf the whole word.

Figures 4.4.1.c-d exhibit the spectrograms of the minimal words /niʃiːd/ and /niʃiːɜ/. It is evident that the effect of the final /ɜ/ spreads to affect all the four preceding segments. The adjacent /iː/ has an F2 value which ends at 1500 Hz and then rises gradually to reach its steady state value of 2200 Hz. /ʃ/ does not block the spread of pharyngealization to the preceding short vowel /i/ as its F2 value lowered from 1750 Hz to 1500 Hz. The initial /n/ also exhibits signs of pharyngealization as its F2 is slightly lowered. This contradicts Card's 1983 results where she reports that both /iː/ and /ʃ/ block emphasis as they neither acquire it nor transmit it.

Comparing the words /maːfaːd/ and /maːfaː%/ in
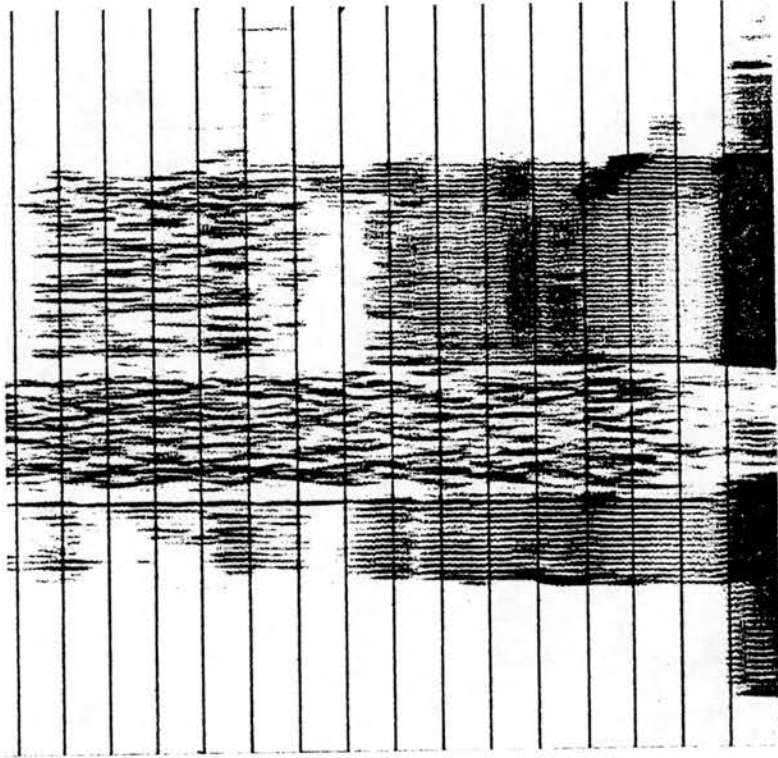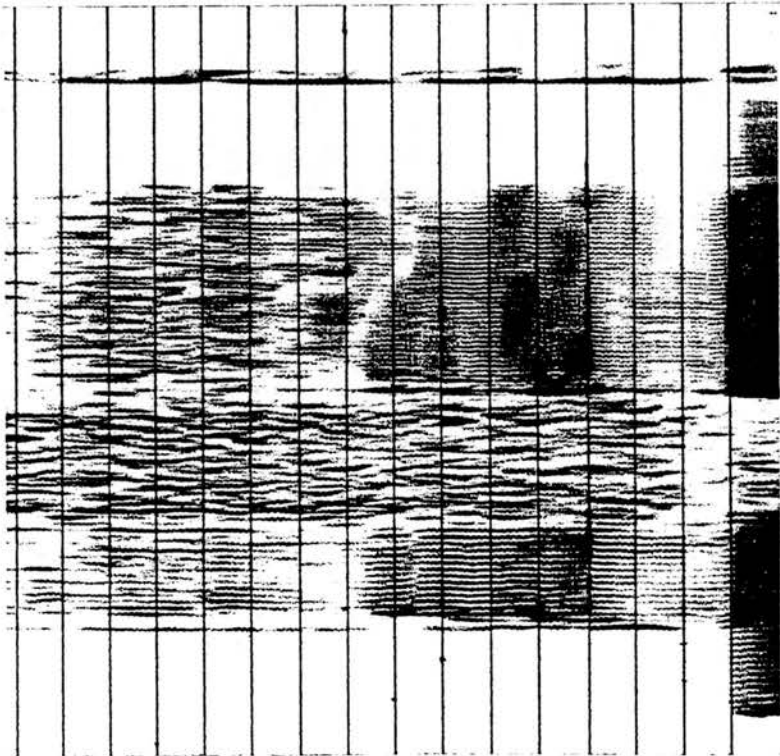
/bi:fi:%/
Figure 4.4.1.b

/bi:fi:d/
Figure 4.4.1.a

/naʃiːɛ/
Figure 4.4.1.d
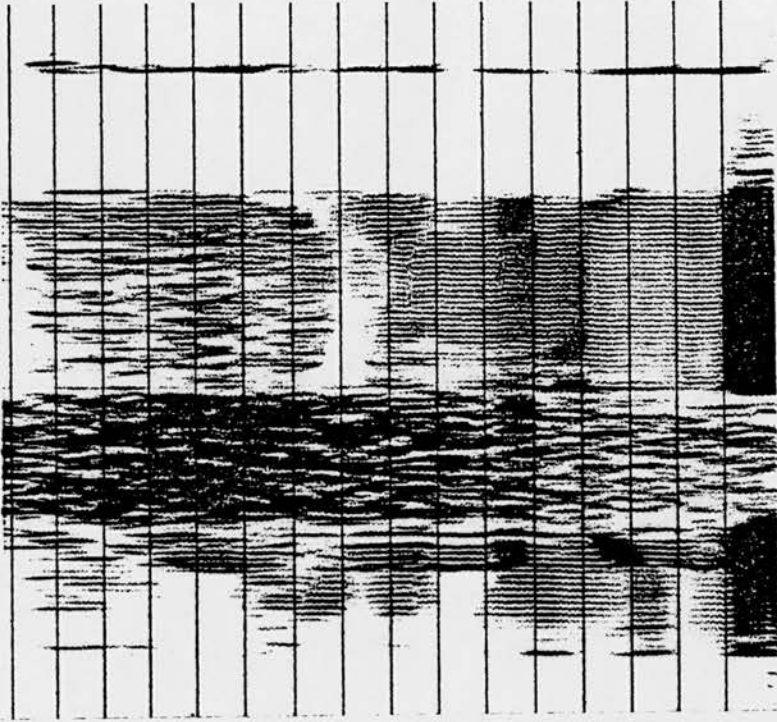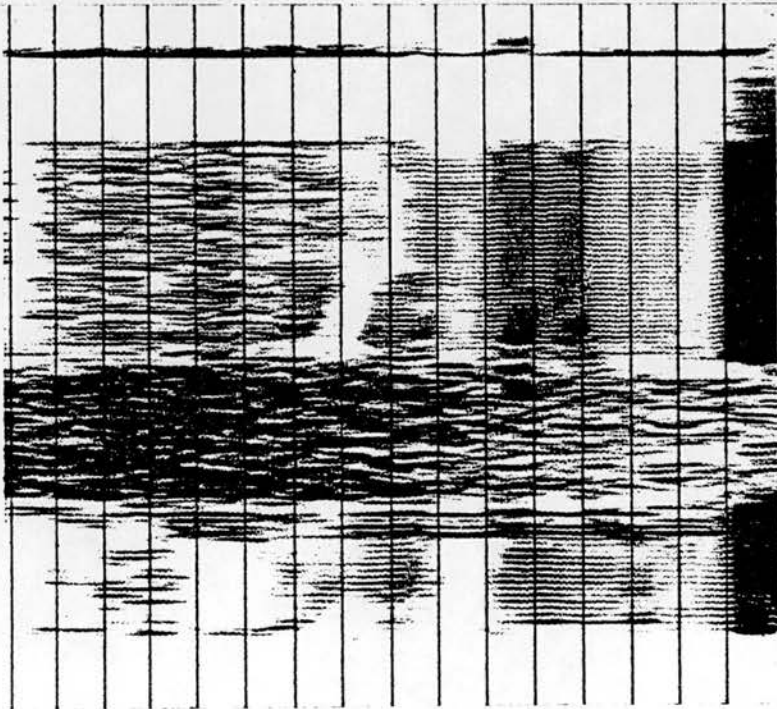
/naʃiːd/
Figure 4.4.1.c

Figures 4.4.1.e-f, we notice that emphasis spreads from the final segment /ᶄ/ regressively to affect the entire word. The first /a:/ has an F2 value of 1100 Hz in the emphatic word and 1250 Hz in the non-emphatic word. F2 of the second /a:/ also drops from 1500 Hz to 1200 Hz. The first /a:/ is much shorter in duration, 125.5 msec., than the second /a:/ which has a duration of 204 msec. This is due to the fact that the first vowel is unstressed while the second is stressed.

4.4.2   Perseverative Coarticulation

Spectrograms of the words /safra/ and /ṣafra/, Figures 4.4.2.a-b, reveal that pharyngealization spreads forward from /ṣ/ to cover the following four segments. F2 of the first /a/ is lowered from 1500 Hz to 1000 Hz and F1 is raised from 500 Hz to 600 Hz. F2 of /r/ is lowered from 1200 Hz to 900 Hz, and F2 of the final /a/ is lowered from 1250 Hz to 1050 Hz.

Similarly, the minimal pairs /su:mla/ and /ṣu:mla/, /sa:matla/ and /ṣa:matla/, /tiba:ʃ i:r/ and /ṭiba:ʃ i:r/, Figures 4.4.2.c-h all reveal carry over emphatic coarticulation. /u:/ has a low F2 onset of 750 Hz in /ṣu:mla/, while it has an onset of 1150 Hz in /su:mla/. F2 of /l/ is lowered from 1400 Hz to 750 Hz in the emphatic context, and F2 of /a/ is lowered from 1500 Hz

/ma:fa:ɣ/
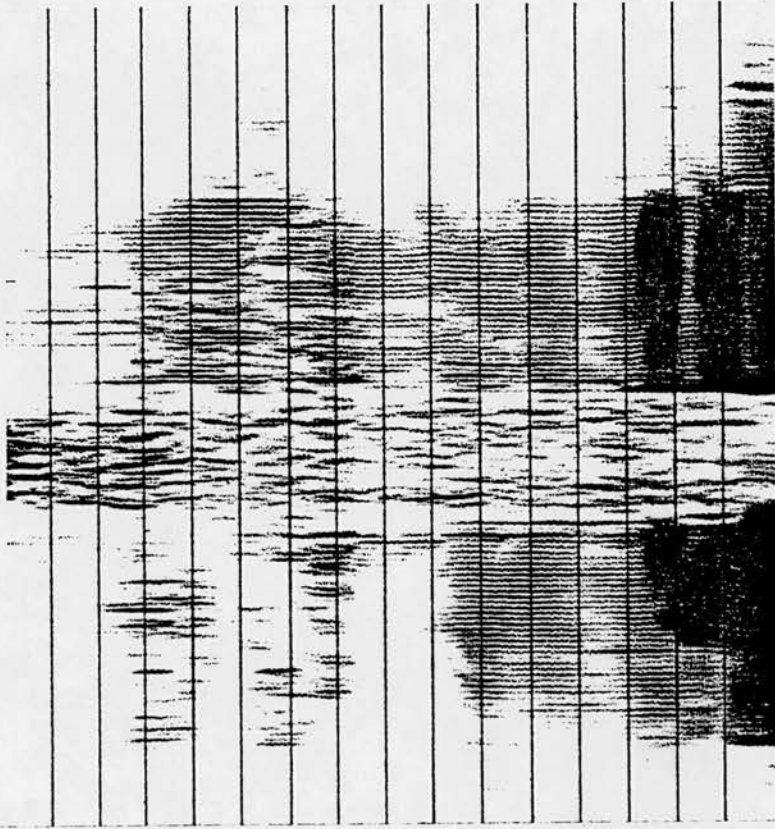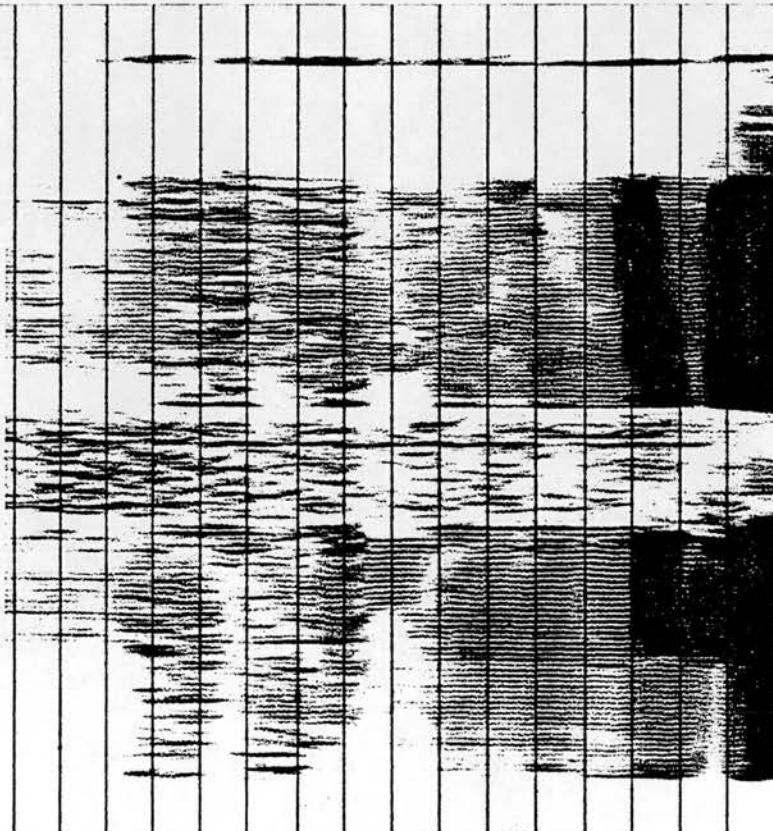
Figure 4.4.1.f

/ma:fa:d/

Figure 4.4.1.e
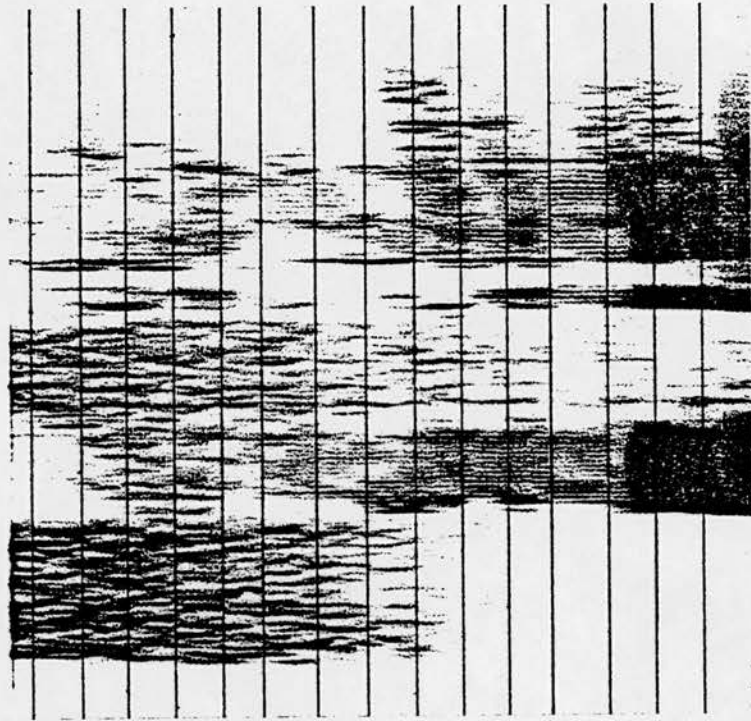
/safra/

Figure 4.4.2.b
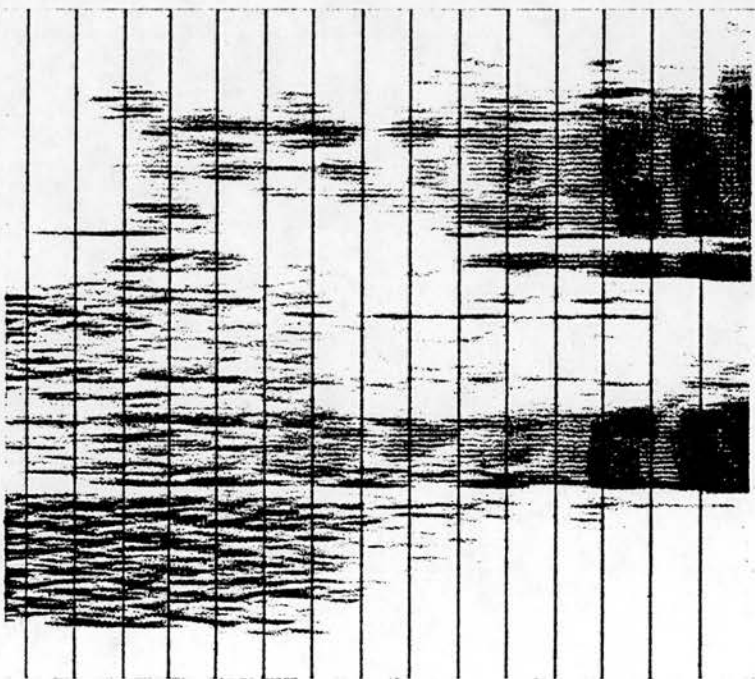
/safra/

Figure 4.4.2.a
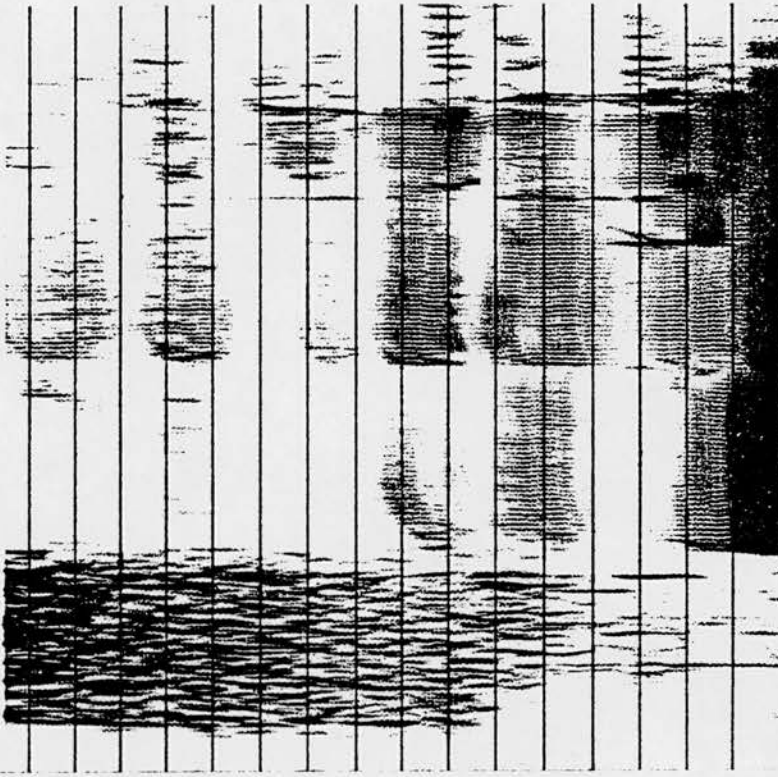
/su:mla/

Figure 4.4.2.d
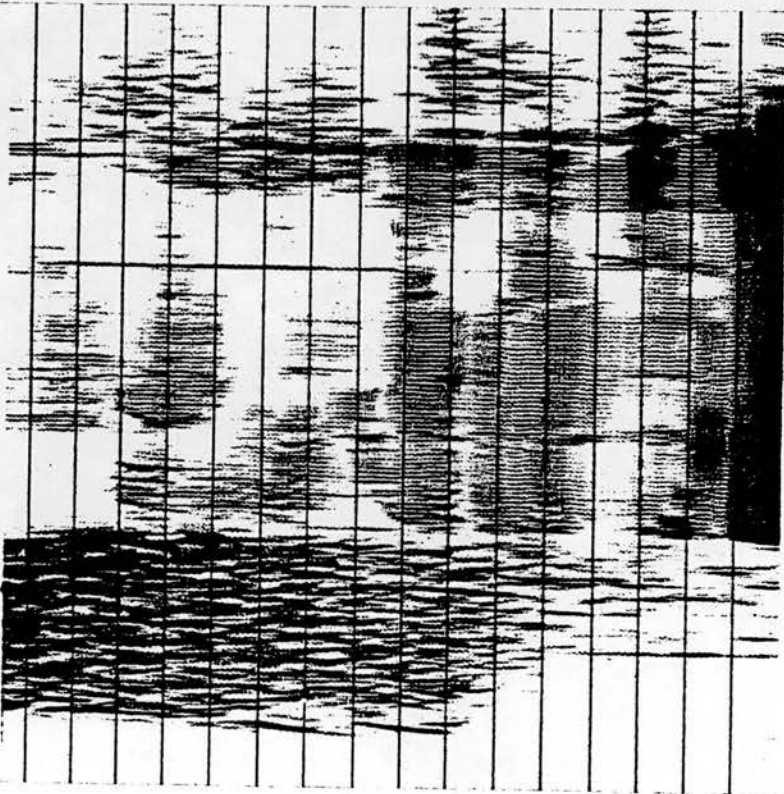
/su:mla/

Figure 4.4.2.c
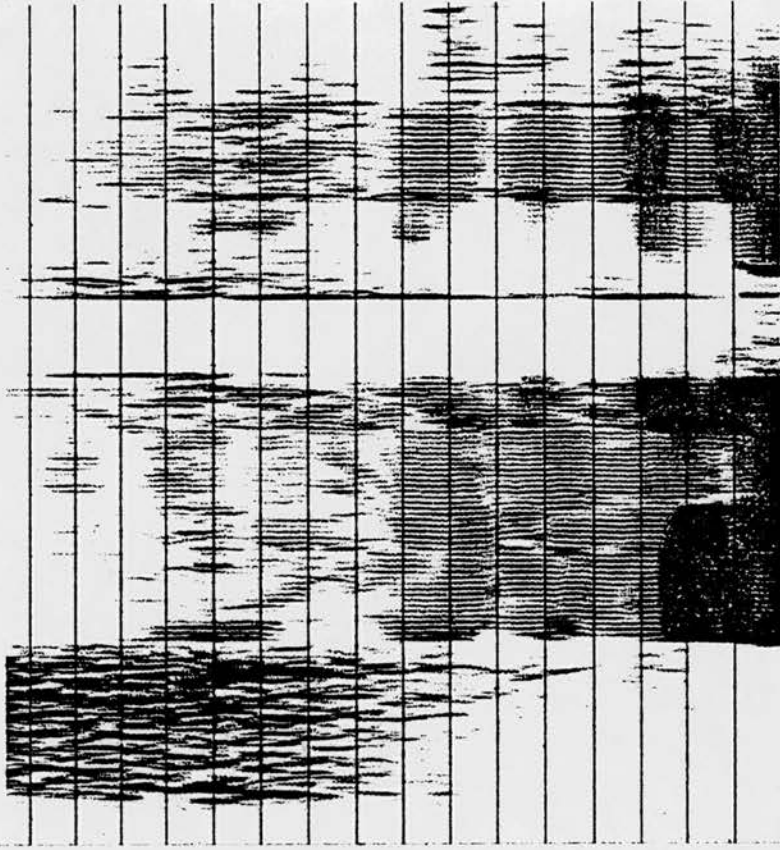
/sa:matla/

Figure 4.4.2.f
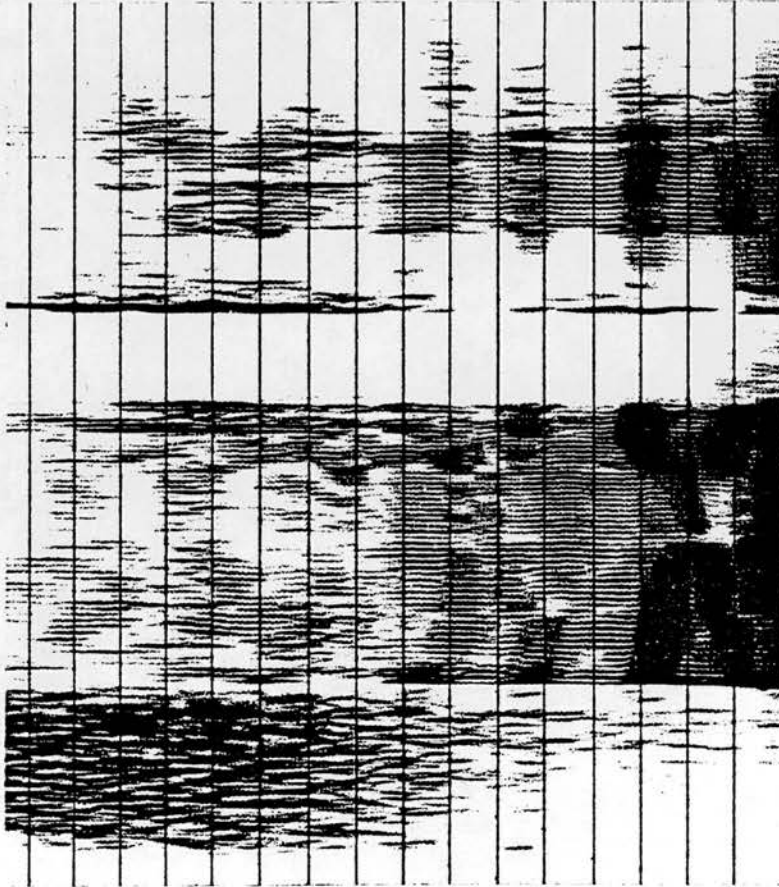
/sa:matla/

Figure 4.4.2.e

/ʈiba:ʃiːr/
Figure 4.4.2.h
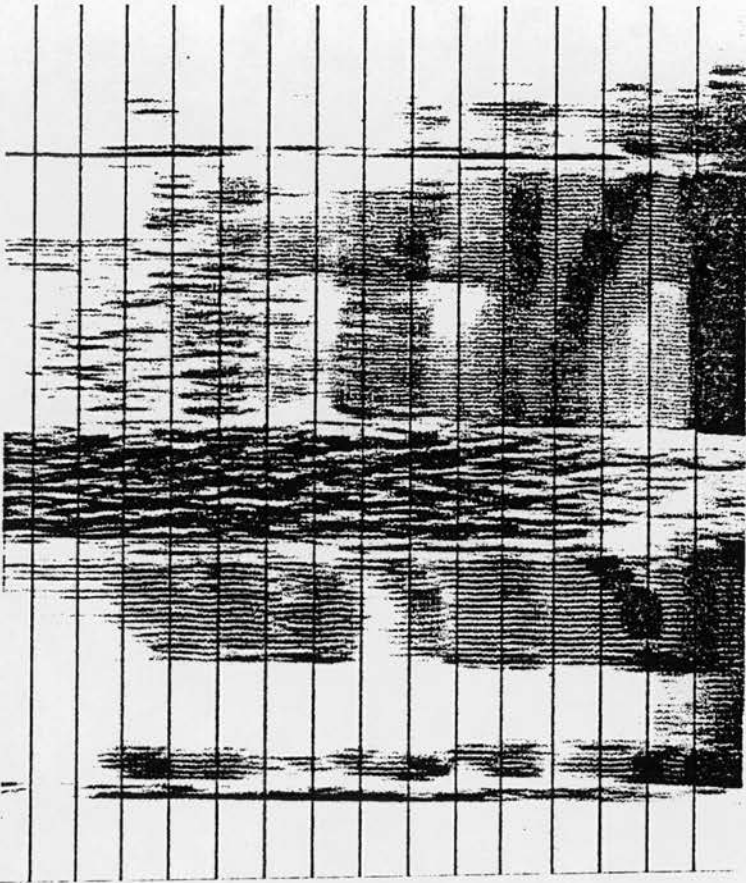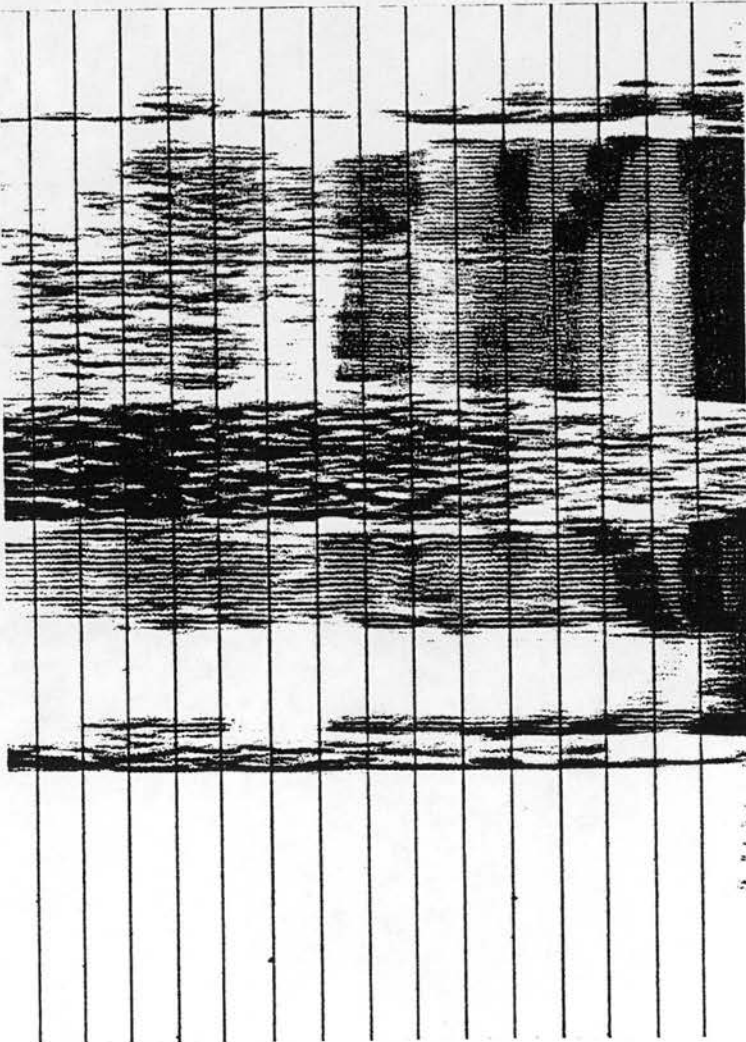
/tiba:ʃiːr/.
Figure 4.4.2.g

to 1150 Hz. In /sa:matla/, emphasis spreads from the initial /s/ to engulf the entire word (6 segments), but the degree of its effect gets weaker and weaker as we progress away from the emphatic /s/. F2 of /a:/ drops from 1250 Hz to 1000 Hz, F2 of the first /a/ drops from 1500 Hz to 1250 Hz, F2 of /l/ drops from 1450 to 1300 Hz and F2 of the final /a/ is slightly lowered from 1500 Hz to 1400 Hz. The F2 value of /l/ and /a/ usually drops to 1000 Hz when adjacent to an emphatic consonant; but, in this example, being a few segments away from the phonologically emphatic segment the degree of their pharyngealization is not as extensive. In /tiba:ʃi:r/ and /ṭiba:ʃi:r/, it is evident that /i/ is pharyngealized in the emphatic context as its F2 value drops from 1700 Hz to 1000 Hz. /a:/ exhibits a slightly lower F2 onset at 800 Hz and then rises to 1500 Hz before /ʃ/. /i:/ has a high F2 onset and a short steady state at 1900 Hz before it falls in a long transition to 1150 Hz before /r/. /r/ also exhibits a slight lowering of its F2 value in the emphatic environment, indicating that it is affected by pharyngealization even though it is 6 segments away from /ṭ/. Also /i:/ ends in a slightly lower value before /r/in the emphatic context than before /r/ in the non-emphatic context. Here the palato-alveolar sound /ʃ/ did not block the spread of emphasis although it did not acquire it, as it has kept the onset and offset of F2 value of the adjacent vowels /a:/ and /i:/ high.

The acoustic effect of pharyngealization is bidirectional. Being in a word medial position, an emphatic consonant affects both the preceding and the following segments as exhibited in the following examples: In /nisi:b/ and /niɐi:b/ (Figures 4.4.2.i-j), the effect of /s/ spreads to the left to affect /n/ which shows a lowering in its F2 value, from 1350 Hz to 1000 Hz, and affects /i/ which is lowered from 1750 Hz to 1100 Hz. It also spreads to the right to affect the following /i:/ as its onset is lowered from 2000 Hz to 1250 Hz, and its steady state is also slightly lowered. The pair /bi:ði:ʕ/ and /bi:ˀɤi:ʕ/ (Figures 4.4.2.k-l) clearly displays the effect of /ˀɤ/ on the adjacent vowels. It causes a long falling transition for the preceding vowel, from 2250 Hz to 1250 Hz, and a long rising transition for the following vowel, from 1500 Hz to 2000 Hz. Its effect on the preceding vowel is more dramatic than on the following vowel. This may be due to the fact that the preceding vowel is unstressed or could be signalling that anticipatory coarticulation is stronger than carryover coarticulation. The effect of /ɬ/ in /Xaɬe:ta/ and /Xaɬe:na:/ (Figures 4.4.2.n, 4.2.h), cover both the preceding and the following segments. In both words F2 of /X/ is lowered from 1500 Hz to 1250 Hz. F2 of the preceding /a/ is lowered to approximate F1. /e:/ has a low onset of 1250 Hz before it rises to its steady state value of 1750 Hz. The final /a/ has a low F2 value in the first
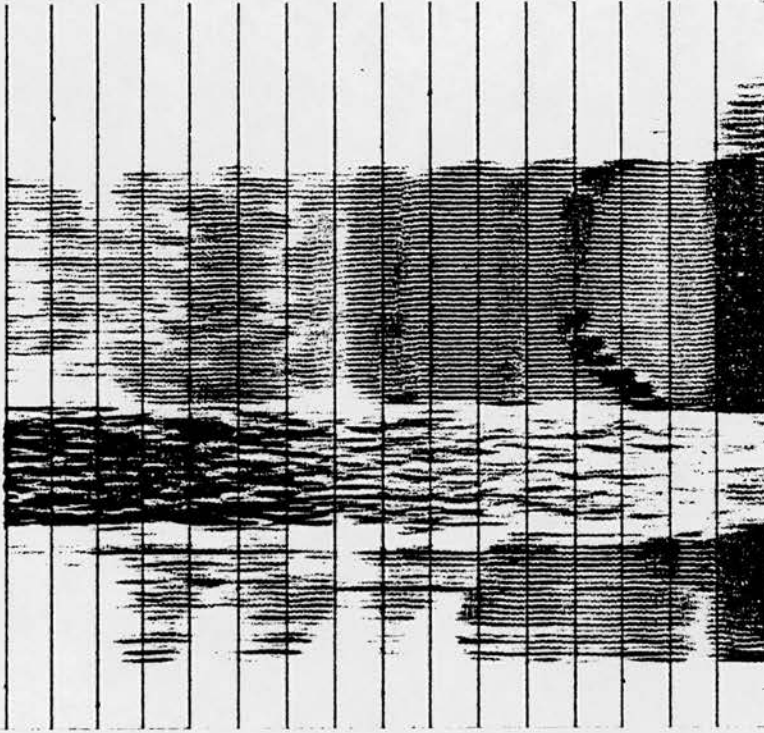
/nisi:b/

Figure 4.4.2.j
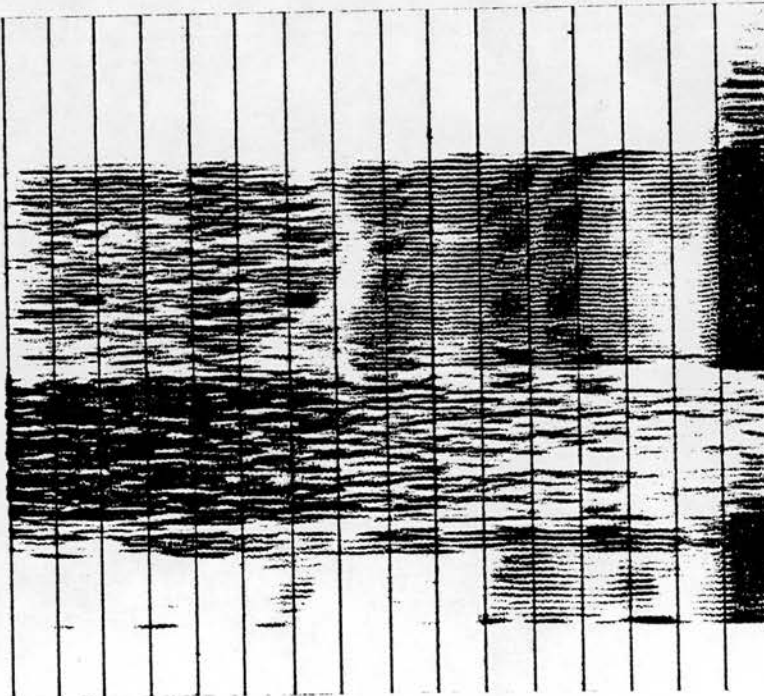
/nisi:b/

Figure 4.4.2.i

/bi:ʔi:ʕ/

Figure 4.4.2.1

/bi:ʁi:ʕ/
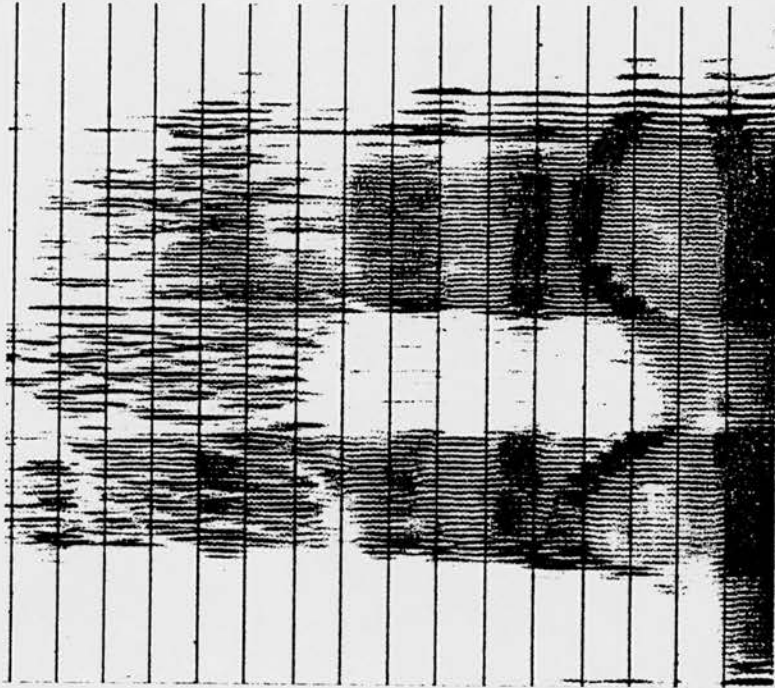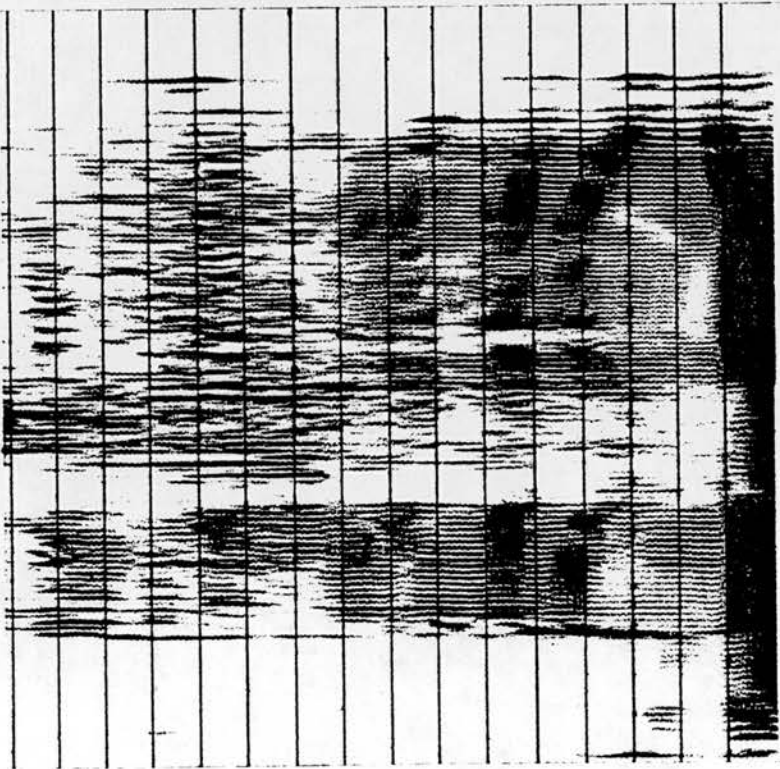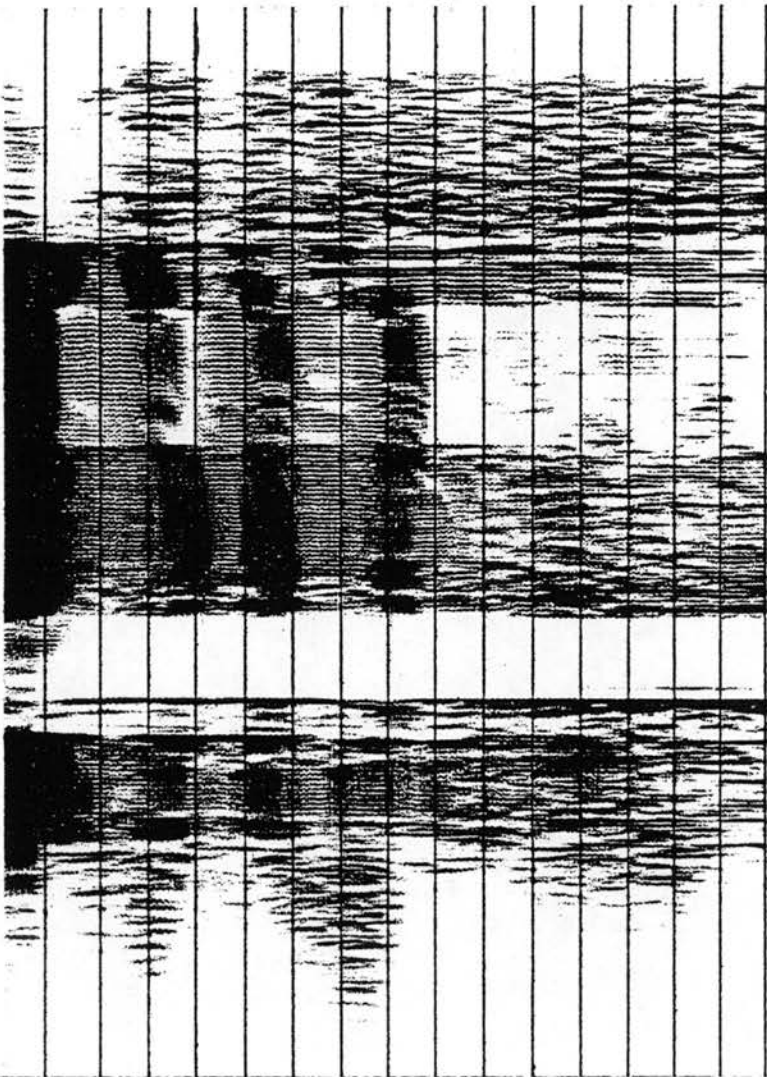
Figure 4.4.2.k

/Xalle:ta/
Figure 4.4.2.m
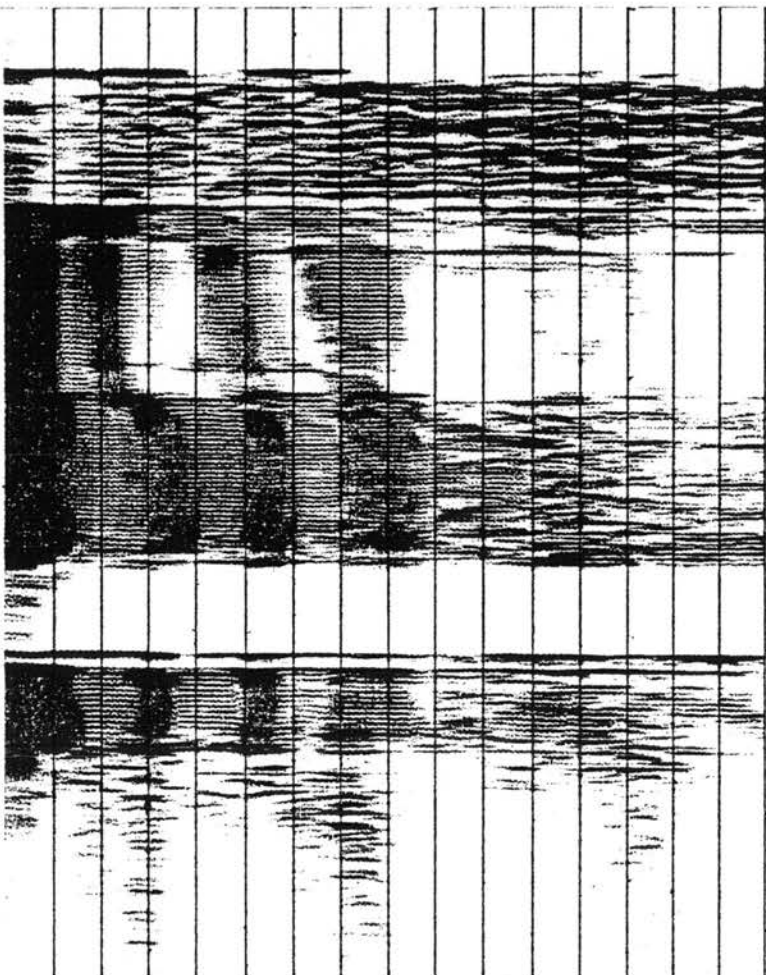
/Xaɬe:ta/
Figure 4.4.2.n

word and high F1 in the second word.

4.4.3   The Effect of Word Boundary

The result of our acoustic investigation of emphatic coarticulation demonstrates that the effect of emphasis does spread to cross a word boundary. This contradicts the results of most previous investigators of emphasis of Arabic who claimed that emphasis does not cross a syllable boundary (Harrell 1957, Lehn 1963, and Ali and Daniloff 1972) or a word boundary (Ghazeli 1977, Card 1983). Ghazeli confirms that "while a backing gesture can extend over an entire word (400 to 600 msec), it will not extend over 15 msec across a word boundary" (p.183). Our spectrographic data reveals that the effect of emphasis can travel backward or forward across word boundaries. If a word ends in an emphatic consonant, the initial segment of the following word is affected; and similarly, if a word begins with an emphatic consonant the last segment of the preceding word is affected. This is illustrated by the following minimal phrases. The two-word phrase /be:t ta:jir/ (Figures 4.4.3.a-b) shows that /e:/ of the first word is pharyngealized as it ends in a much lower F2 value of 1500 Hz as opposed to 1800 Hz in the non-emphatic phrase. This indicates that the final /t/ of the first word has been assimilated to the
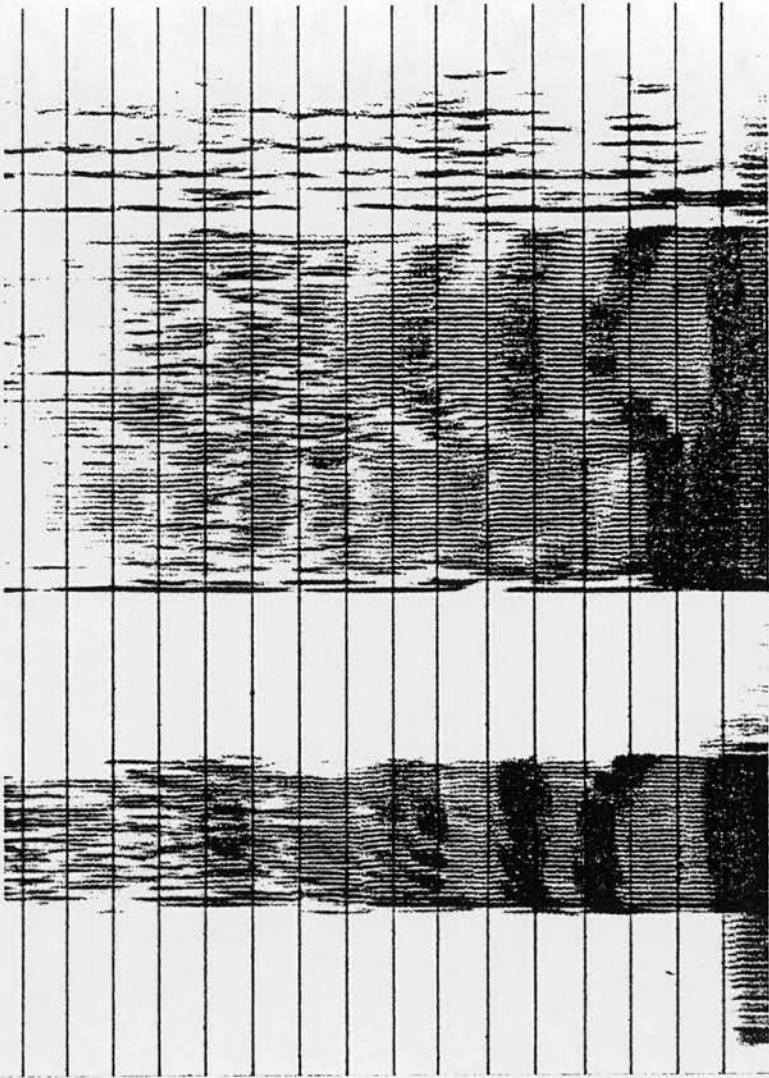
/be:t ta:jir/
Figure 4.4.3.a

/be:t ʧa:jir/
Figure 4.4.3.b

initial /æ/ of the second word, thus spreading its effect across the word boundary to /e:/. The effect of /æ/ also spreads to the right to cover all the segments as they all exhibit a lower F2 value. The phrase /bas iʃi:r/ (Figures 4.4.3.c-d) illustrates also that pharyngealization effect can cross word boundary from right to the left inspite of the fact that the front vowel /i/ separates the two words. The effect of /ʃ/ crosses the word boundary to affect the vowel /a/ of the preceding word even though they are 220 msec. apart. The F2 value of /a/ drops from 1500 Hz to 1250 Hz and F2 of /i/ drops from 1850 Hz to 1600 Hz and the following /i:/ has a low F2 onset of 1400 Hz and a low end of 1200 Hz as opposed to 1900 Hz and 1350 Hz respectively in the non-emphatic environment. Thus the coarticulatory anticipatory effects of emphasis extend across word boundaries.

Similarly, the coarticulatory carryover effects of emphasis can extend across word boundaries as it is demonstrated in the phrase /ħaæ ismi/ (Figures 4.4.3.e-f). The word final /æ/ spreads its effect across to the word initial /i/ and causes its F2 to fall from 1700 Hz to 1250 Hz. In /Xaʃ ami:ni/ (Figures 4.4.3.g-h), the coarticulatory effect of the word-final /ʃ/ crosses to the word-initial /a/ and causes its F2 value to drop from 1500 Hz to 1250 Hz. Also comparing /bi:f:d ilma:j/ with /bi:fi:ð ilma:j/ (Figures 4.4.3.i-j), we find that /ð/ which terminates the first word affects /i/ which initiates the second word
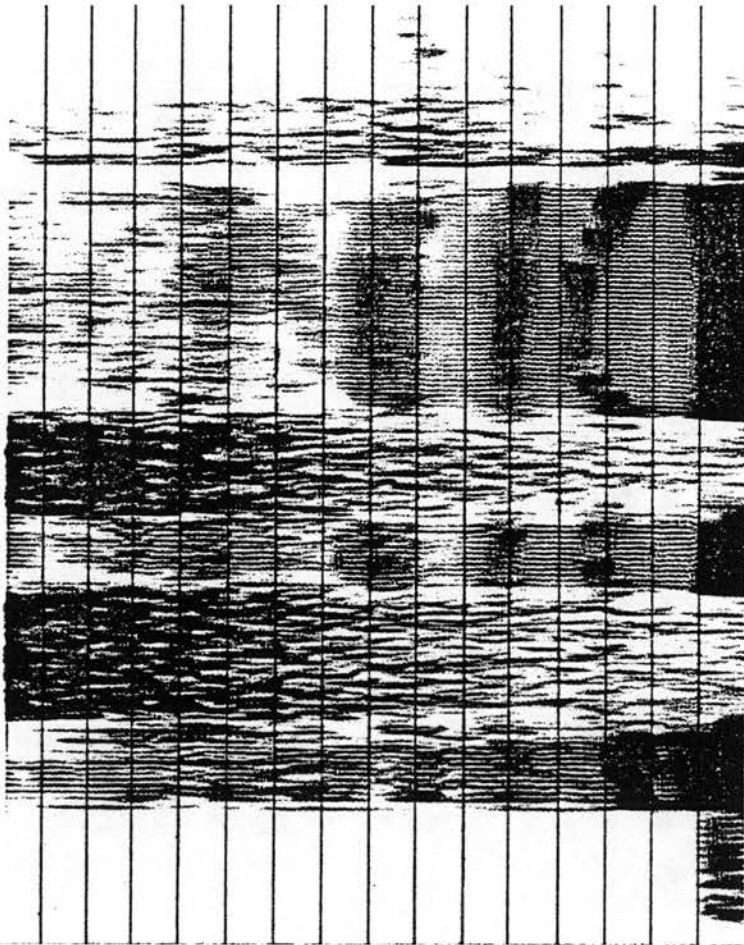
/bas isi:r/

Figure 4.4.3.d
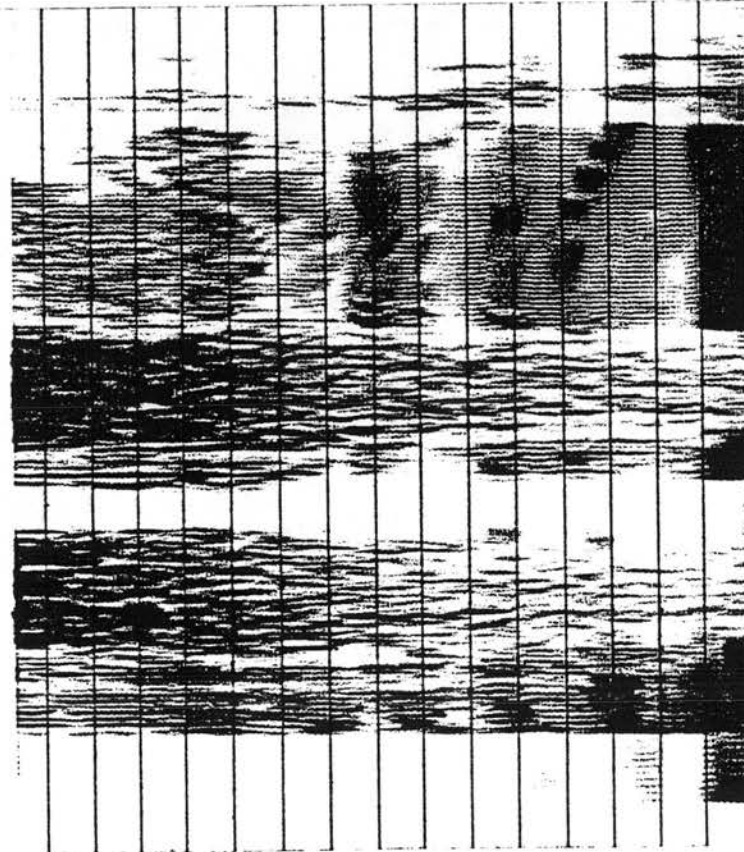
/bas isi:r/

Figure 4.4.3.c

/ʧaɫ ismi/
Figure 4.4.3.f
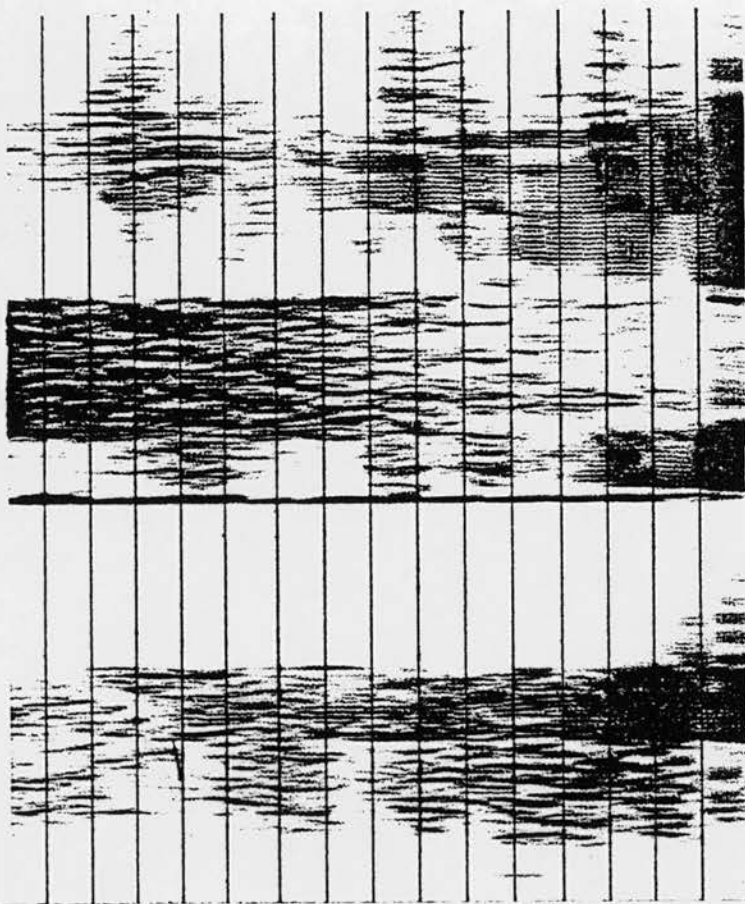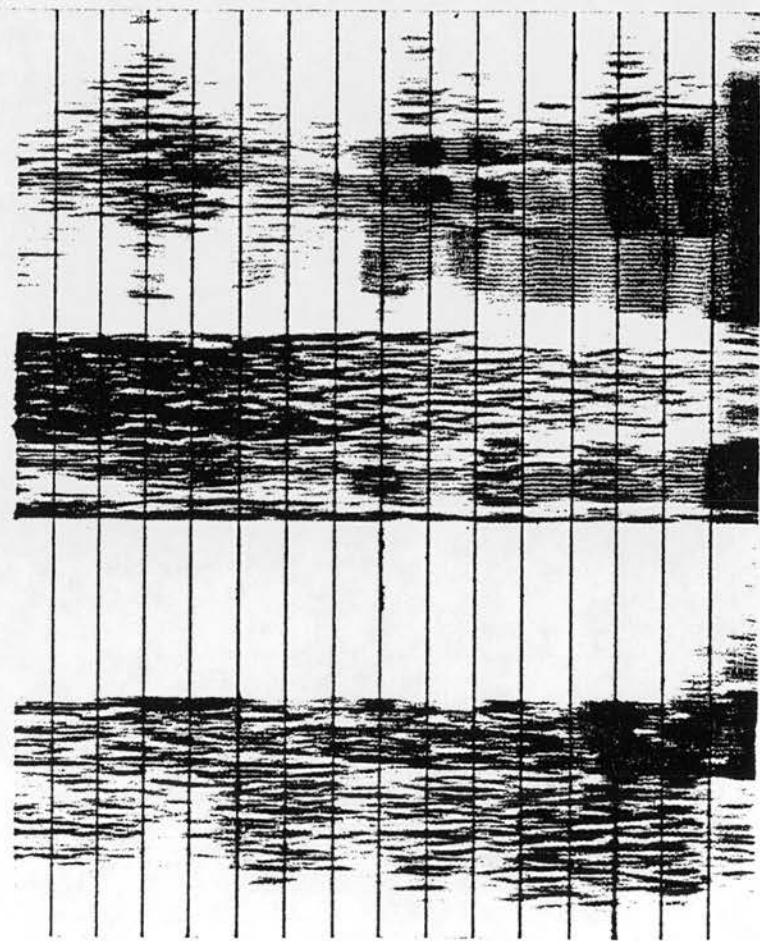
/ʧat ismi/
Figure 4.4.3.e
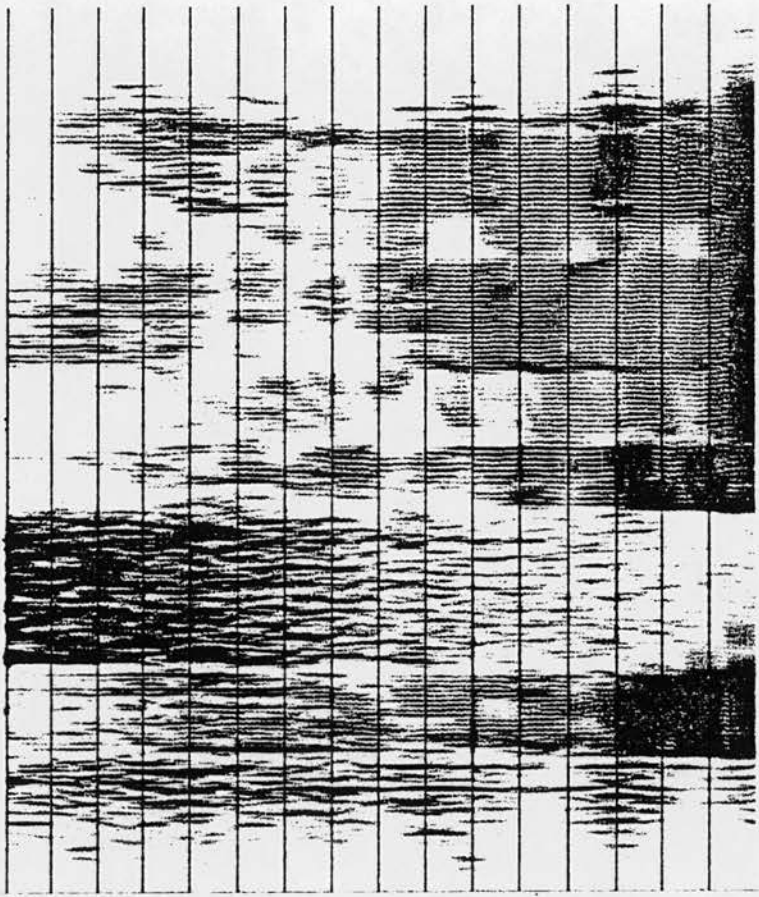
/Xas ami:ni/
Figure 4.4.3.h
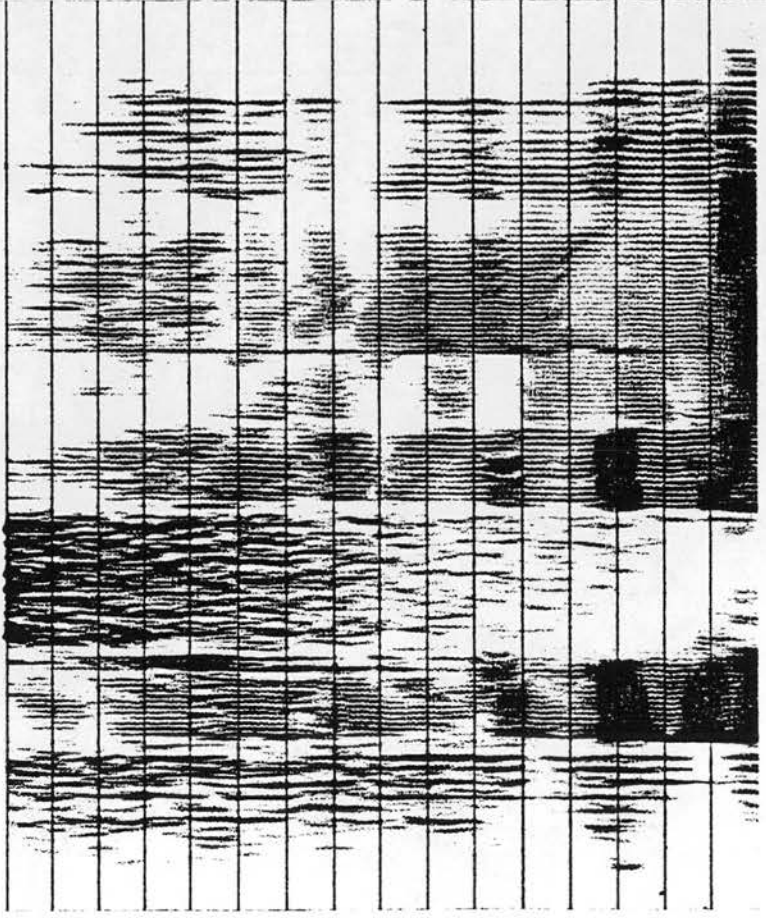
/Xas ami:ni/
Figure 4.4.3.g
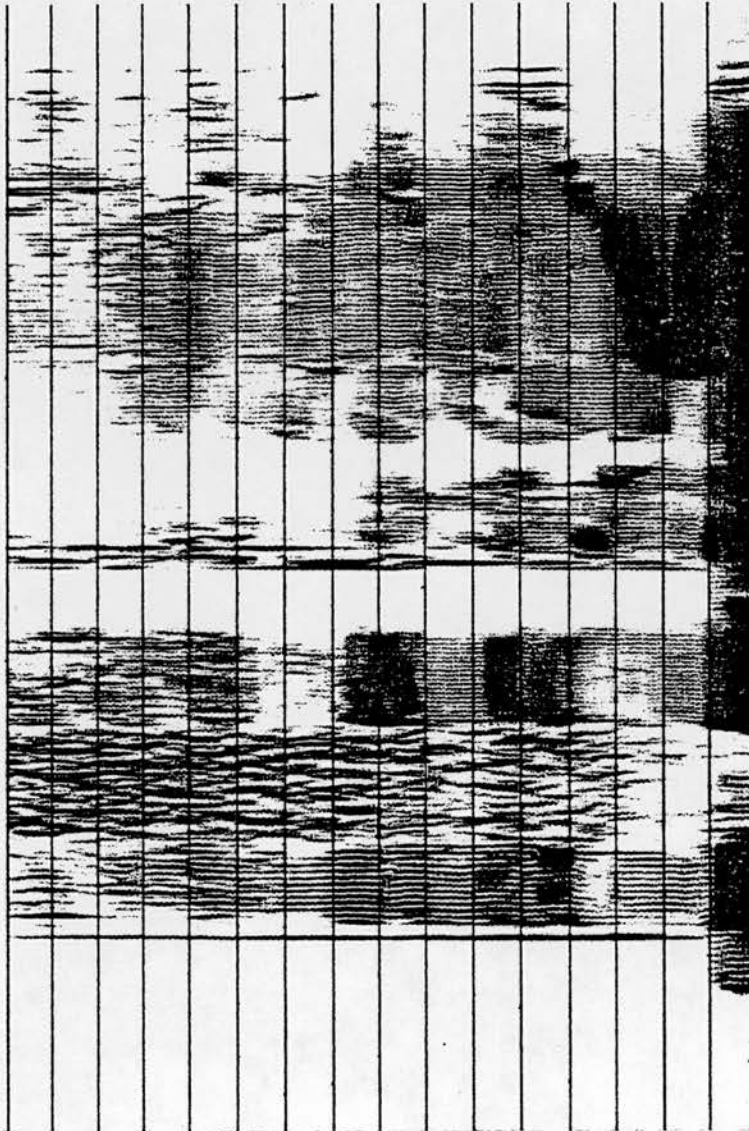
/bi:fi:d ilma:j/

Figure 4.4.3.i
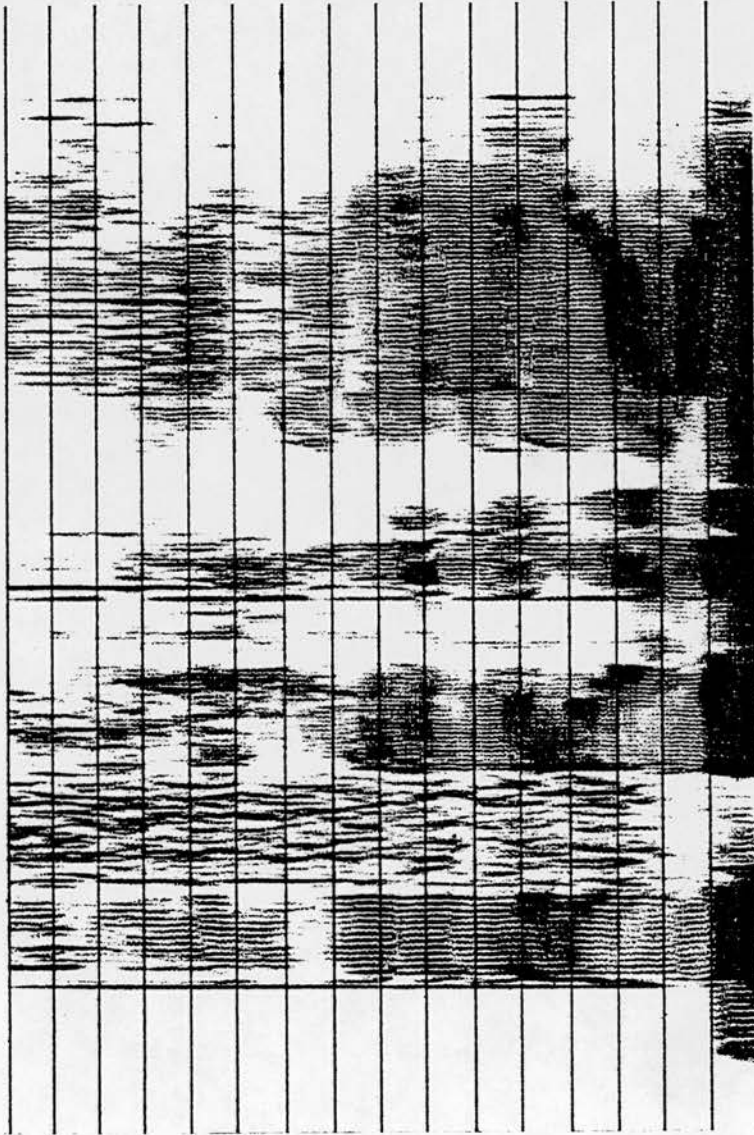
/bi:fi:% ilma:j/

Figure 4.4.3.j

and causes the lowering of its F2 value from 1750 Hz to 1250 Hz.

The fact that the coarticulatory effect of pharyngealization pervades regressively and progressively across word and syllable boundaries leads us to consider emphatic coarticulation to be a low level phenomenon, in terms of speech production control system, from the point of view of the control system, all that the system needs to know is the location of the phonologically emphatic segments. The domain of emphatic pharyngealization is then soley a matter of articulatory control, without any need for access to information about the location of boundaries of higher order units such as words and syllables. In this sense the place of emphasis in the speech production control system is quite different in QA from its role in other dialects of Arabic researched so far. Although the speech production control system is thus rather simple in this regard in QA, the articulatory and timing characteristics of performance are quite complex. As we have said earlier, emphasis requires a rather complicated manoeuvre of the vocal organs to achieve the necessary configuration. They have to attain the secondary stricture which requires tongue lowering and backing, then they have to attain the primary stricture which involves tongue tip and blade. This complex configuration requires a certain

time to be achieved, depending on the nature of the other neighbouring segments, it can not be achieved suddenly, but only gradually. Thus the assimilatory effect of emphasis starts further away from the phonologically emphatic consonant and gets stronger and stronger as we proceed towards it. Once the optimal configuration required for the emphatic consonant is achieved it is not terminated suddenly either. The primary stricture is the first to be dissolved as tongue tip and blade move quickly towards the posture required for the following segment; the secondary stricture lasts for a longer duration as the massive back of the tongue is not as briskly mobile as tongue tip and blade. Thus, the following segments get coloured by pharyngealization which fades away gradually as we move away from the phonologically emphatic consonant. Thus, the phonologically emphatic consonant represents the maximum phonetic realization of emphasis which spreads increasingly towards or diminishingly away from the emphatic consonant regardless of syllable or word boundaries.

CHAPTER   FIVE

THE PHARYNGEAL CONSONANTS

All dialects of Arabic contain two pharyngeal phonemes, one is the voiced /ʕ/ and the other is the voiceless /ħ/ and, traditionally, both of them are described as fricatives.

In spite of the difficulties in examining the nature of these two pharyngeal consonants, in terms of their place and manner of articulation, as they are both produced in an inobservable and unaccessible area of the vocal tract, that is the pharynx, attempts have been made to describe these two pharyngeals since the Middle Ages. Ibn Si:na: (980-1037 AD) writes in his ´Risa:lah´ on the points of articulations of Arabic speech sounds describing the process involved in producing the pharyngeal /6/ (/ʕ/) and /ħ/ (/ħ/): "In the production of /6/, the obstruction (of the air stream) is again incomplete, but now (the expulsion of the air) is forceful, being driven through the deepest place in the throat, at the opening of the larynx, (where) it is most yielding and most liable to stretch. The expulsion of the air is straight forward so that it agitates and shakes that yielding part equally in all directions; yet without there being any forcing apart or branching. Thus numerous acute sounds which blend togather with the tone and roughen it with the kind of roughness there is in the

(sounds) /kh/ and /gh/, may be produced through the interstices of its parts. In (the production of /6/) the arytenoid cartilage is wide open (while) the nameless cartilage is (only) half way so. Although /ḥ/ shares with /6/ (the place and fashion of articulation), it differs from it in the form of the point of articulation, in the (amount of) obstruction, in the strength (of the air stream), and in the place where the air is released. The opening between the two lower cartilages is narrower (than it is in the production of /6/) and the air is expelled with a greater forward inclination. (The air) strikes the same border of the concave place which the air of /6/ hits while being expelled, and it also strikes that solid edge. The upward pressure (of the air) is also stronger. (This) forces the yielding membrane, making it advance forwards, and causes there in a forcing apart and an out-branching contrary to what (happens while) /6/ (is being produced), and this is the reason why there is heard there a certain roughness produced by weak acute sound, which mingles (or blends) with the tone. /6/ is deeper in the throat, in the place where the air involved in vomiting is located, while /ḥ/ is at the place where the air for clearing the throat is located." (Semaan 1963, pp. 35-37).

With the introduction of x-ray and spectrography techniques in the field of phonetics, interest in the physiological and acoustic properties of the pharyngeal

consonants in different dialects of Arabic began in the late Nineteen Sixties onward. Klatt and Stevens (1969) studied the acoustic properties of the pharyngeal and uvular consonants in the dialect of Lebanese Arabic and came to the conclusion that "there is a class of consonants, with a constriction well back in the vocal tract, having the distinctive property that F1 is high and is relatively close to F2. This property distinguishes the pharyngeal consonants from consonants with a more anterior constriction position, all of which are characterized by a low-frequency first formant ... there are two subclasses within the class of pharyngeal consonants: a more posterior one with a low F3, which is the lowest formant that is excited by noise in the case of a fricative, and a more anterior one with a high F3, which is characterized by excitation of F2 when there is friction noise at the constriction. The more posterior of these two constriction positions is usually called a pharyngeal consonant, and the more anterior one is a uvular consonant." (p.210). They also found that the difference between the glottal consonants /h/ and /ʔ/ and the pharyneal /ħ/ and / ʕ / is that the glottal consonants exhibit "no formant transitions at the vowel onsets" (p.211).

Delattre (1971) defines a pharyngeal sound as that "in which the root of the tongue assumes the shape of a bulge and is drawn back towards the vertical back wall

of the pharynx to form a stricture. This radical bulge generally divides the vocal tract into 2 cavities, one below extending from the stricture to the glottis, the other above extending from the stricture to the lips" (p.129). In his study, Delattre examines the pharyngeal features in the consonants of five languages: Arabic, German, French, Spanish and American English through x-rays and spectrograms. In Arabic he investigated the pharyngeals in the speech of a Lebanese. His x-ray film showed that /ʕ/ is "produced with a very low stricture between the tongue root and the pharyngeal wall" (p.133), and that the stricture for /ħ/ is "very low (even lower than for /ʕ/, and its pharyngeal cavity is very small (even smaller than for /ʕ/). The pharyngeal stricture is also narrower for /ħ/ than for /ʕ/, which is to be expected since in the absence of voicing, the friction noise must be loud enough to carry the load of perception alone. The back of the tongue is cambered, as if the radical bulge toward the lower pharynx forced a compensating hollow above it" (p.134). Acoustically, his results confirm those of Klatt and Stevens in that both /ħ/ and /ʕ/ exhibit a high first formant which approximates the relatively low second formant.

Hetzron (1969) cites Delattre as describing the pharyngeal consonants of an Iraqi speaker as articulatory having "three motions in common: (a) the root of the tongue backed very sharply toward the lower part of the

pharyngeal wall; (b) the larynx rose considerably ...; (c) the uvula ... lowered far down along the root of the tongue and curled up its tip as if to vibrate" (p.72).

In his acoustic and motion-picture x-ray investigation of the pharyngeal sounds in Standard Arabic as said by an Iraqi speaker, Al-Ani (1970) describes /ħ/ as a "voiceless pharyngeal constricted fricative" and that in producing it the constriction is "formed by the dorsum of tongue against the posterior wall of the pharynx" (p.60). He also found that the "most common allophone of /ʕ/ is actually a voiceless stop and not a voiced fricative" (p.62).

Ghazeli (1977) carried out a cinefluorographic, acoustic and airflow examination of the pharyngeal consonants in Tunisian Arabic. Physiologically, he found that they exhibited "an elevation of structures at the base of the pharyngeal cavity and a compression at the anterior-posterior dimension of the pharyngeal cavity below the epiglottis. The larynx is generally raised approximately 9 mm from rest position, and 7 mm from the posture it generally assumes during speech ... Movements of the hyoid bone during the production of pharyngeals are most unpredictable and do not seem to follow any particular pattern. Although an anterior displacement of the hyoid bone of about 2 mm is observable in most instances, horizontal movements can vary from 0 to 4 mm ... the soft palate streches as if its

lower tip is being pulled downward ... the upper posterior tip of the velum slides down the pharyngeal wall but remains in contact with it" (pp.36-39). His airflow measurements showed "no nasal leak during the production of pharyngeals." (p.41). Acoustically, Ghazeli found that /ʕ/ exhibits formant frequencies similar to those of vowels with the vertical spikes being "further apart in [ʕ] than in vowel formants" (p.43). Next to /a/, /ʕ/ was found to have the following average formant frequencies: F1 900, F2 1450, F3 2300; next to /i/ F1 700, F2 1700, F3 2700; and next to /u/ F1 650, F2 1300, F3 1700. As for /ħ/, it was found to be characterized by "strong non-periodic noise but with visible formant structure" (p.45). It has the following formant frequencies next to /a/ F1 1100, F2 1700, F3 2300; next to /i/ F1 700, F2 1800, F3 2700; and next to /u/ F1 550, F2 1100, F3 1700.

Catford (1977) distinguishes two types of pharyngeal articulation : a faucal type in which "the part of the pharynx immediately behind the mouth is laterally compressed, so that the faucal pillars move towards each other. At the same time the larynx may be somewhat raised" and a pharyngeal type in which "the root of the tongue, carrying with it the epiglottis, moves backwards to narrow the pharynx in a front-back dimension" (p.163). The first type seems to be characteristic of the pharyngeal sounds in Caucasian languages while the second type seems to be characteristic of the pharyngeal sounds

in Arabic.

In their fibreoptic endoscopic investigation of the pharyngeal consonants in Hebrew, Laufer and Condax (1981) found that during the production of /ħ/ and /ʕ/ "the only structure we see moving to any large extent is the epiglottis, although we can also see smaller movements of the lateral pharyngeal wall that bring it against the lateral edge of the epiglottis. The back of the tongue is seldom seen, and when it is visible in the field of view, it is nevertheless much farther from the pharyngeal wall than is the epiglottis. Thus ´pharyngeal´ articulations are clearly made by the epiglottis; in all cases, we see it moving towards the posterior pharyngeal wall" (p.47). Thus they come to the conclusion that the epiglottis is the primary active articulator in the production of the pharyngeal consonants. /ħ/ is described by them as "fully voiceless and well fricated" (p.47), and that its stricture is "made by the epiglottis against the pharynx, and it no way involves the tongue" (p.49). /ʕ/ they say is phonemically a voiced fricative which "has a number of phonetic realizations ranging from stop to semi-vocalic glide" and that "it has a number of different articulations varying between narrow opening to complete closure. What all the articulations have in common is the fact that they are made between the epiglottis and the posterior pharyngeal wall and may involve contact between the epiglottis and the arytenoids" (p.51).

Adamson (1981) examined the acoustic characteristics of the pharyngeal consonants in Sudanese Arabic. Her results showed that / ʕ / has the following average formant frequencies when preceding /a/ F1 580, F2 1440; when preceding /i/ F1 500, F2 1600; and when preceding /u/ F1 475, F2 1150. While /ħ/ showed the following average formant frequencies when preceding /a/ F1 650, F2 1450; when preceding /i/ F1 433, F2 1800; and when preceding /u/ F1 460, F2 1050. She found great differences between the subjects in the realization of /ʕ/, while there was much less variation between them in the realization of /ħ/. She comes to the conclusion that "/ħ/ is an epi⁹lotto-pharyngeal fricative and /ʕ/ an epiglotto-pharyngeal stop, with approximant and a creaky voice allophones, being the results of uncompleted gestures towards a stop" (p.95).

Laradi (1983) conducted an extensive investigation of the pharyngeal consonants in . Libyan Arabic using videofluorography, xeroradiography, endoscopy and aerometery techniques. She found that both /ħ/ and /ʕ/ exhibit a "very considerable constriction of the pharyngeal cavity at the level of the epiglottis, an anteroposterior one made by the retraction of the epiglottis towards the back wall of the pharynx-(possibly coupled with a forward movement of the back wall of the pharynx itself). Also, a lateral constriction made by the side walls of the pharynx, which enclose

against the epiglottis" (p.294). Her airflow investigation revealed that "there is a nasal airflow for /ħ/ and /ʕ/, whether there is a nasal sound in the utterance or not with more nasal airflow for /ħ/ than for /ʕ/" (p.129). This was only true for the male subject, as the data of the female subject showed no such nasal airflow unless in the neighbourhood of a phonologically nasal consonant.

5.1

The Physiological characteristics of the Pharyngeal Consonants in QA

A xeroradiographic experiment was carried out in the Middlesex Hospital, London, to investigate the place of articulation of the pharyngeal sounds /ħ/ and /ʕ/ in QA and the role of the lips, tongue, velum, epiglottis, hyoid bone, larynx and the pharyngeal walls in their realization.

Xeroradiography is "a relatively new x-ray imaging technique in which the conventional film is replaced by a charged selenium-coated plate. After exposure, the visible image is produced by electrostatic powder-cloud development. The electrostatic development process leads to edge-enhancement of the image ... which improves visualization of detail in low contrast areas ... and increases exposure latitude, i.e. enables bone and soft

tissue detail to be observed simultaneously. These features, combined with low radiation dose ... suitable for use with volunteer informants ... make it attractive for viewing the vocal tract, where soft tissue, airway and bone all make important contributions" (MacCurtain 1981, p.25).

Two subjects took part in this experimant, one female (FB) and the other male (HJ), who were seated comfortably on a chair. Nine lateral xeroradiograms were taken for each of the two subjects. The first exposure was taken with the articulators being in their ´at rest´ position. The second and the third were taken while the subject was producing /ħ/ in the words /ħiːli/ and /ħuːt/; the forth, fifth, sixth and seventh exposures were taken while the subject was articulating /ʕ/ in /ʕiːd/, /ʕuːd/, /naʕam/ and /naʕʕam/ respectively; the eighth was taken while the subject was producing /s/ in /saːd/; and the ninth while producing /ṣ/ in /ṣaːd/. Here we will be only concerned with /ħ/ and /ʕ/ as we have already examined /s/ and /ṣ/ in chapter three.

The exposure time was very brief, less than o.2 seconds per image. The radiation dose was 3m Gy (300 m Rad) per exposure. This value is one tenth of the permissible dose to the neck as required by the Middlesex Hospital Ethnical Comittee (MacCurtain 1981).

The xeroradiograms were taken while the speaker were trying to maintain an articulatory posture for the

relevant sound in the word. Consequently the data may not provide a valid description of the pharyngeals as they occur in natural speech. However the general consistency of the images both across the two speakers and within each subject tend to confirm the validity of the xeroradiograms.

Measurement

Tracing was made of all the still life size blue and white prints. The ´at rest´ posture was chosen for reference by superimposing each tracing on it and the contrastive gestures were studied in relation to it. Aligment was made by using two fixed reference points: the ´A´ point (which is the thin projection of the alveolar ridge) and the ´Bolton´s Notch´ in the base of skull.

Certain points of reference were chosen and the distances between them were measured in mm and a comparison was made in relation to those in the ´at rest´ position and the other sounds. The following are the anatomical parameters chosen for measurements (see Figure 5.1):

1. Minimum vertical distance between the upper and lower lips.

2. Vertical distance between the tongue and the palate at narrowest point
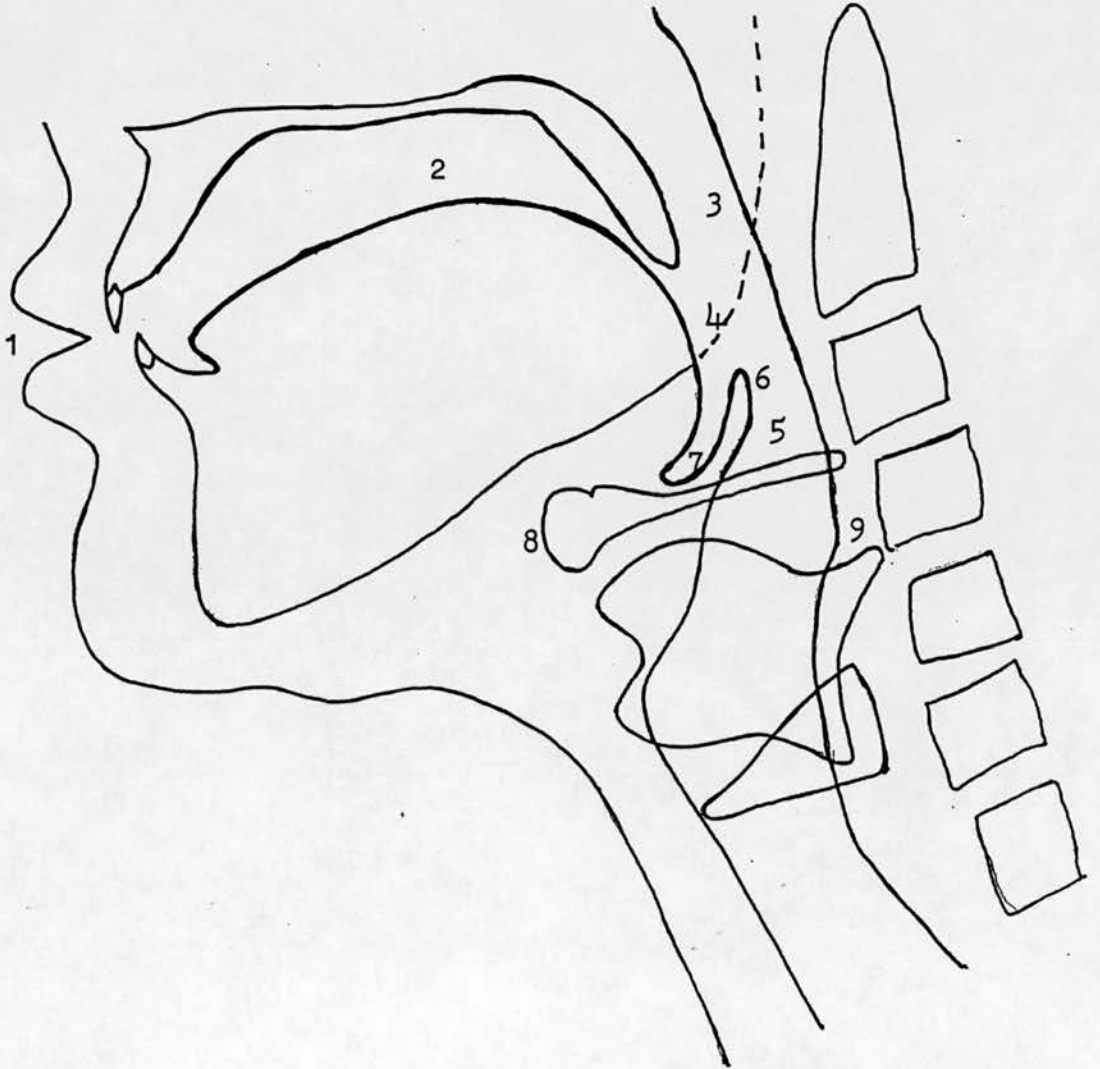
Figure 5.1

Anatomical parameters
chosen for measurements

3.   Minimum horizontal distance between the soft plate and the back wall of the pharynx.

4.   Horizontal distance between the tongue and the posterior pharyngeal wall at narrowest point.

5.   Horizontal distance between the epiglottis and the back wall of the pharynx at narrowest point.

6.   Horizontal distance between the epiglottis tip and the pharyngeal wall.

7.   Maximum anteroposterior dimension of the vallecula.

8.   Horizontal distance between the top of the front of the body of the hyoid bone and the nearest cervical vertebra.

9.   Horizontal distance between C2, C3 and C4 and the pharyngeal wall. (MacCurtain 1981; Laradi 1983).

Tables 5.1.1 and 5.1.2 show the results of the measurements of the pharyngeal sounds parameters for both speakers.

5.1.a

The Physiological Properties of /ħ/

Comparing the ´at rest´ xeroradiogram (Figure 5.1.a.1) with that of /ħ/ in /ħi:li/ (Figure 5.1.a.2), as said by FB, we notice that the constriction for /ħ/ takes place in

Parameters	1	2	3	4	5	6	7	8	9
At Rest	10	4	12	9	2	5	4	34	5 5 13
ħi:li	18	5	0.5	1	1	2	1	37	6 5 9
ħu:t	5	10	0	6	2	6	3	39	5 4.5 6
ʕi:d	17	7	1	4	0.5	3	2	38	6 5 9
ʕu:d	3	12	1	2	1	5	1	38	6 5 7
naʕam	−	8	3	7	1	3	3	34	6 5.5 10
nəʕəm	15	12	1	1	0	0	0.5	35	6 5.5 10

Table 5.1.1

Measurements of the anotomical parameters

Subject FB

Parameters	1	2	3	4	5	6	7	8	9
At Rest	0	13	11	16	8	16	4	46	6 4.5 10
ħi:li	4	6	0	6	3	8	4	55	5 6 11
ħu:t	2	10	0	11	3	8	4	49	5 4 6
ʕi:d	5	11	0.5	11	4	7	5	48	4.5 4 5
ʕu:d	2	13	0	11	3	6	5	48	4 4 5
naʕam	–	11	6	14	5	8	7	48	4.5 4 5
naʔʕam	–	12	5	11	1.5	5	5	49	5 5 10

Table 5.1.2

Measurements of the anatomical parameters

Subject HJ
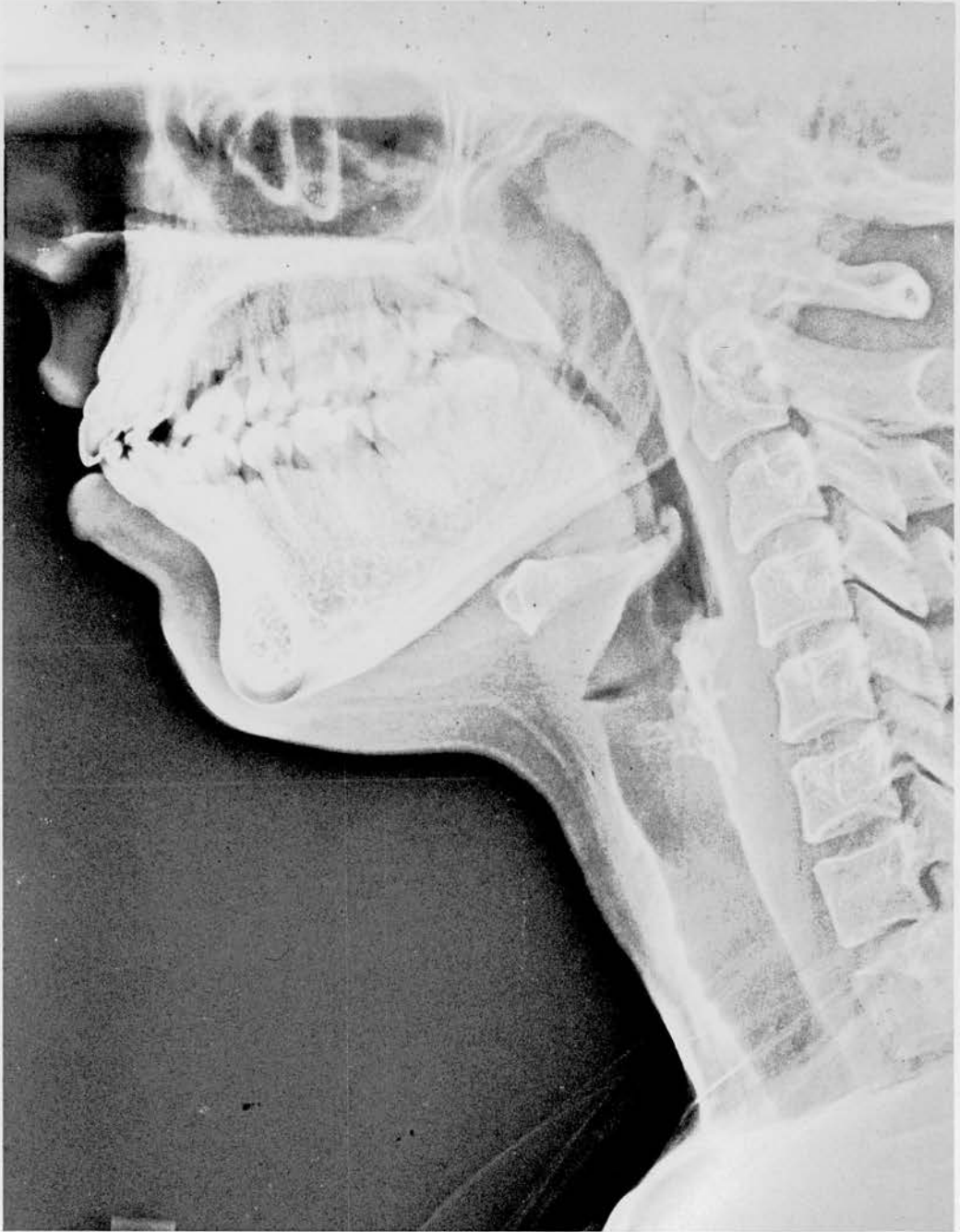
Figure 5.1.a.1: The articulators in the
'at rest' position. Subject FB

Figure 5.1.a.2 / ħ/ in / ħi:li/ ´trick´

as said by FB

the middle of the pharynx between the epiglottis and the posterior wall of the pharynx at the level of the area between C2 and C3 (C= body of cervical vertebra) leaving a very narrow gap of about 1 mm wide. The larynx is raised by about 8 mm from its ´rest´ position. The hyoid bone is displaced upward by about 3 mm and forward by about 5 mm with its horns pointing towards the area between C2 and C3 while they point towards the middle of C3 in the ´at rest´ posture. Tongue root is retracted inferiorly and posteriorly to approximate the pharyngeal wall. The epiglottis is bunched up against the root of the tongue probably as a result of the pressure exerted on it by the downward movement of the tongue and the upward movement of the larynx, thus constricting the epiglottis and the vallecula at the base of the epiglottis. Epiglottis tip is in contact with tongue root. The soft palate bunches up against the posterior pharyngeal wall leaving a very narrow velopharyngeal opening of about 0.5 mm wide, compared to 12 mm wide in ´at rest´ posture; the uvula hangs away from the wall of the pharynx. Tongue dorsum takes the shape required for the following front vowel /i:/ with its tip lying behind the lower front teeth. The lips are spread in anticipation of the following vowel.

Comparing /ħ/ in /ħu:t/ (Figure 5.1.a.3), as said by FB, with that of /ħi:li/ one notices that the area of constriction is much lower (about 5 mm) and not as big

Figure 5.1.a.3 / ħ/ in / ħu:t/ ´whale´
as said by FB

and narrow as that for /ħi:li/. The 2 mm wide constriction takes place between the epiglottis and the pharyngeal wall at the level of C3. The larynx is much lower, almost as low as for the ´at rest´. The hyoid bone is displaced by about 2 mm forward with its horns pointing towards the front top of C3. The ventricle is slightly more open. The epiglottis is not as tightly bunched up with its tip curling forward without touching tongue root. The soft plate assumes a similar posture, but its contact with the pharyngeal wall seems to be a bit firmer at the top. Tongue body is lowered to the floor of the mouth with its back raised towards the pharyngeal wall. The lips are rounded in anticipation of the rounded back vowel /u:/.

Comparing the ´at rest´ xeroradiogram (Figure 5.1.a.4) with that of /ħ/ in /ħi:li/ (Figure 5.1.a.5), as said by the second speaker HJ, we find that they exhibit a similar configuration as those of FB. The area of constriction takes place between the epiglottis and the back wall of the pharynx at the level of C3, leaving a narrow airway passage of about 3 mm wide, compared to 8 mm wide when ´at rest´. The larynx is raised by about 6 mm from ´at rest´. The hyoid body is tilted downward while its horns are tilted upward to the level of C3. The root of the tongue is pushed backwards leaving a 6 mm gap between it and the pharyngeal wall. The shape and size of the epiglottis change dramatically during the
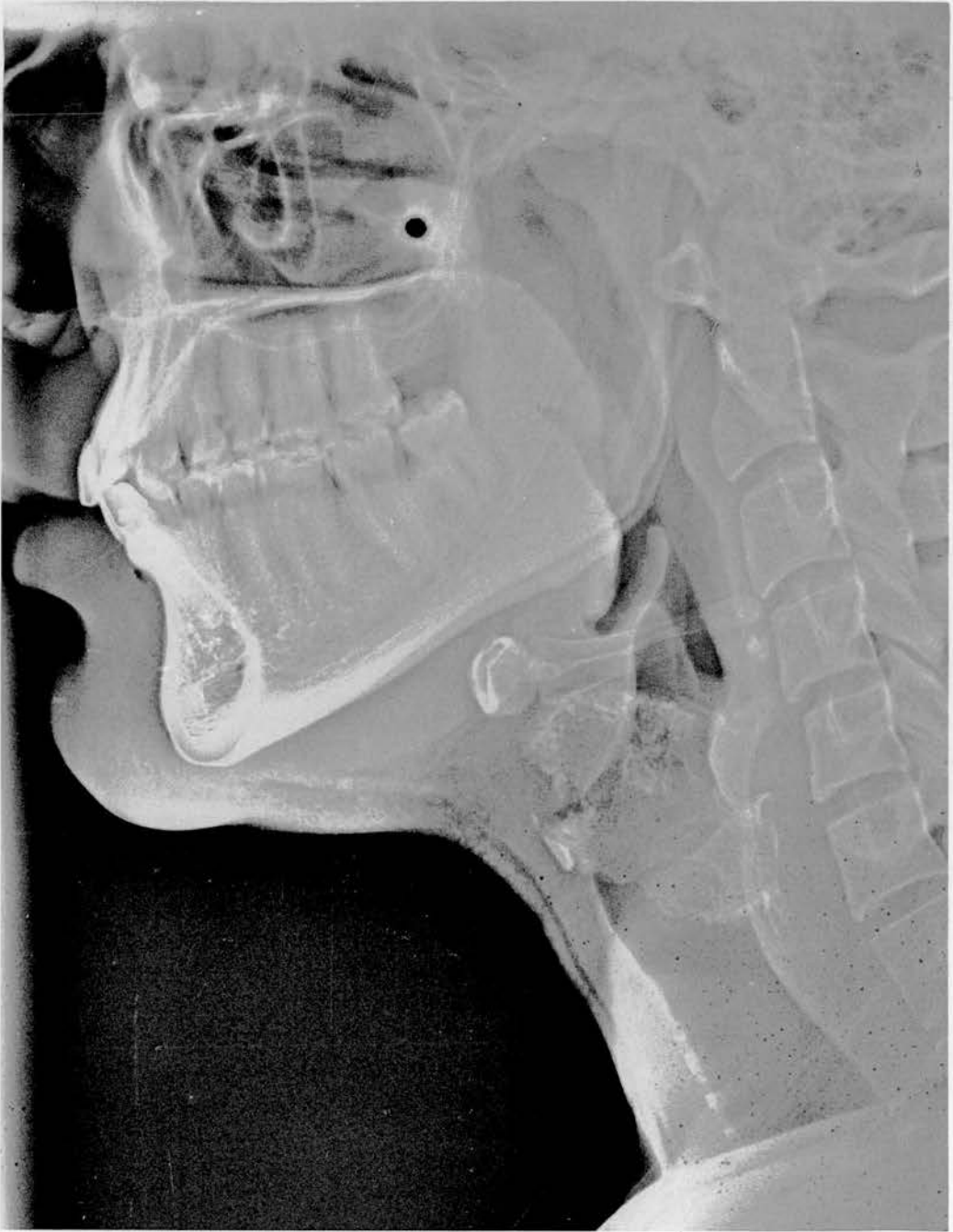
Figure 5.1.a.4: The articulators in the
´at rest´ position. Subject HJ
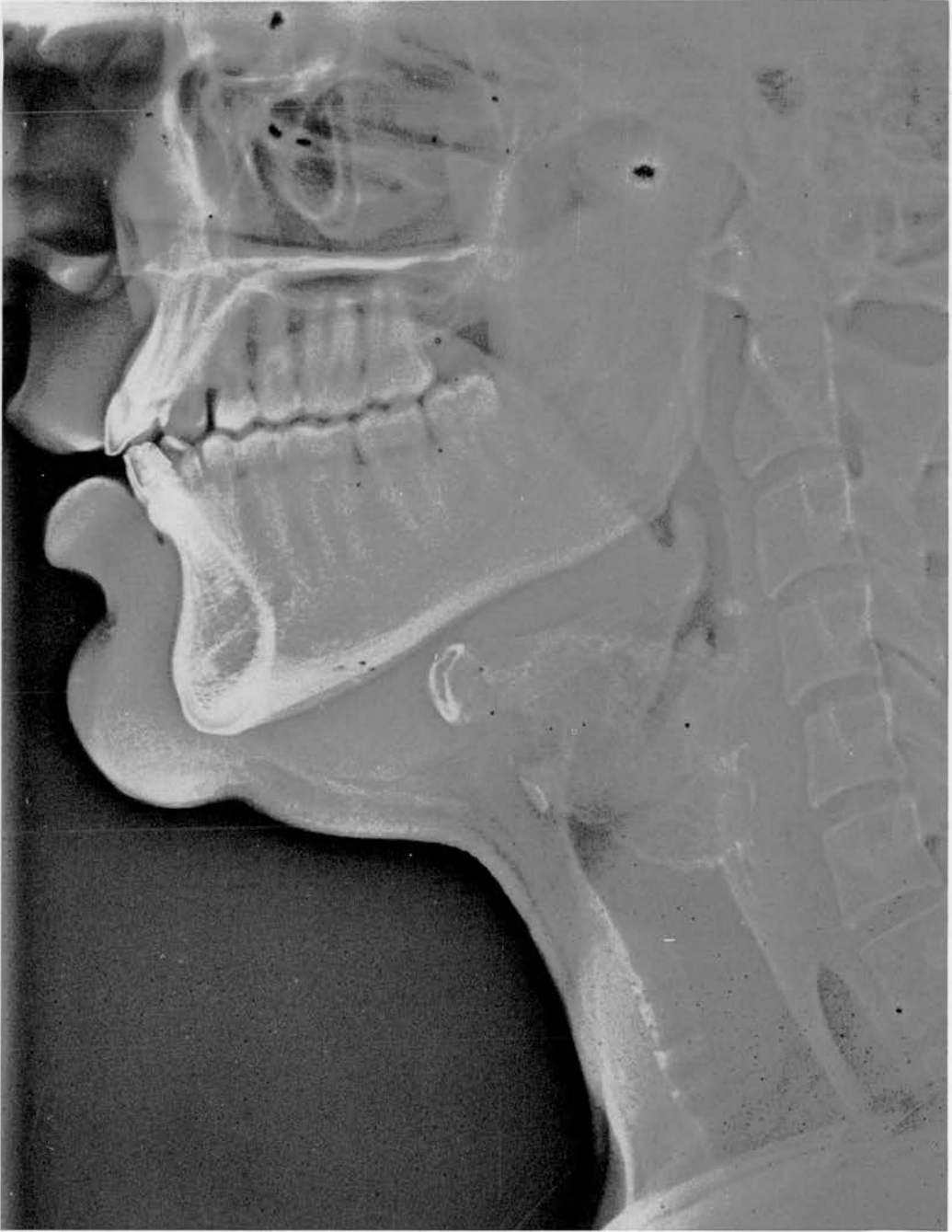
Figure 5.1.a.5 / ħ/ in / ħi:li/ ´trick´
as said by HJ

articulation of /ħ/. In ´at rest´ the epiglottis is about 20 mm long, in an upright shape with its tip uncurled and about 4 mm away form tongue root. While during the articulation of /ħ/ the epiglottis bunches up and gets shortened to about 6 mm long, its tip curls forward without touching the tongue. This dramatic change is due to the pressure exerted on it by tongue root retraction and larynx raising . The soft palate leaves its ´rest´ position, where it lies resting on tongue back and leaving an 11 mm wide naso-pharynx passage, and bunches up against the pharyngeal wall where it gets in contact with it while its tip curves away towards the back of the tongue. Tongue front raises against the middle of the hard palate anticipating the following high front vowel /i:/. The lips are spread.

In /ħu:t/ (Figure 5.1.a.6), as said by HJ, we can see that the larynx is lowered down in the pharynx, even lower than ´at rest´ position by about 4 mm, an about 10 mm lower than in /ħi:li/. The hyoid body and horns are lowered by about 5 mm than ´at rest´ with the horns pointing towards C4. The place of constriction is also lower in the pharynx, at the level between C3 and C4. The epiglottis has more or less the same shape as for /ħi:li/, but it is much thinner, probably stretched by the pulling down action of the larynx. The back and root of tongue are retracted backward, but not as much as in /ħi:li/. The velum curves up against the posterior wall

Figure 5.1.a.6 / ħ/ in / ħu:t/ ´whale´
as said by HJ

of the pharynx. Tongue tip and front are lowered down in the mouth, while tongue back rises and slops backwards with the narrowest point being between tongue back and the far end of the hard palate in preparation for the following back vowel. The lips are rounded.

<u>5.1.b.</u>

<u>The physiological Properties of /ʕ/</u>

Analysis of /ʕ/ in /ʕiːd/ (Figure 5.1.b.1), as said by FB, shows that it has a similar configuration to that of /ħ/, the main area of constriction takes place between the epiglottis and the posterior pharyngeal wall at the level of the area between C2 and C3. The larynx is not as highly raised as that for /ħiːli/, but it is about 4 mm higher than ´at rest´ position and about 4mm lower than /ħ/. The hyoid bone is raised for about 2 mm from its ´at rest´ with its horns pointing toward the area between C2 and C3, but it is not as anteriorly displaced as in /ħ/. The epiglottis is not as tightly constricted as in /ħiːli/, its tip is uncurled and moving away from tongue root towards the pharyngeal wall where it leaves a very narrow passage between them, about 0.5 mm wide. Tongue back and root are not as much retracted as in /ħiːli/ where the constriction between tongue root and

Figure 5.1.b.1 / ʕ / in / ʕ i:d/ ´festival´

as said by FB

pharyngeal wall is about 1 mm wide, while it is 4 mm wide in /ʕiːd/. The soft palate is raised towards the pharyngeal wall, but without causing a naso-pharyngeal closure as it leaves a narrow gap of about 1 mm wide. Thus /ʕ/ has a wider velic opening than /ħ/ and also has a flatter tongue position. The lips are spread.

/ʕ/ in /ʕuːd/ (Figure 5.1.b.2), as said by FB, has a similar conFiguration as /ħ/ in /ħuːt/. The larynx is not at all raised from its ʹat restʹ posture, it is even slightly lower. The ventricle is more open than in /ʕiːd/. The hyoid bone is about 4 mm lower than ʹat restʹ and 6 mm lower than /ʕiːd/ and its horns point towards C3. The epiglottis is more bunched up and the vallecula is constricted. The constriction between the epiglottis and the wall of the pharynx is 1 mm wide and takes place at the level of C3. The passage between the back of the tongue and the pharyngeal wall is much narrower and bigger for /ʕuːd/ than for /ʕiːd/. The nasopharynx is open. Tongue front and tip are down on the floor of the mouth while tongue back is retracted. The lips are rounded.

Figure 5.1.b.3 represents /ʕ/ in /naʕam/. It has a raised larynx, about 4 mm higher from its rest position. The ventricle is open but slightly narrower. The hyoid body takes the same position as when it is ʹat restʹ while its horns are slightly tilted upward towards the upper edge of C3. The epiglottis uncurls and constricts

Figure 5.1.b.2 / ʕ / in / ʕuːd/ ´stick´

as said by FB

Figure 5.1.b.3 / ʕ / in /na ʕ am/ ´yes´

as said by FB

the pharynx at the level of the area between C2 and C3 leaving a 1 mm wide passage. The vallecula and the airway passage are narrowed by the posterior movement of the tongue. The soft palate bunches up but leaves the nasopharynx widely open (about 3 mm wide) as a result of the nasal consonants in the utterance. The tongue takes the posture required for the vowel /a/ with its highest point being central. The lips are neutral.

Figure 5.1.b.4 shows the articulation of the geminate /ʕ/ in /naʕʕam/ as said by FB. Comparing this geminate /ʕʕ/ to the above single /ʕ/, we find that the geminate has a lower larynx, about 2 mm lower than the single and 2 mm higher than 'at rest'. The ventricle is tightly closed; the hyoid bone is about 2 mm lower; the epiglottis is pressed by tongue root against the posterior wall of the pharynx at the level of C3, thus constricting the oropharynx and the vallecula. The back and root of the tongue are retracted backward leaving a much narrower and bigger area of constriction. The nasopharynx is open, but not as widely as for the single. Tongue dorsum is much flatter and the lips are more open. This shows that the single /ʕ/ is an approximant while the geminate /ʕʕ/ is a plosive. /ʕʕ/ seems to exhibit a double stricture or closure, one is an epiglotto-pharyngeal which involves the epiglottis tip and the posterior pharyngeal wall and the other is glottal

Figure 5.1.b.4 / ʕʕ / in /na ʕʕ am/ ´to grind´
as said by FB

which involves a sphentric constriction of the ventricle, the vestibular and the aryepiglottic fold. This glottal constriction seems to support the delicate epiglotto-pharyngeal constriction.

Analysing the xeroradiograms of /ʕ/ as said by HJ revealed a similar results to those of FB. Comparing /ʕ/ in /ʕi:d/, (Figure 5.1.b.5) to /ħ/ in /ħi:li/ we notice that /ʕ/ has a much lower larynx position, about 11 mm lower than /ħ/ and about 4 mm lower than ´at rest´. The hyoid body is lowered by about 6 mm while its horns are lowered by about 13 mm and they point towards C4. The epiglottis is not as tightly constricted, it has a thinner and longer shape and constricts the oropharynx at the level of the lower edge of C3. Both tongue back and root are retracted toward the pharyngeal wall. The soft palate bunches up against the pharyngeal wall but the velic closure is not as tight or firm as for /ħ/, in fact it is very lax, with a very narrow velopharyngeal opening. For the same vowel the tongue has a lower position than that for /ħ/, while the lips are neutral.

Comparing /ʕ/ in /ʕu:d/ (Figure 5.1.b.6) to /ħ/ in /ħu:t/, as said by HJ, we can see that /ʕ/ has a lower constriction in the pharynx, about 3 mm lower than /ħ/ and 7 mm lower than ´at rest´, thus leaving a bigger laryngo-pharyngeal cavity. The body of the hyoid bone is slightly lowered while its horns keep more or less the

Figure 5.1.b.5 / ʕ/ in / ʕi:d/ ´festival´

as said by HJ

Figure 5.1.b.6 / ʕ/ in / ʕu:d/ ´stick´
as said by HJ

same position as in /ħ/ and point towards the upper part of C4. The epiglottis tip unfolds towards the pharyngeal wall where it leaves a 3 mm wide passage. Tongue back and root are not as much retracted as for /ħ/ and tongue dorsum is not as low as for /ħ/ (surprisingly the tongue has a different shape than when /u:/ is the following vowel). The soft palate curves up against the pharyngeal wall where it touches it with its body while the uvula hangs away from the pharyngeal wall. The lips have a similar conFiguration as for /ħ/ which are rounded.

Comparing the intervocalic /ʕ/ in /naʕam/ (Figure 5.1.b.7), as said by HJ, with the ´at rest´ we notice that the larynx is lowered by about 6 mm. The hyoid body is about 13 mm lower while its horns are only about 4 mm lower and point towards the area between C3 and C4. The root of the tongue is retracted posteriorly where it constricts the vallecula and pushes the epiglottis away towards the pharyngeal wall where it leaves a 5 mm wide passage at the level of the lower part of C3. Tongue back is retracted while the dorsum takes a central position with the highest point being against the hard palate. The soft palate lifts up without constricting the naso-pharynx and leaves a 6 mm wide velopharyngeal opening.

Comparing the geminate /ʕʕ/ in /naʕʕam/ (Figure 5.1.b.8) to the above single /ʕ/, as said by HJ, we see a

Figure 5.1.b.7 / ʕ/ in /na ʕ am/ ´yes´
as said by HJ

Figure 5.1.b.8 / ʕʕ/ in /na ʕʕam/ ´to grind´
as said by HJ

dramatic change. The larynx is raised to almost its 'at rest' position. The hyoid bone is raised by about 8 mm with its horns pointing towards the lower edge of C3. The laryngo-pharynx is much more constricted. The epiglottis is bunched up and constricted to a minimum size and pushed towards the posterior wall of the pharynx where it leaves 1.5 mm gap at the level of C3. Tongue root is retracted and pressed against the body of the epiglottis, thus constricting the vallecula while its tip being pushed away from tongue root. Tongue dorsum maintains a similar posture as for the single / ʕ /, anticipating the following vowel /a/. The velopharynx is wide open as a result of the neighbouring nasal sounds. Here we also suspect that the geminate /ʕʕ/ to be a stop as a result of the glottal closure, even though the epiglotto-pharyngeal constriction is not complete. This is to be confirmed later by spectrographic and aerometric analysis.

<u>5.2</u>

The Acoustic Properties of the Pharyngeal Consonants

Two male speakers tape-recorded a list of thirty-four words containing the pharyngeal sounds /ħ/ and /ʕ/. Each test item was read three times. Wide band spectrograms were made of the 284 words with a

frequency range of 0-8000 Hz. The spectrograms were analysed by measuring the frequencies of the first three formants of the pharyngeal sounds and the adjacent vowels. The mean of the formant frequencies were calculated across the data of the two subjects.

5.2.a

The Acoustic Properties of /ħ/

The voiceless pharyngeal /ħ/ exhibits, acoustically, a clear non-periodic noise (friction) which is concentrated in visible formant-like bands extending from about 500 Hz upward. This acoustic characteristics of /ħ/ is found to consistant across the two speakers and in different positions in the word structure: initially, medially and finally (see Figures 5.2.a.1-3). Next to /a/, /ħ/ exhibits the following average formant frequencies: F1 800, F2 1600, F3 2250; next to /a:/ F1 800, F2 1750 and F3 2500; next to /i/ F1 800, F2 1750 and F3 2650; next to /i:/ F1 750, F2 1750 and F3 2750; next to /u/ F1 750, F2 1500 and F3 2000; and next to /u:/ F1 500, F2 1500 and F3 1800. Having a place of articulation down in the pharynx, tongue dorsum and lips are free to coarticulate with the adjacent vowel and takes the posture required for its production as seen in the above xeroradiograms. Acoustically, the adjacent vowel influences the pharyngeal

/ba:ɦ/
Figure 5.2.a.3

/ɦa:b/
Figure 5.2.a.1

/siɱar/

Figure 5.2.a.4

/siɱar/
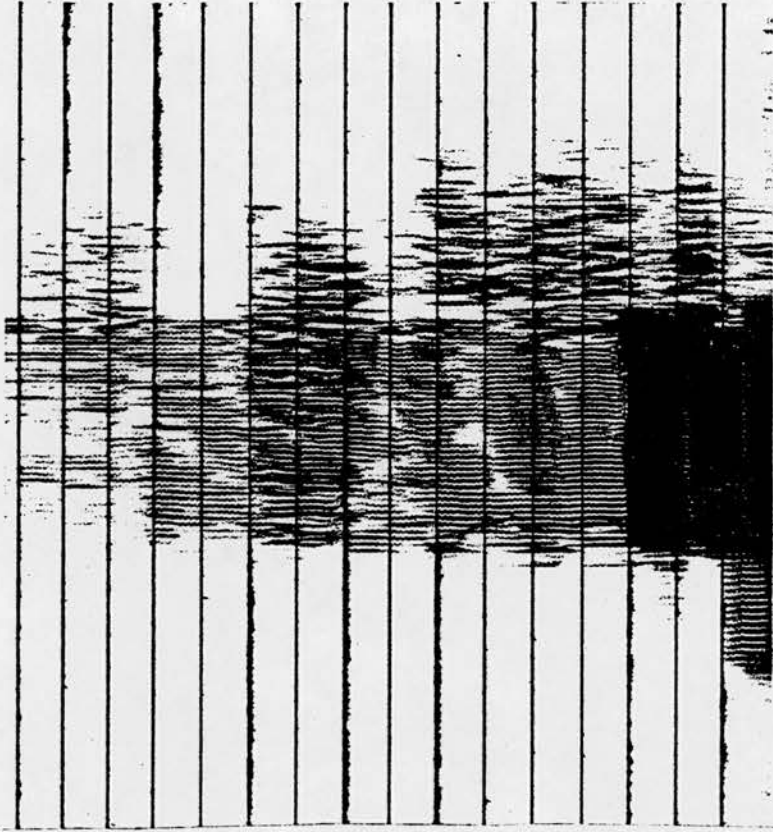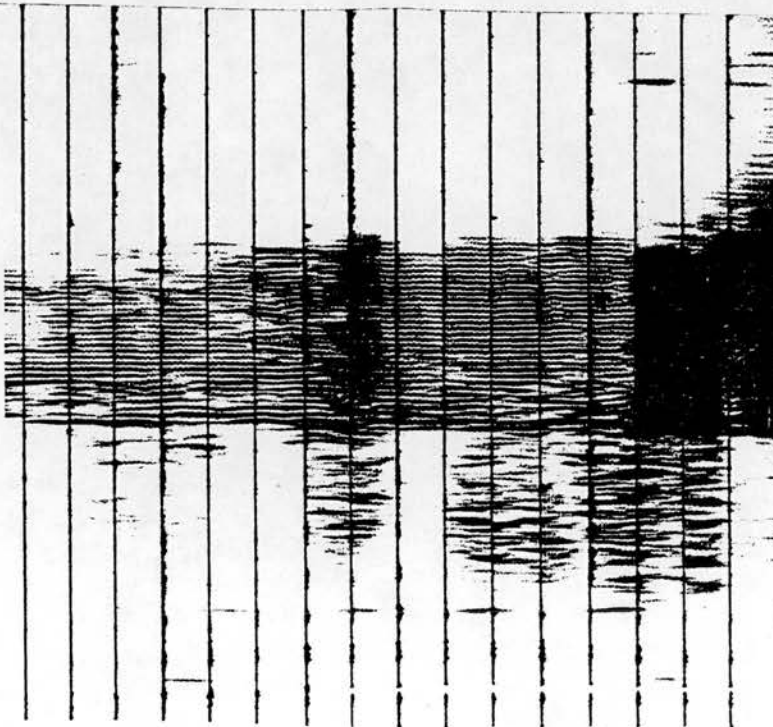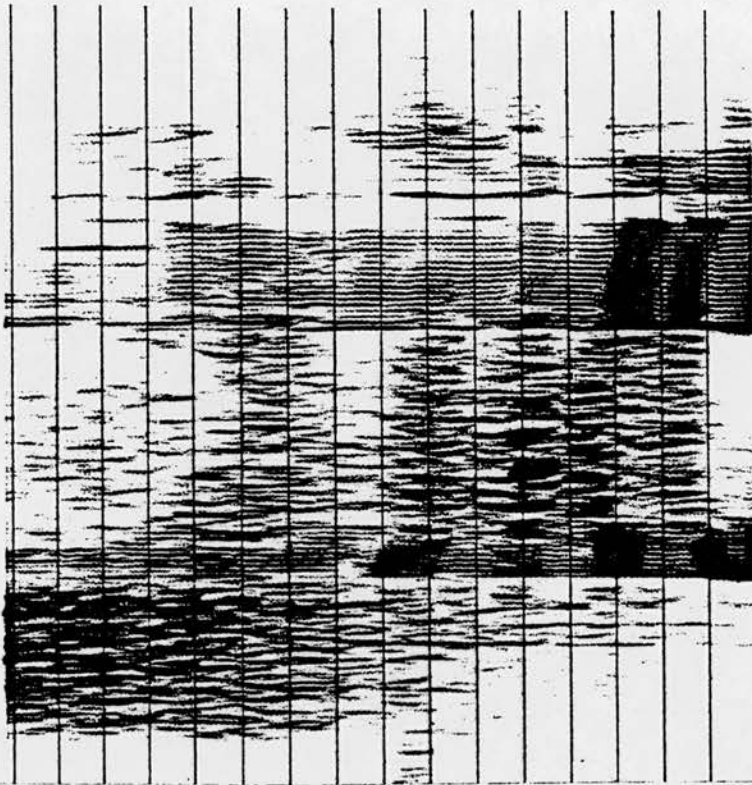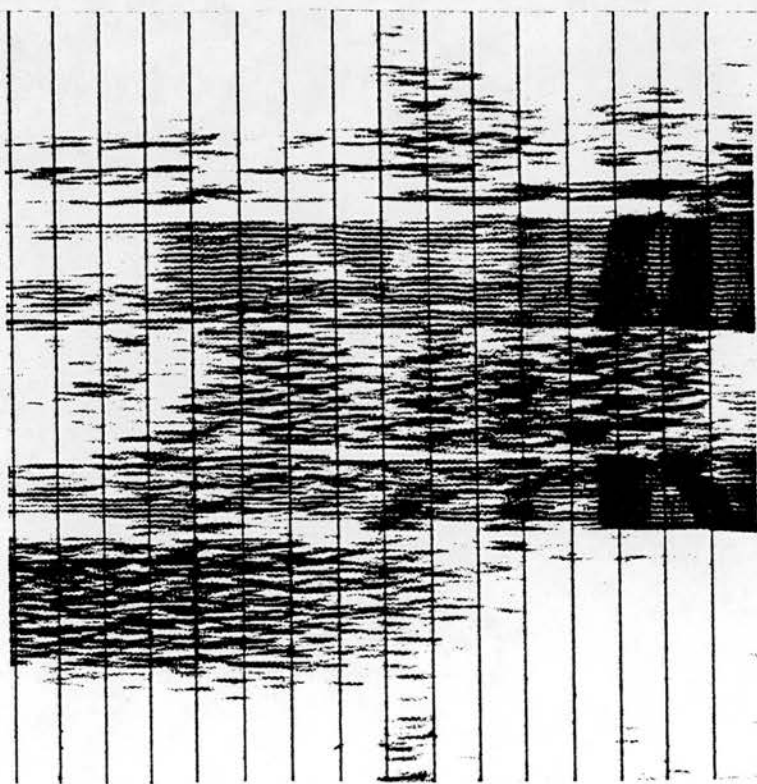
Figure 5.2.a.2

/ħ/ by affecting its formant frequencies by slightly lowering its first formant when it is a high vowel and lowering its second formant when it is a back vowel and raising it when it is a front vowel.

But the influence seems to be mutual as the low pharyngeal constriction seems to affect the formant frequencies of the adjacent vowels or at least affects their onsets if they are following the pharyngeal consonants or their ends if they are preceding it. Next to /ħ/, /a/ exhibits the following formant frequencies: F1 750, F2 1500, F3 2500; /a:/ F1 800, F2 1250, F3 2100; /i/ F1 500, F2 1500, F3 2500; /i:/ F1 300, F2 1800, F3 2800; /u/ F1 500, F2 1200, F3 2000; /u:/ F1 375, F2 1200, F3 2000. Thus it can be seen that /ħ/ influences the adjacent vowels by raising their first formant, lowering the second formant of the front high vowels and raising the second formant of the high back vowels and also lowering the third formant, of almost all the vowels.

5.2.b

The Acoustic Properties of /ʕ/

Spectrographic analysis revealed that the most common realization of /ʕ/ is a voiced pharyngeal approximant with the vertical spikes, which indicate the glottal pulses, being slightly further apart than those of

the adjacent vowels (indicating a lower fundamental frequency), and with clear and well defined formant bands similar to those of the vowels and without any noticeable noise or friction (see Figure 5.2.b.1). But /ʕ/ seems to have some other realizations depending on its position in the utterance or word structure and whether it is single or geminate. In word-initial position /ʕ/ tends to start as a creak with the voice striations very wide apart for about one third or half of its duration, then as the fundamental frequency rises the striations get closer together and it becomes a vowel-like sound (see Figure 5.2.b.2). In word-medial position, whether in an intervocalic position or not, /ʕ/ is an approximant as it exhibits a very vowel-like structure (see Figure 5.2.b.3). In word or utterance final position /ʕ/ can be a vowel-like approximant or it can be a combination of a creaky voice and a stop, indicated on the spectrogram by the slow vertical spikes followed by a short blank gap which may be followed by a voiceless friction at its release (see Figure 5.2.b.4). The intervocalic geminate /ʕʕ/ is realized as a stop as it can be seen in /naʕʕam/, Figure 5.2.b.5; compare it to /naʕam/ in Figure 5.2.b.3 where /ʕ/ is a glide, a continuation of the preceding /a/ to the following /a/ with a very similar formant structure.

Like /ħ/, /ʕ/ affects the formant frequencies of the neighbouring vowels and gets affected by them. Next to
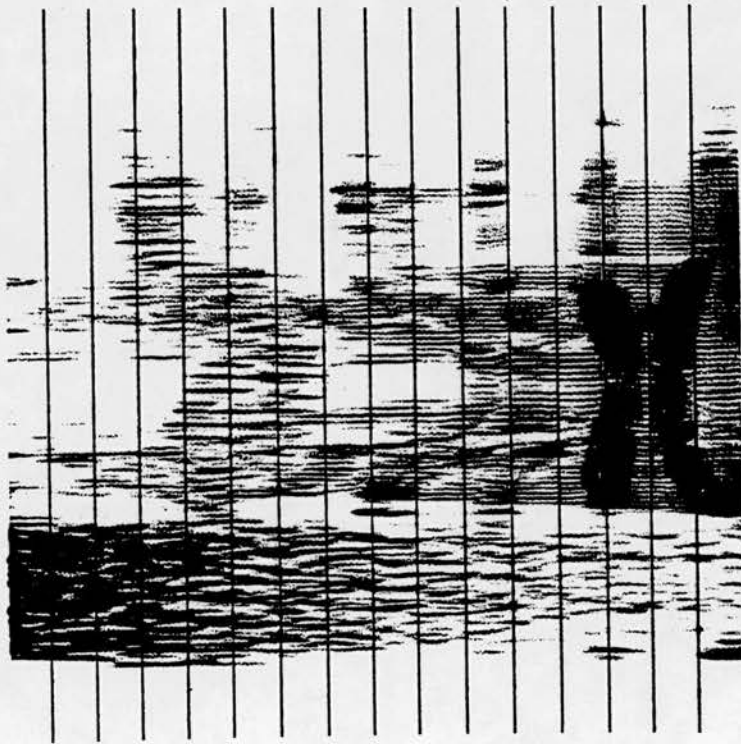
/siʃal/
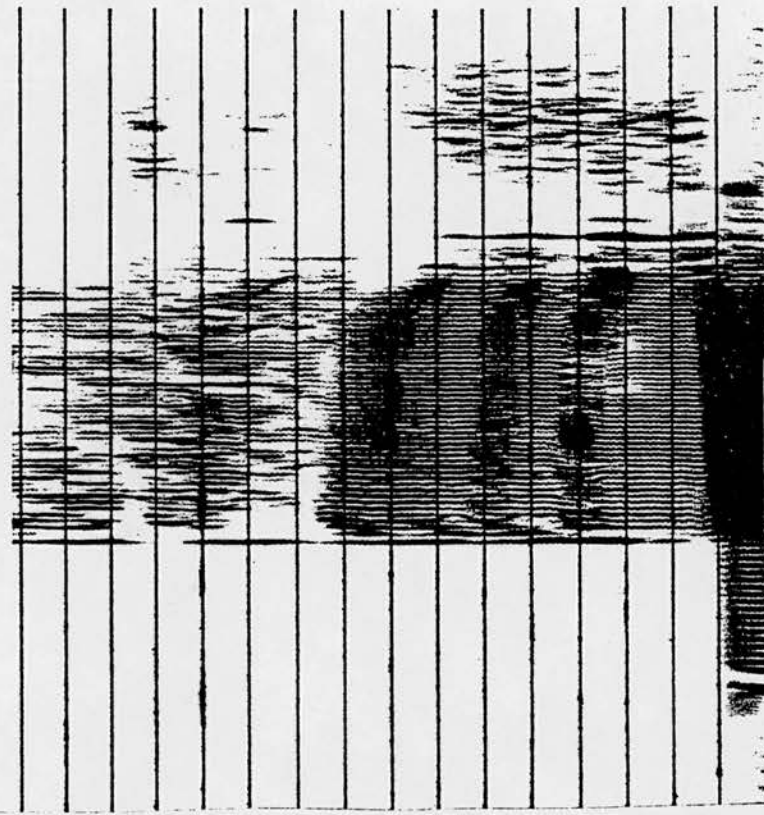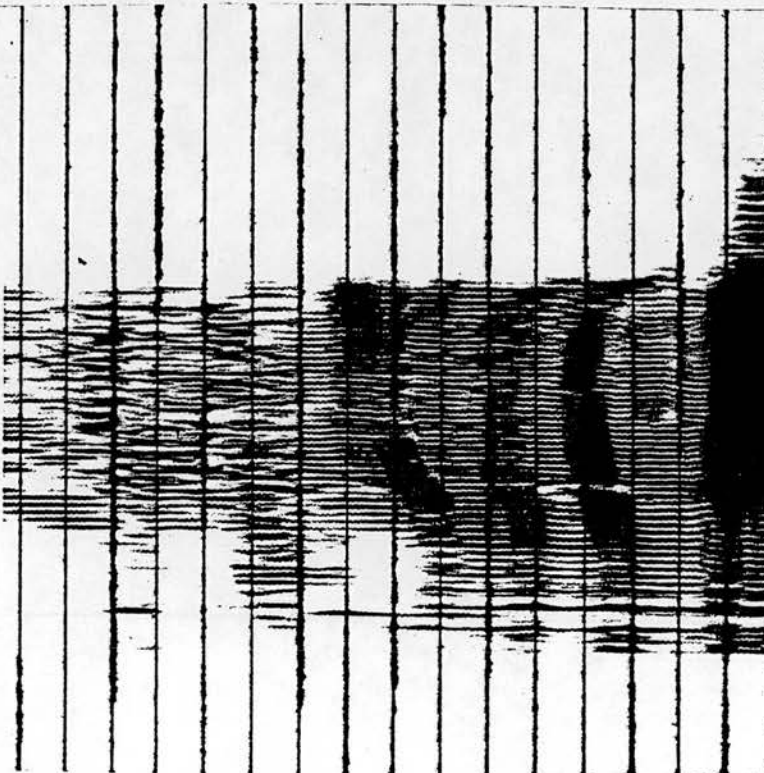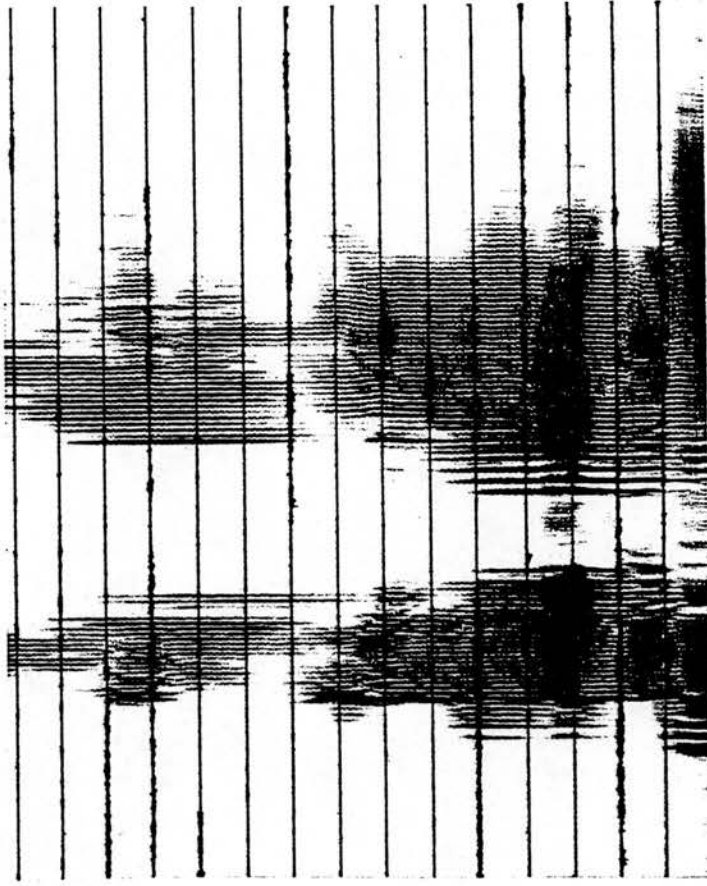
Figure 5.2.b.1

/beːʒ/

Figure 5.2.b.4

/ʃeːb/

Figure 5.2.b.2

/naʃʃan/

Figure 5.2.b.5

/naʃan/
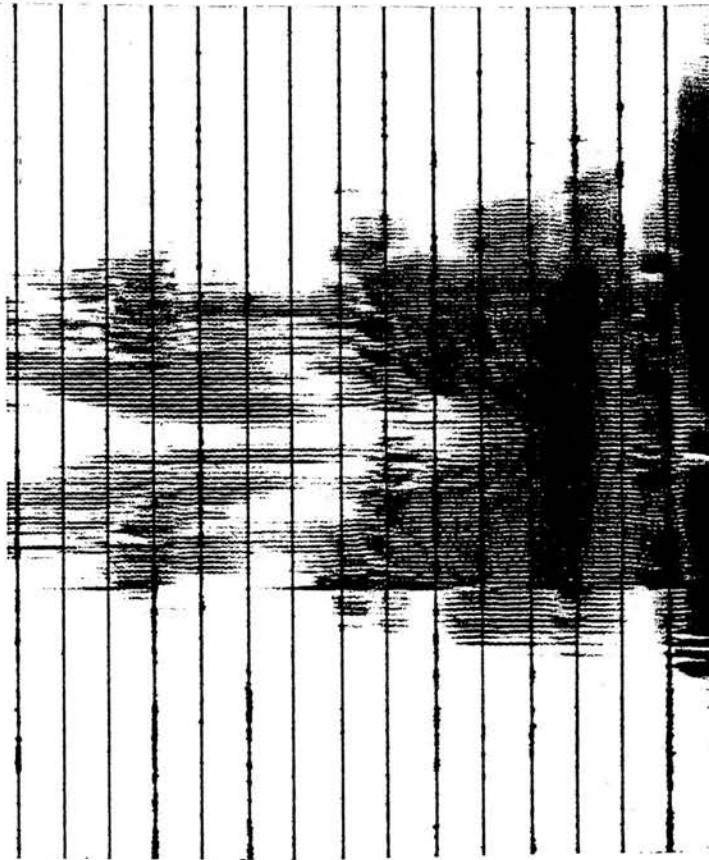
Figure 5.2.b.3

/a/, /ʕ/ exhibits the following formant frequencies: F1 800, F2 1500, F3 2250; next to /a:/ F1 800, F2 1250, F3 2000; next to /e:/ F1 500, F2 1700, F3 2650; next to /i/ F1 700, F2 1500, F3 2500; next to /i:/ F1 500, F2 1700, F3 2750; next to /u:/ F1 350, F2 1250, F3 1750. Thus the first formant of /ʕ/ gets lowered next to high front and back vowels while it stays unaffected by the front low vowels. Its second formant gets raised next to the high front vowels while it gets lowered next to high back vowels. Its third formant gets raised by the front vowels.

Next to /ʕ/ the vowel formants or their onsets get affected, /a/ exhibits the following formant frequencies: F1 800, F2 1500, F3 2200; /a:/ F1 800, F2 1250, F3 2000; /e:/ F1 500, F2 1700, F3 2600; /i/ F1 600, F2 1500, F3 2500; /i:/ F1 350, F2 1500, F3 2650; /u:/ F1 300, F2 1200, F3 1800. Thus all the vowels have a higher F1 onset and a lower F3 onset, while the front vowels have lower F2 onset and the back vowels have a higher F2 onset.

5.3 Nasal Airflow During the Production

of the Pharyngeal Consonants

Aerometric recordings of words containing the pharyngeal consonants in different word positions were

made by two subjects, one male, HJ, and the other is female, FB, in order to examine whether the oral articulation of these pharyngeal consonants is accompanied by a concomitant nasal airflow (see appendix H for a full list of the test items). FB aerograms revealed that the voiceless pharyngeal /ħ/ exhibits a significant nasal airflow during its production, no matter whether it is in word-initial, medial or final position, whether it is single or geminate and whether it is in the environment of a phonologically nasal sound or not. While the voiced pharyngeal /ʕ/ exhibits a zero or very little nasal airflow during its articulation, unless it is in the neighbourhood of a nasal consonant then it becomes heavily nasalized.

Figure 5.3.1 shows that /ħ/ in /ħiːr/ is nasalized initially where the nasal airflow increases to a maximum of 96 ml/sec at about one third of its duration, then it decreases gradually to reach a zero-flow with the onset of the following vowel. Medially, /ħ/ in /riħli/ (Figure 5.3.2) exhibits a nasal flow which starts from the end of the preceding vowel /i/ to reach a maximum flow of about 89 ml/sec half way through its articulation where it starts decreasing but continues through the rest of the word. Figure 5.3.3 reveals that the geminate /ħħ/ in /kaħħa/ is also accompanied by nasal airflow of about 55 ml/sec which starts half way through the preceding vowel to continue through the following vowel. In

/ɦi:r/

Figure 5.3.1

/riñli/

Figure 5.3.2

/kañña/

Figure 5.3.3

/ri:ħ/
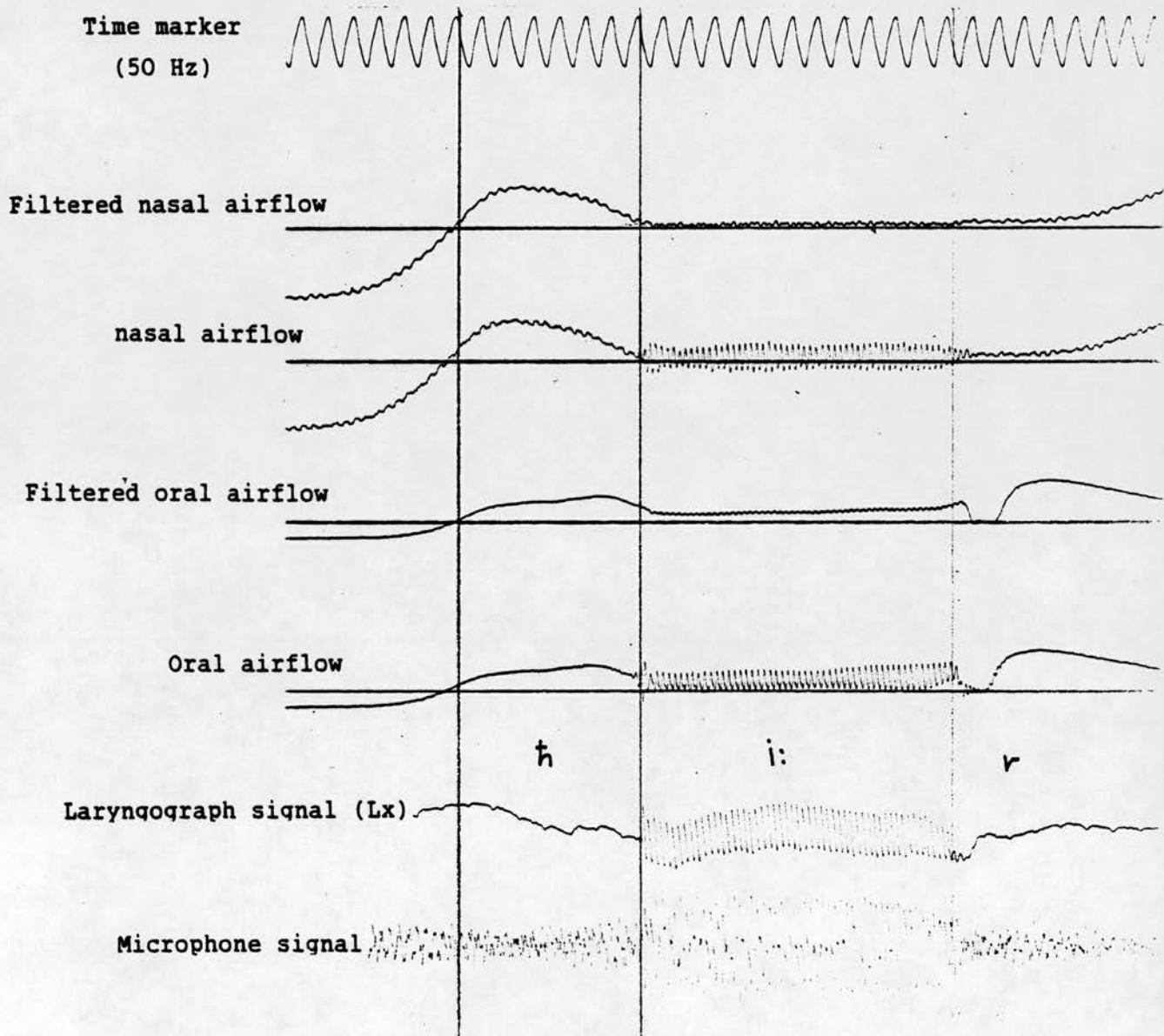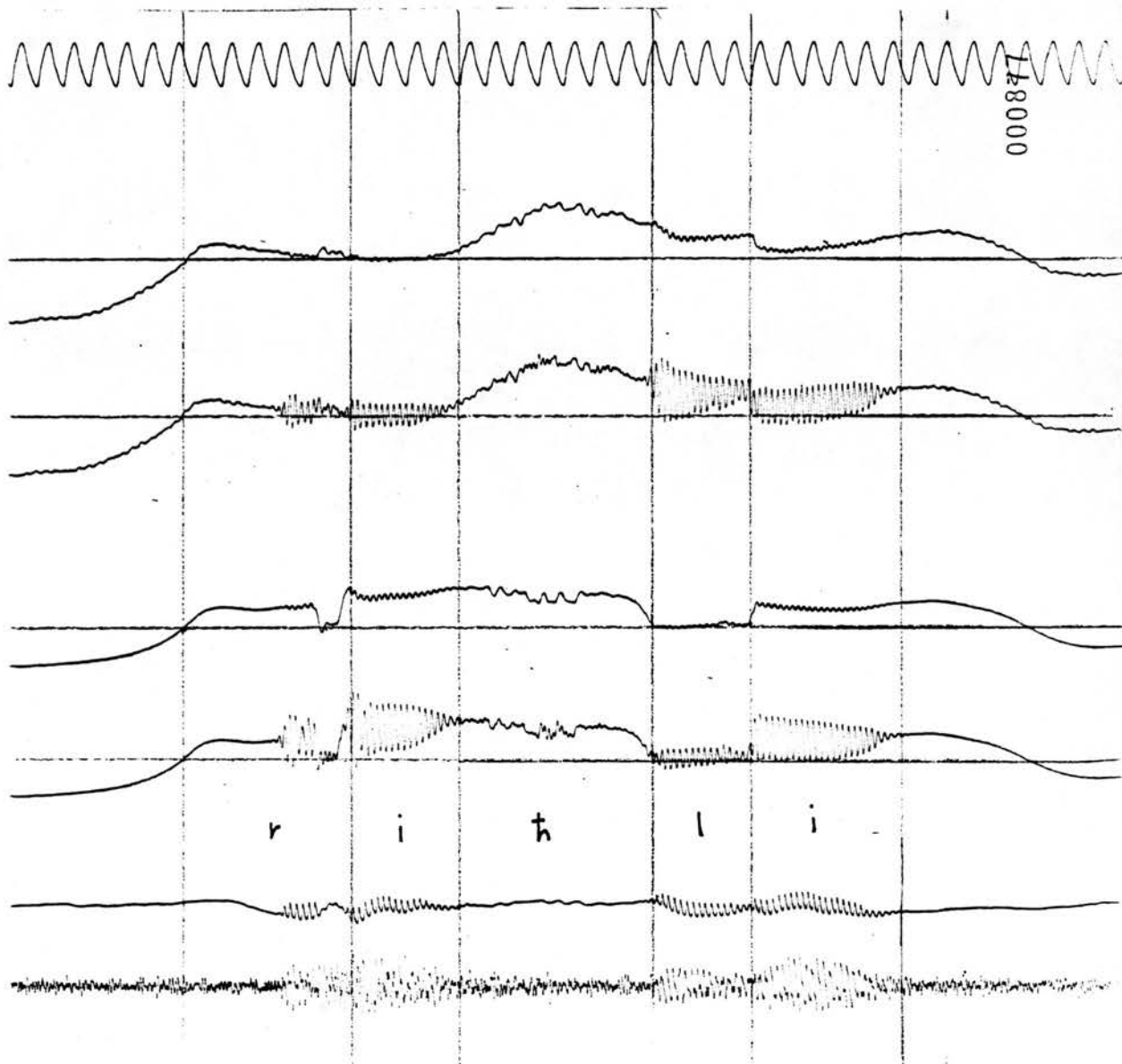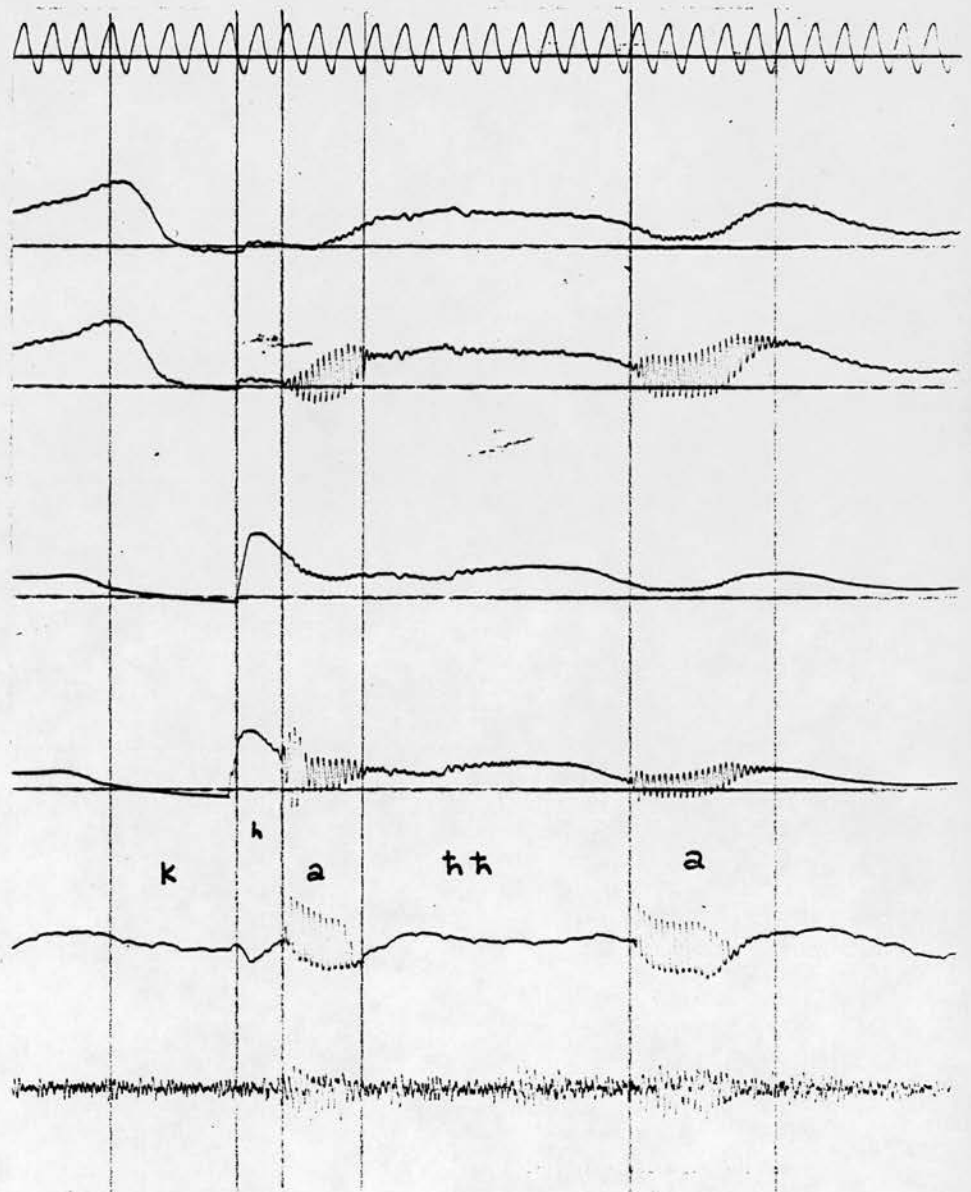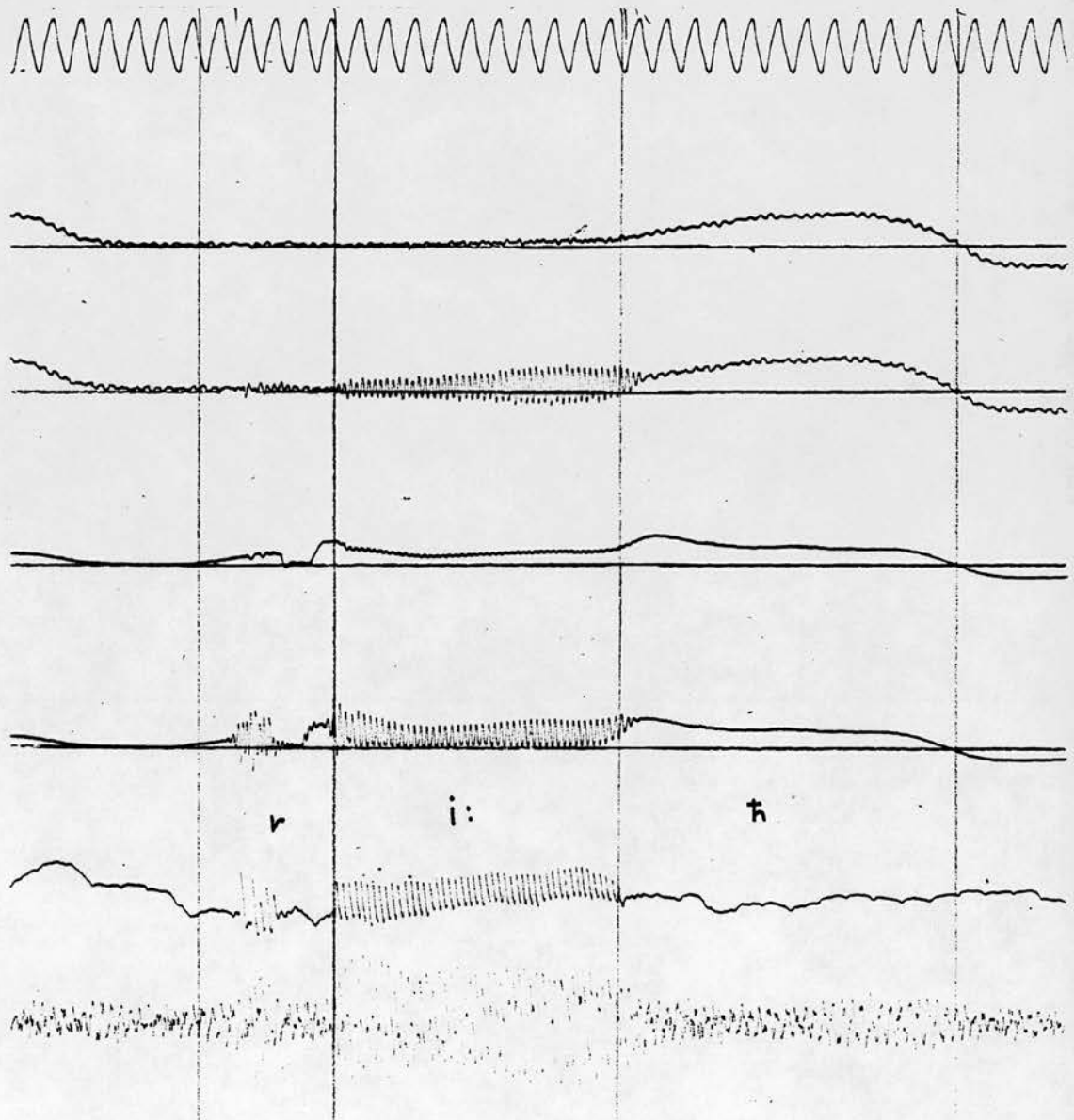
Figure 5.3.4

word-final position /ħ/ is produced with a concomitant nasal airflow as can be seen in Figure 5.3.4 of /riːħ/ with a maximum flow of about 72 ml/sec. In word-initial position /ʕ/ exhibited a very slight nasal airflow as can be seen in /ʕiːd/, Figure 5.3.5, where it has a flow of about 15 ml/sec. Medially and finally /ʕ/ is articulated with zero or very little nasal airflow as can be seen in /ʃuʕaːʕ/, Figure 5.3.6. But /ʕ/ gets heavily nasalized in the context of nasal consonants as can be seen in /naʕam/, Figure 5.3.7, where it exhibits a nasal airflow of about 45 ml/sec; while the geminate /ʕʕ/, being a plosive, displays zero nasal airflow even when it is in the neighbourhood of nasal consonants as can be seen in /naʕʕam/, Figure 5.3.8.

These airflow findings contradicts our expectation from the the xeroradiography findings. As we have seen earlier, the xeroradiograms of /ħ/ showed a velic closure during its production, but it seems that the closure is not tight or firm, thus permitting the air to leak through the nasal cavity to produce nasal airflow on the aerometric recordings. On the other hand, the xeroradiograms of /ʕ/ showed a velic opening, thus we expected it to have some air flowing through the nasal cavity, but the aerograms showed no such nasal airflow. This could be explained by the fact that, to acheive its nasal quality, /ʕ/ seems to use the naso-pharynx chamber plus the oro-pharynx chamber while it keeps the lateral

301059

ʕ   i: d

/ʕi:d/

Figure 5.3.5

/ʃoɣaːʃ/
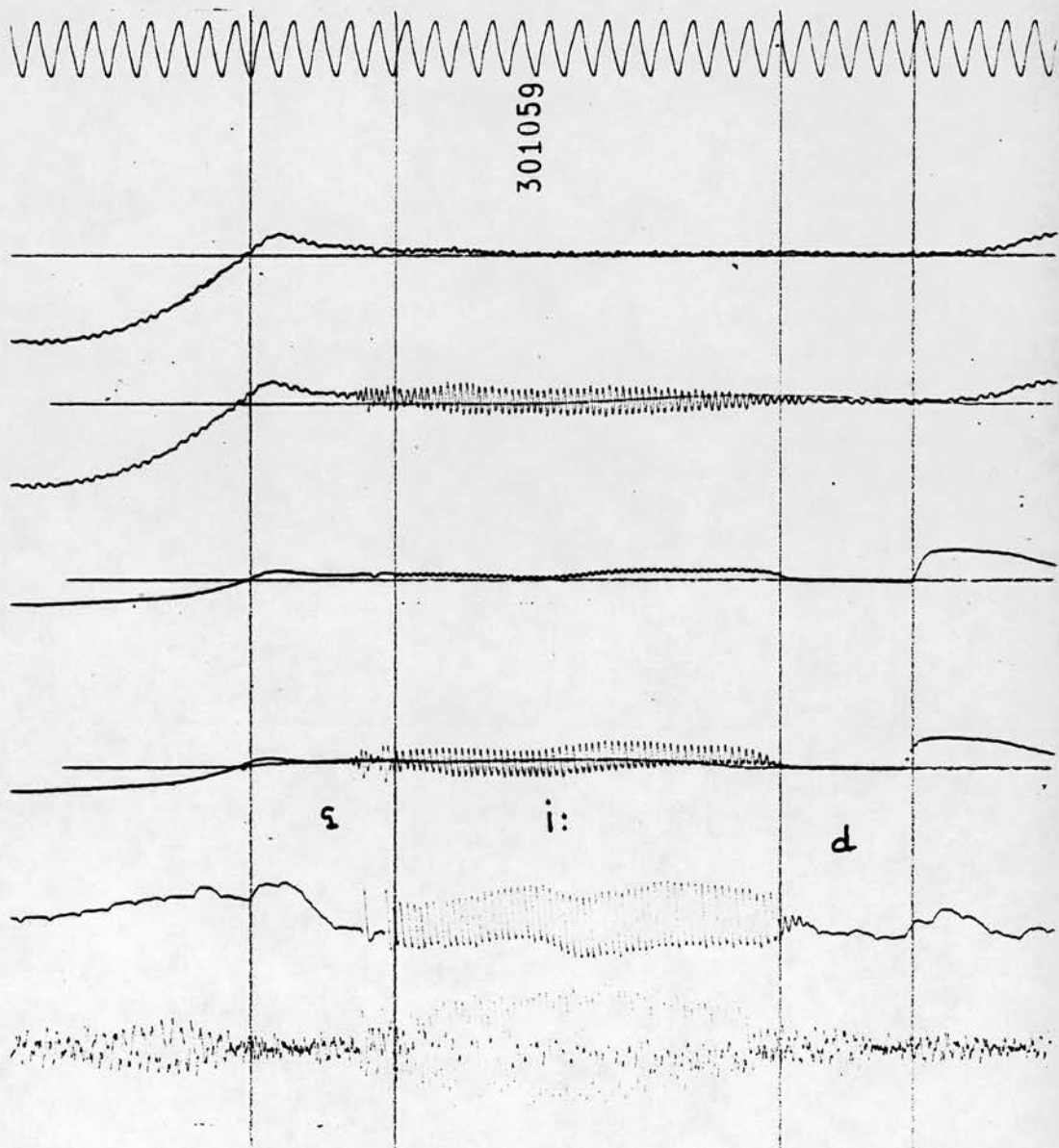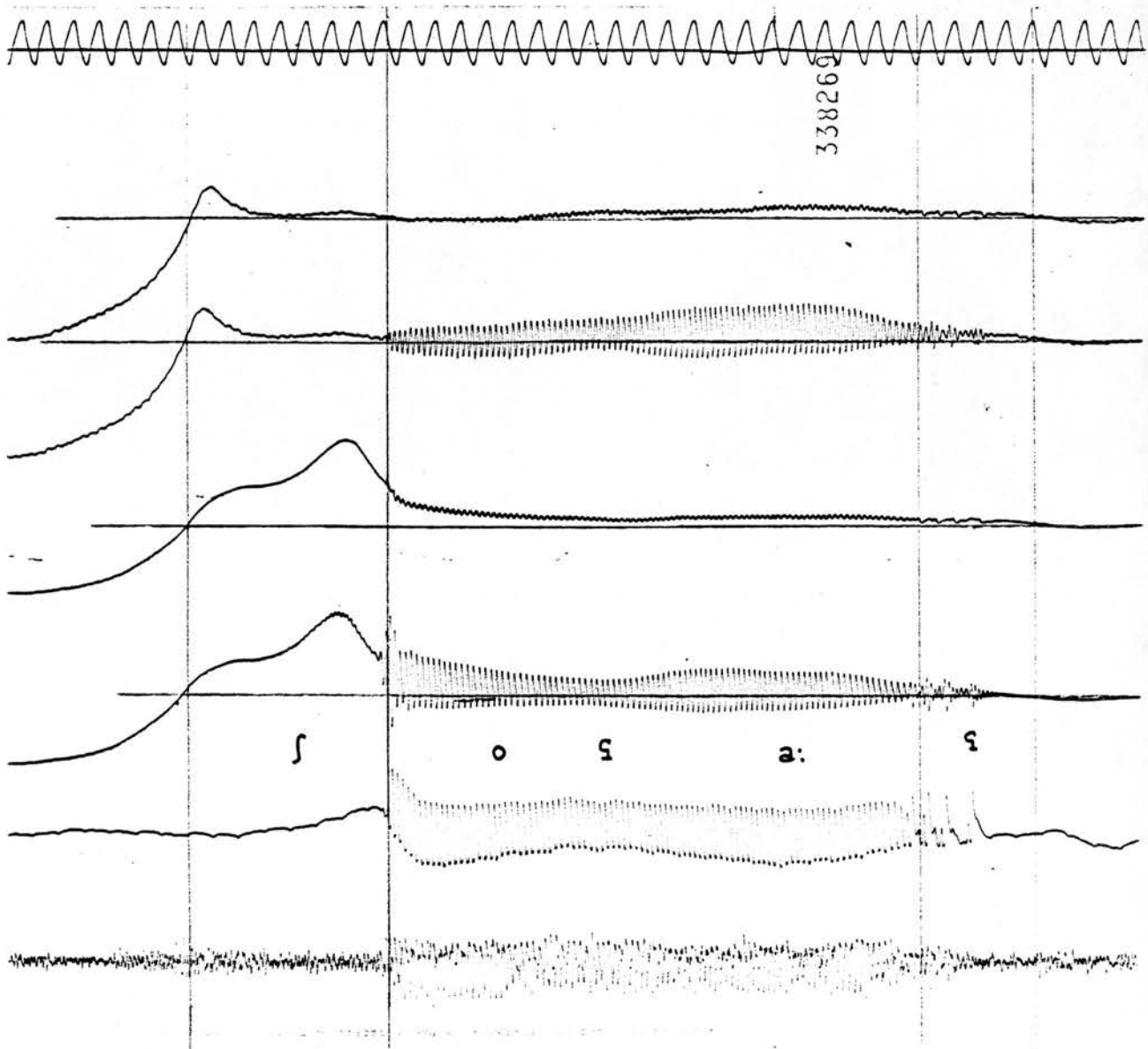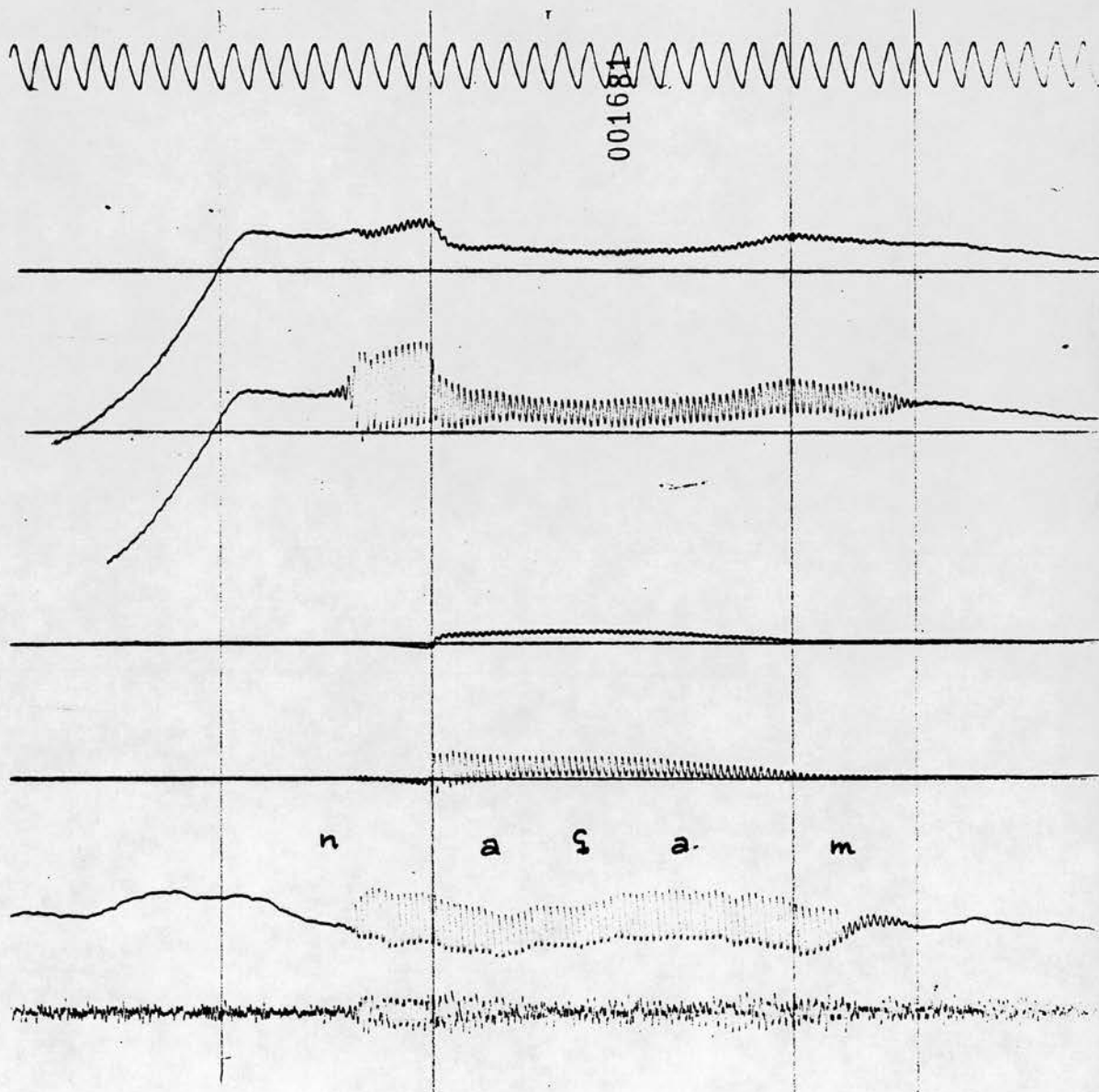
Figure 5.3.6

/naʕam/
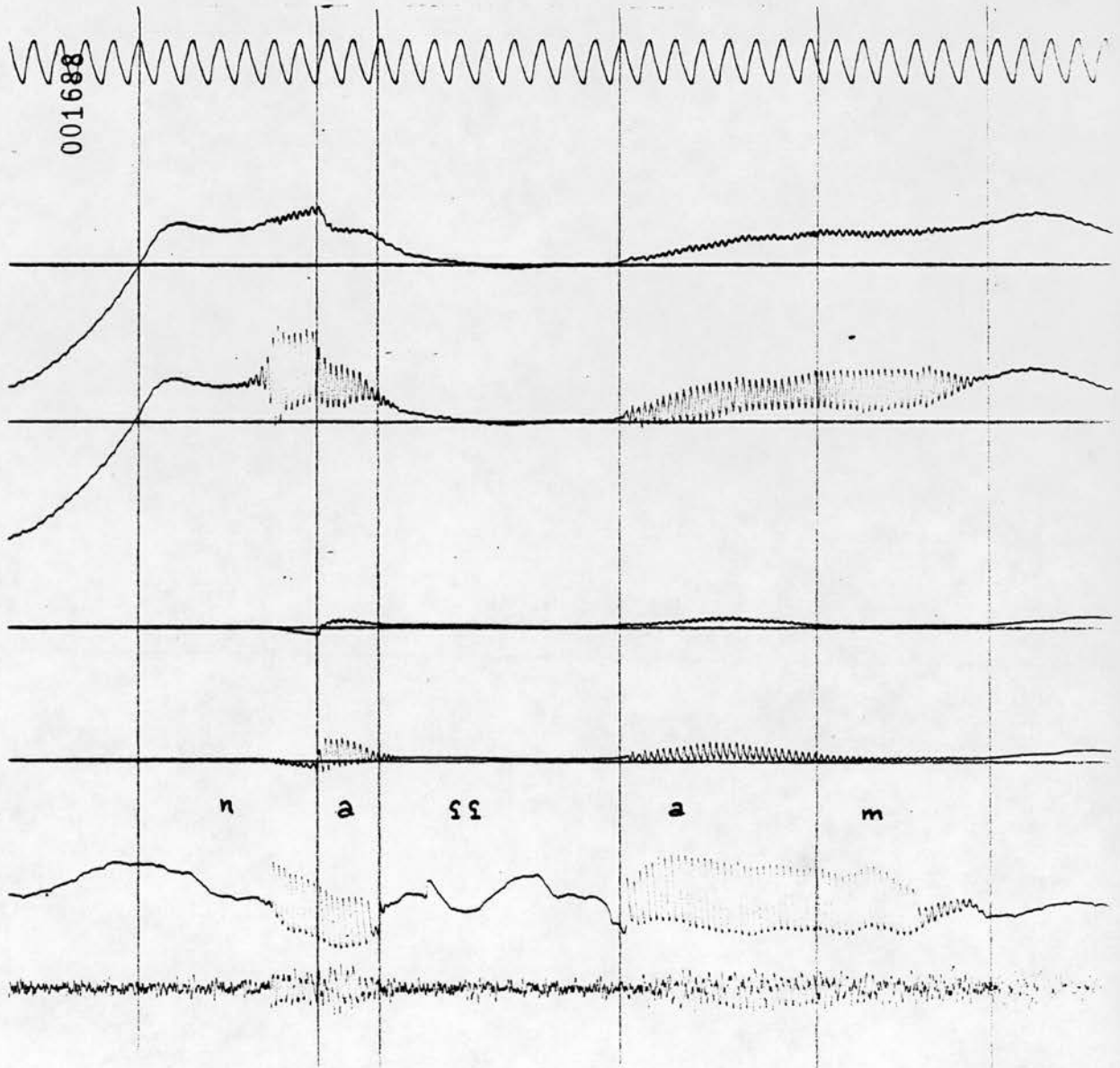
Figure 5.3.7

/naʃʃam/

Figure 5.3.8

wall of the naso-pharynx contracting to close off the velopharyngeal airway, thus preventing the air from passing through the nose (MacCurtain, personal communication). The perceived nasal quality of the pharyngeal sounds could be enhanced by the constriction and tensing of the pharynx as Curry (1910), cited in Zemlin (1968), believes that they do result in an audible nasalization "nasality could be caused by insufficient velopharyngeal closure, by pharyngeal constriction, or by excessive tensing, or by a combination of all of these" (p.210). This nasal quality of the pharyngeals is supported by the fact that these sounds are reduced to the nasal /n/ in some other semitic languages like East Gurage (a south Ethiopic language) "n occurs in a context where there had been ... initial laryngeal ḥ or ... followed by a vowel that is, in its turn, followed by another consonant ... In this context, the laryngeal is reduced to ḥ -> h and ʕ -> 2 ..., and an n appears between the vowel and the subsequent consonant" (Hetzron 1969, p.71).

By examining HJ airflow records we found that both /ħ/ and /ʕ/ exhibit very little or zero nasal airflow during their production unless in the neighbourhood of a nasal consonant where they display nasal airflow even higher than the nasal consonant itself.

5.4 Summary

The physiological, acoustic and airflow characteristic of the pharyngeal /ħ/ and /ʕ/ in QA were investigated in the above sections. Physiologically, they are characterized by a considerable retraction of tongue back and root and a narrow constriction of the pharynx at the level of the epiglottis. Larynx and hyoid bone position differe according to the nature of the adjacent vowel. They are raised when they are adjacent to front vowels and lower when adjacent to back vowels. This contradicts the results of previous research in which it was found that the larynx can be only raised during the production of the pharyngeals; it certainly contradicts Delattre's (1969) findings where he states that the height of the larynx increases as the adjacent vowel gets backer "the larynx rose considerably (by about 8 mm after /i/, 13 mm after /a/ and 15 mm after /u/)" (p.72).

Acoustically, the narrow constriction of the laryngo-pharynx is translated into a relatively high F1 and low F2 which affects the adjacent vowels by raising their first formant and lowering their second formants if they are front vowels, and raising their first and second formants if they are back vowels. The pharyngeal formants also get affected by the adjacent vowels by lowering their first formant and raising their second formant next to front vowels and by lowering both their first and second formants when next to back vowels. /ħ/ has been shown to be a voiceless fricative

with the non-periodic noise being structured in formant-like bands; / ʕ / has shown to be a voiced approximant in most cases with creaky voice and stop variations.

Airflow investigation showed that the articulation of /ħ/ is accompanied by nasal airflow in the data of one of the two subjects only, while both speakers showed no nasal airflow during the production of /ʕ/ unless it is in the context of a phonologically nasal consonant.

CHAPTER   SIX

VOWEL DURATION

6. Vowel Duration

Previous research on many languages has revealed that timing patterns are carefully controlled in speech production and closely attended to in speech perception (Lehiste 1970, Lisker 1974, Klatt 1976, Mitleb 1981). That there is a law which governs the variations in vowel duration. This law sheds some light on the various phonetic-universal and language-specific phenomena.

By vowel duration we mean a physical measurable duration of their articulation. Following Lehiste (1970) the duration of a speech sound is defined as "the physical correlate of timing of articulatory sequences" which represents the "time dimension of the acoustic signal" (p.9).

In this study we will try to delineate the factors which cause variations in the duration of vowels in QA and find out whether these variations are language-universal or language-specific, i.e. whether the factors determining the variations in vowel duration are inherent in the physiological process of articulation or imposed by the phonology of the language.

The duration of a vowel is affected by two main types of phonetic conditioning factors:

1) Intrinsic or internal factors which are related to the nature of the vowel itself. Thus the intrinsic duration of a vowel is determined by its phonetic quality. Vowel height is one of the intrinsic factors which influences the temporal correlate of the vowel. Lehiste (1970) states that "as far as the vowels are concerned, their duration appears to be correlated with tongue height: other factors being equal, a high vowel is shorter than a low vowel." (p.18), and that this difference in vowel duration according to tongue height or degree of opening is "physiologically conditioned and thus constitutes a phonetic universal" (p.19).

Vowel length is another factor which influences vowel duration. This factor is phonologically and not physiologically determined and it operates in languages where the durational difference between short and long vowels is phonologically significant. The lengthening of a long vowel is deliberately maintained by the speaker to differentiate it from its corresponding short vowel.

2) Extrinsic or external factors which can be either segmental or suprasegmental factors. By segmental factors we mean the influence exerted by the following consonant on the duration of the preceding vowels. This influence varies according to voicing, manner of articulation and place of articulation of the consonant that follows the vowel. By suprasegmental factors we mean the effect of stress and tempo on the duration of

a vowel.

Delattre (1962) proposes eight factors which influence vowel duration in American English apart from stress and tempo, "three 'internal' factors that are in the vowel itself, and five 'external' factors all to be found in the single consonant that follows the vowel. The internal factors are: vowel abridging/vowel expanding, less open vowel/more open vowel and monothong/diphthong. The external factors are: surd consonant/sonorant consonant, stop consonant/fricative consonant, liquid consonant/solid consonant (all except r and l), oral stop consonant/nasal stop consonant, and more front consonant/more back consonant" (p.1141).

6.1.

Electro-aerometric investigation of vowel duration in QA

In the following sections an aerodynamic investigation of vowel duration is carried out to delineate the intrinsic and extrinsic factors that may influence the duration of vowels in QA.

6.1.1 Technique

The electro-aerometer used for the experiment

was the Edinburgh Aero Equipment MKII manufactured by Gaeltec Limited (Isle of Skye, Scotland) for measuring oral and nasal airflow. It has a face mask, an adapted anaesthetic mask, which is divided into two separate chambers, by a relatively hard rubber diaphragm, the upper part for the nose and the lower part for the mouth. Each part is fitted with a pneumotachographic head (supplied by Mercury Electronics Limited) which is basically an air pipe across which there is a fine wire mesh. The system is linear in that the flow through the mesh is proportional to the pressure across it. Attached to the head is a small, sensitive, semi-conductor transducer (a Gaeltec pressure transducer) whose diaphragm is deflected by the difference in pressure which in turn changes the resistive balance of an electrical bridge resulting in a change in the voltage output. The airflow is first measured in terms of pressure, the pressure is then converted into voltage which is increased by the amplifier connected to the transducer. Thus we have volume velocity---> pressure---> voltage---> deflection. A difference of 1cm of water pressure (1cm Aq.) at the transducer gives a difference of 1 volt at the output of the amplifier which is recorded on a high-speed mingograph (ink-jet oscillograph) at a paper speed of 25 cm. per second and gives 2 cm. deflection of the trace on the paper. The system is calibrated by determining the flow rate

through the pneumotachographic head which results from a pressure difference of 1 cm. Aq. across the mesh. (Hewlett & Anthony 1982).

An electrical laryngograph was also used in this experiment. It was the voicescope made by the Laryngograph Limited, London, which is developed by Fourcin and Abberton (1971). It is an "electrical impedance technique for the direct examination of vocal fold closure, which does not interfere with phonation" (Fourcin 1974,p.315). There are three types of waveform which can be obtained from the laryngograph: Gx waveform which represent the gross movement of the larynx. Fx waveform which extracts fundamental frequency from the speech wave form and displays a visual correlate of intonation. Lx waveform which represents the larynx vibration output. It reflects the nature of the vocal folds adduction and abduction from one cycle to another. "The main contribution to the detailed form of Lx comes from the area and nature of the electrically conducting surfaces that are in contact during vocal fold adduction. In consequence, if there is a change in area, or in the nature of a contacting area, from one cycle of vibration to another this will be shown by a corresponding change in Lx amplitude." (Fourcin 1974, p.32). For the purpose of our investigation, Lx waveform was chosen to detect the presence or absence of voicing. Two electrodes were positioned

superficially on each side of the thyroid cartilage (a constant voltage source) as the input to the subject's neck and they detect the current output from the larynx in a low impedance circuit which changes as the vocal folds change their configuration.

6.1.2. Experimental set-up

The experiment was carried out in the cleft-palate speech laboratory of the Royal Hospital for sick children in Edinburgh. The aerometer was calibrated first. The flow head used for the oral flow measurement had a flow of 42.5 liters per minute, that is 708 ml. per second for a pressure difference of 1 cm. Aq. across the mesh. This pressure applied to the transducer and its amplifier gives 1 volt which is when applied to the Mingograph gives a deflection of the trace on the paper of 2 cm. To give a nasal trace comparable in overall size to that of the oral trace it was necessary to increase the gain of the nasal amplifier of the Mingograph by four times, so 1 volt would give a deflection of 8 cm. The flow head used for the nasal flow measurement had a flow of 40 liters per minute for a pressure of 1 cm. Aq. across the mesh.

After the calibration of the system, the subject was seated comfortably on a chair and two small

electrodes were placed superficially on each side of his larynx, at the level of the thyroid cartilage. One electrode transmits the signal from the oscillator and the other electrode picks up the signal and sends it to the detector, which measures the attenuation of the signal between the two electrodes and a permanent record of the Lx output is displayed by the Mingograph. The mask was lightly pressed on the subject's face covering the nose and mouth areas to prevent the leakage of air in and out around the mask edge. A microphone which was connected to a Revox tape recorder, was placed in front of the mouth of the subject to pick up the speech radiated from the outlet of the pneumotachograph as   he read the word list. To get a permanent and a simultaneous record of the output of the mask, the laryngograph and the microphone, they were all connected to the Mingograph (see Figure 6.1.2.1 for a block diagram of the experimental set-up). Thus a permanent mingographic record was obtained which displays the oral and nasal airflow waveforms from the mask, a time calibration waveform, a laryngographic waveform and an acoustic speech waveform. Figure 6.4.1.c.1 represents a mingographic record with seven traces, from top to bottom: trace 1 is the time trace (T) with a paper speed of 25 cm. per second, 1 millimeter equals 4 milliseconds, it provides the calibration for measuring the duration of segments; trace 2 is a filtered nasal airflow

Figure 6.1.2.1

Experimental setup for simultaneous aerometric, acoustic and electrolaryngographic recording
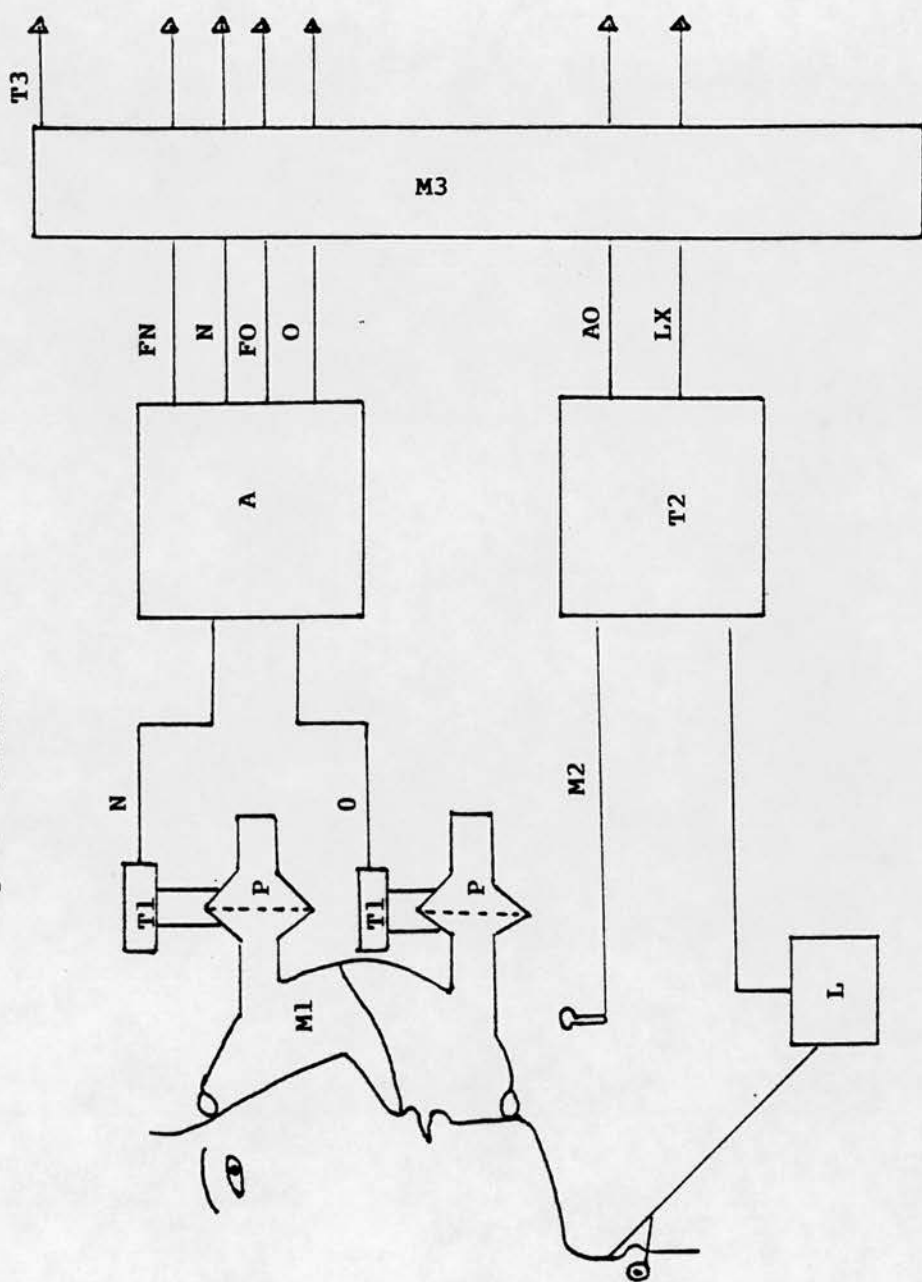
A= Amplifier

Ao= Acoustic signal

E= Electrode

FN= Filtered nasal airflow

FO= Filtered oral airflow

L= Laryngograph

Lx= Larynx signal

M1= Mask

M2= Microphone

M3= Mingograph

N= Nasal airflow

O= Oral airflow

P= Pneumotachograph

T1= Transducer

T2= Tape-recorder

T3= Time marker

(FN), using a low-pass filter of 90 Hz for the male speaker and of 130 Hz for the female speaker; trace 3 is the actual waveform of the nasal airflow (N), it represents the airflow out through the nose and thus indicates the degree of velum closing and opening during speech; trace 4 is the filtered oral airflow (FO) wave form; trace 5 is the unfiltered oral airflow waveform (O), it represents the airflow through the mouth and thus it indicates the degree of obstruction and/or the direction of the air-stream in the mouth during the production of sounds; trace 6 is the Lx trace which represents the presence or absence of voice during speech and thus shows the presence of voicing by a regular waveform (a spiky line) and the absence of it by a straight line; trace 7 represents the actual speech waveform picked up by the microphone; it is the acoustic signal (AO).

As the acoustic quality of speech was considerably affected by the enclosure of the mouth and the nose in the cavity of the mask and by the interference of the noise of the mingograph in the background, the utterances to be investigated were first tape recorded in a recording studio without the mask on. This initial recording was done in the recording studio of the Phonetic Laboratory of the Department of Linguistics at the University of Edinburgh.

The subject was asked first to breathe in and out through the nose only and then through the mouth only

to ensure that there was no leakage through the rubber partition separating the nose from the mouth. The subject then read each of the test items three times in isolation and three times in the carrier phrase /ču:f...ħa:lan/ (ˊsee...nowˊ). Speech tempo or rate was not directly controlled. But it was hoped that by reading the long list of test items three times in citation form in one breath group and three times in context would put the speaker in a consistent rhythm which would reduce the variations in the rate of the utterances.

6.1.3. Subject

Two adult native speakers of QA, one was male and the other female, read the test items.

6.1.4. Data

The data consisted of words in citation forms and in context. By imbedding the words in a carrier phrase it is hoped to elicit more natural utterances from the informants.

Each subject read a word list of 729 items six times, three times in isolation and three times in a carrier phrase (giving us a total of 8748 items), at a normal conversational rate with fixed stress and pitch pattern. The test word list exploits all the conditions

that may influence the duration of the four vowels /i/, /a/, /i:/ and /a:/: vowel height, vowel length, voicing, place of articulation, manner of articulation, gemination, pharyngealization, word length, position in the word and stress (see Appendix H for a full list of the test-words).

6.2. Analysis

The corpus of the data is reduced by analysing only two repetitions out of the six repetitions for each test item: the middle repetition in the isolated word list and the middle repetition in the phrase list. Thus reducing the corpus to 2916 items only. From the airflow records, one can see that speech is made up of continuous patterns reflecting the continuous movements of the articulators. It is not made of separated discrete segments, hence dividing or segmenting the continuous waveforms of speech on the airflow records into different types of consonants and vowels is artificial and arbitrary to some extent. But a knowledge of the acoustics, articulatory and aerodynamic characteristics of speech helps in making a fairly accurate segmentation.

The airflow records were first analyzed by drawing the zero-flow lines horizontally across the records for both the nasal and oral airflow traces and then drawing segmental lines vertically. The convergence of the oral

trace and its zero or base line indicates a complete obstruction of the airflow through the mouth, thus indicating a complete oral closure. And the convergence of the nasal trace and its zero flow line indicates a complete obstruction of the airflow through the nose. Any upward excursion of the nasal and oral traces from their base lines indicates a lack of complete oral and nasal closure. The amplitude of the curve depends on the amount of airflow executed through the nose and/or the mouth. The Lx trace indicates the presence of voicing by a spiky line, representing the vibration of the vocal folds, and indicates the absence of voicing by a straight line. Thus segment boundaries were generally drawn at every point where there is a significant change in the pattern of the tracings, mirroring a change in articulation. Plosives are easily identified by the absence of oral and nasal airflow showing a straight line on the mouth and nose tracings (they were measured from the moment articulators begin to come together indicated by a significant drop in the airflow rate) and their release is characterized by a sharp upward peak immediately after the closure and aspiration is indicated by the delay in voicing onset time. Nasals also are easily recognized by the presence of an upward excursion on the nasal trace indicating a lowered velum and flow of air through the nose, while the flow through the mouth decreases to zero as it approaches its base line.

Fricatives exhibit normally a two-humps pattern, as the oral airflow rises upward to a peak and then falls downward and then rises up again. Vowels exhibit a rising oral airflow trace which continues in a straight line above the base line without changing the pattern during its duration and exhibits a simultaneous periodic voice waveform on the Lx trace. Vowels were first measured in millimeters on the mingograms where 250 millimeters represent one second. The millimeters were then converted to milliseconds as 1 millimeter equals 4 milliseconds.

6.3. Intrinsic Factors Influencing Vowel Duration

6.3.1. Vowel height

There are quite a number of studies in the literature which investigated the intrinsic duration of vowels in several languages: In English by Heffner 1937, House and Fairbanks 1953, Peterson and Lehiste 1960, House 1961 and Delattre 1962; in German by Maack 1949; in Danish by Fischer-Jørgensen 1955; in Swedish by Elert 1964; in Thai by Abramson 1962; in Lappish by Aima 1918; in Spanish by Navarro Tomás 1916; in Arabic by Absi 1966 (Standard Arabic) and Al-Jazary 1981 (Iraqi Arabic). All

these studies have revealed that open or low vowels are longer in duration than close or high vowels, thus, proving likely to be a universal characteristic of human speech. Absi's 1966 acoustic study of vowel duration in standard Arabic revealed that open vowels are longer than close vowels as he reports that the average duration for the vowels /a/ and /i/ to be 146 msec and 132 msec respectively and the average duration for /a:/ and /i:/ to be 288 msec and 250 msec respectively. Al-Jazary's (1981) acoustic and aerodynamic investigation of vowel duration in Iraqi Arabic confirms Absi's results as he found that all open vowels are significantly longer than their corressponding close vowels no matter whether they are long or short, back or front, rounded or unrounded. The average durations of /a/, /i/ and /u/ were 87.5 msec, 60 msec and 72.5 msec respectively; and the average durations for /a:/, /i:/ and /u:/ were 175 msec, 112.5 msec and 117.5 msec respectively.

The result of our investigation of the relation between the height of the vowel and its duration for QA supports the claim reported in the literature. Tables 6.3.1.a and b are represented graphically in Graphs 6.3.1.a, b and c. They show that in the isolated word list /i/ and /a/ have an average duration of 87 msec and 106 msec respectively. The ratio between the two means is 0.82. The difference between the two means is highly significant (t338=5.38, p<0.001). /i:/ and /a:/ have an

Table 6.3.1.a

Average durations in msec and ratios of high to low vowels when all the consonant environments are pooled in isolated words. Subject FB.

Vowel	Duration	Ratio	Significance
i	87	0.82	p < 0.001
a	106		
i:	184	0.84	p < 0.001
a:	218		

Table 6.3.1.b

Average durations in msec and ratios of high to low vowels when all the consonant environments are pooled. In phrase. Subject FB.

Vowel	Duration	Ratio	Significance
i	71	0.87	p < 0.001
a	81		
i:	138	0.77	p < 0.001
a:	178		

Graph showing the average durations of /i/,
/a/, /i:/ and /a:/ when all environments are pooled
in isolation and phrase. Speaker FB.
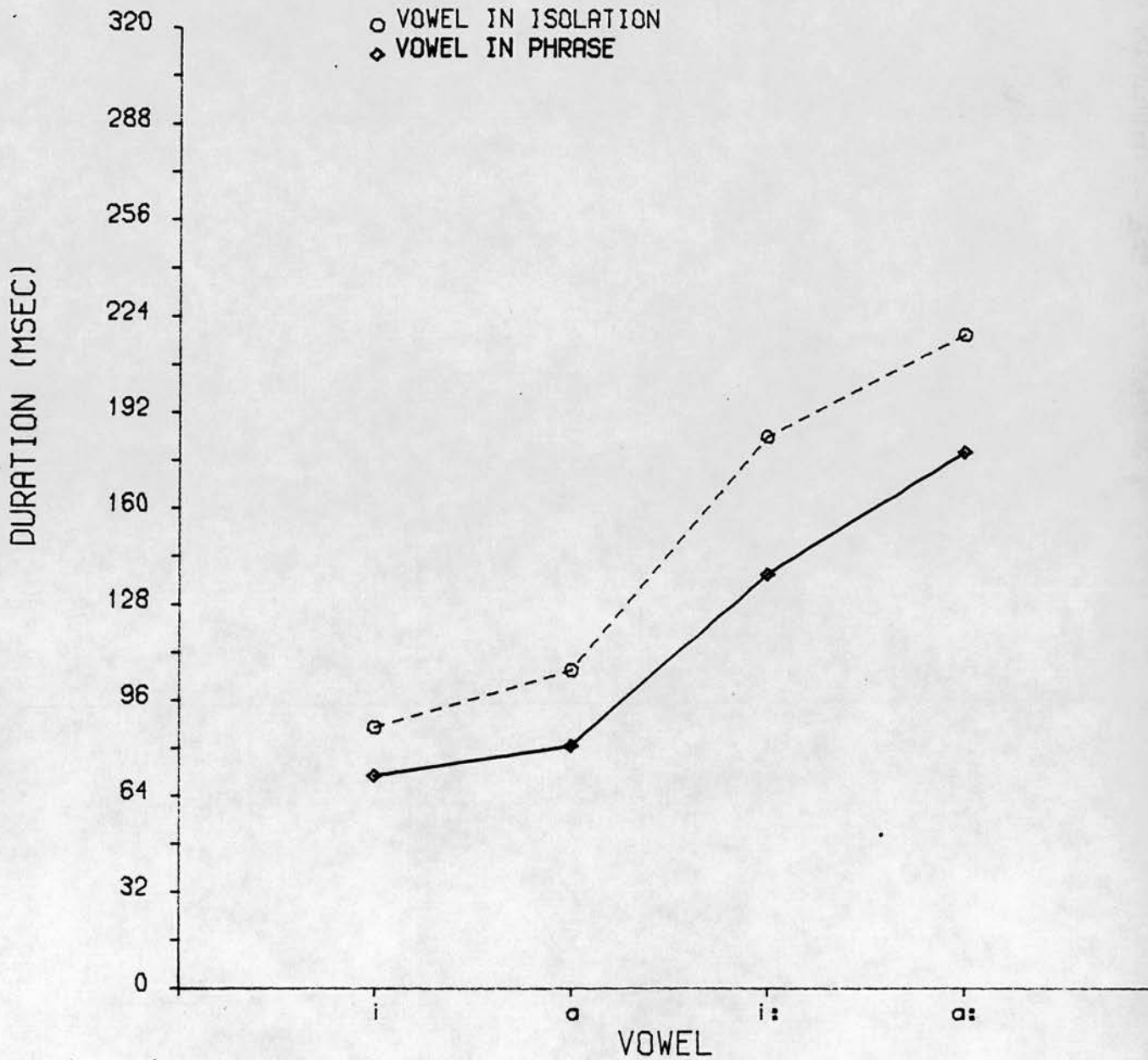
Figure 6.3.1.a

Graph showing the mean durations of /i/, /a/, /i:/
and /a:/ in monosyllabic, general and polysyllabic
positions. In isolation. Speaker FB.
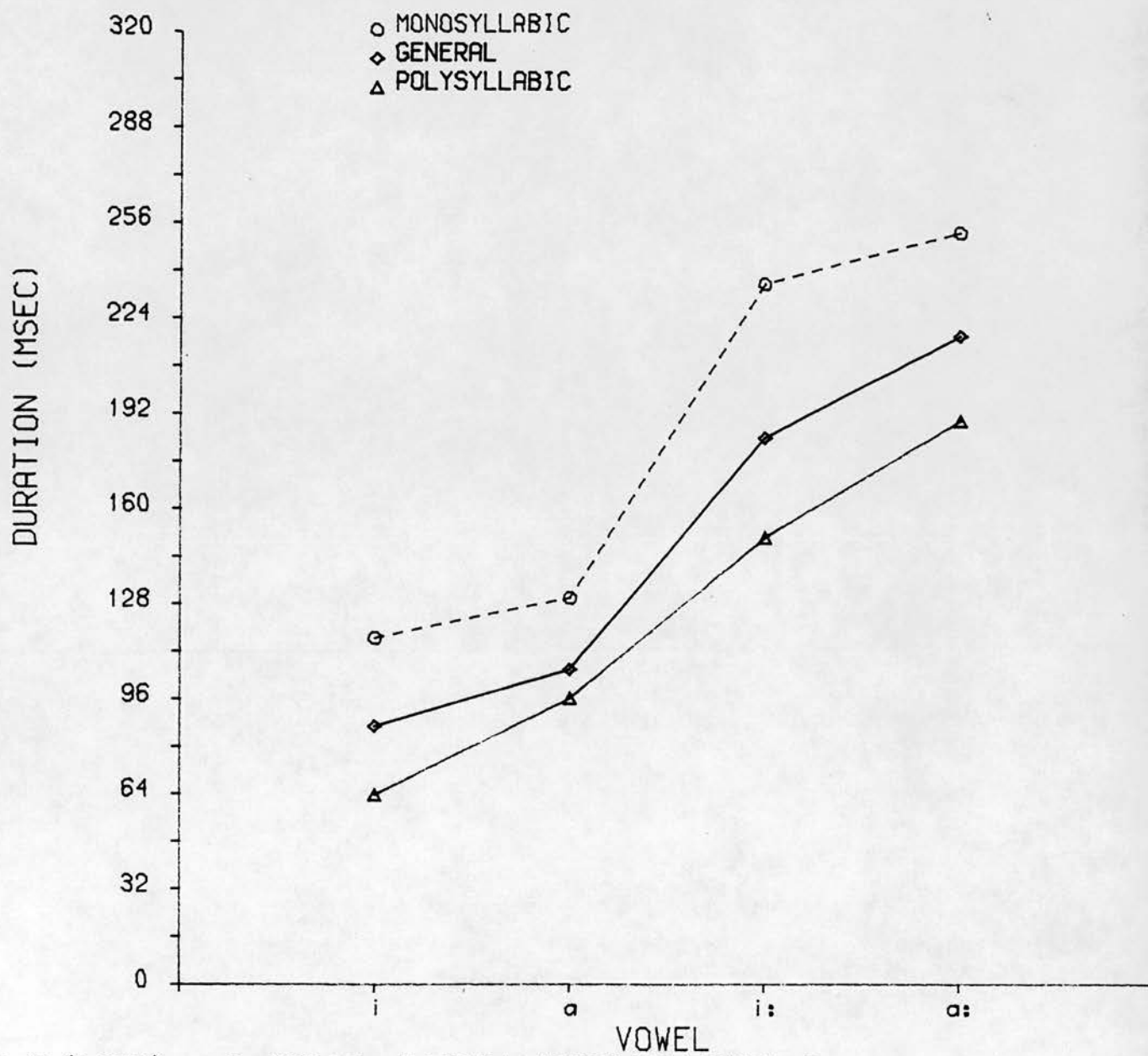
Figure   6.3.1.b

Graph showing the mean durations of /i/, /a/, /i:/
and /a:/ in monosyllabic, general and polysyllabic
positions. In phrase. Speaker FB.
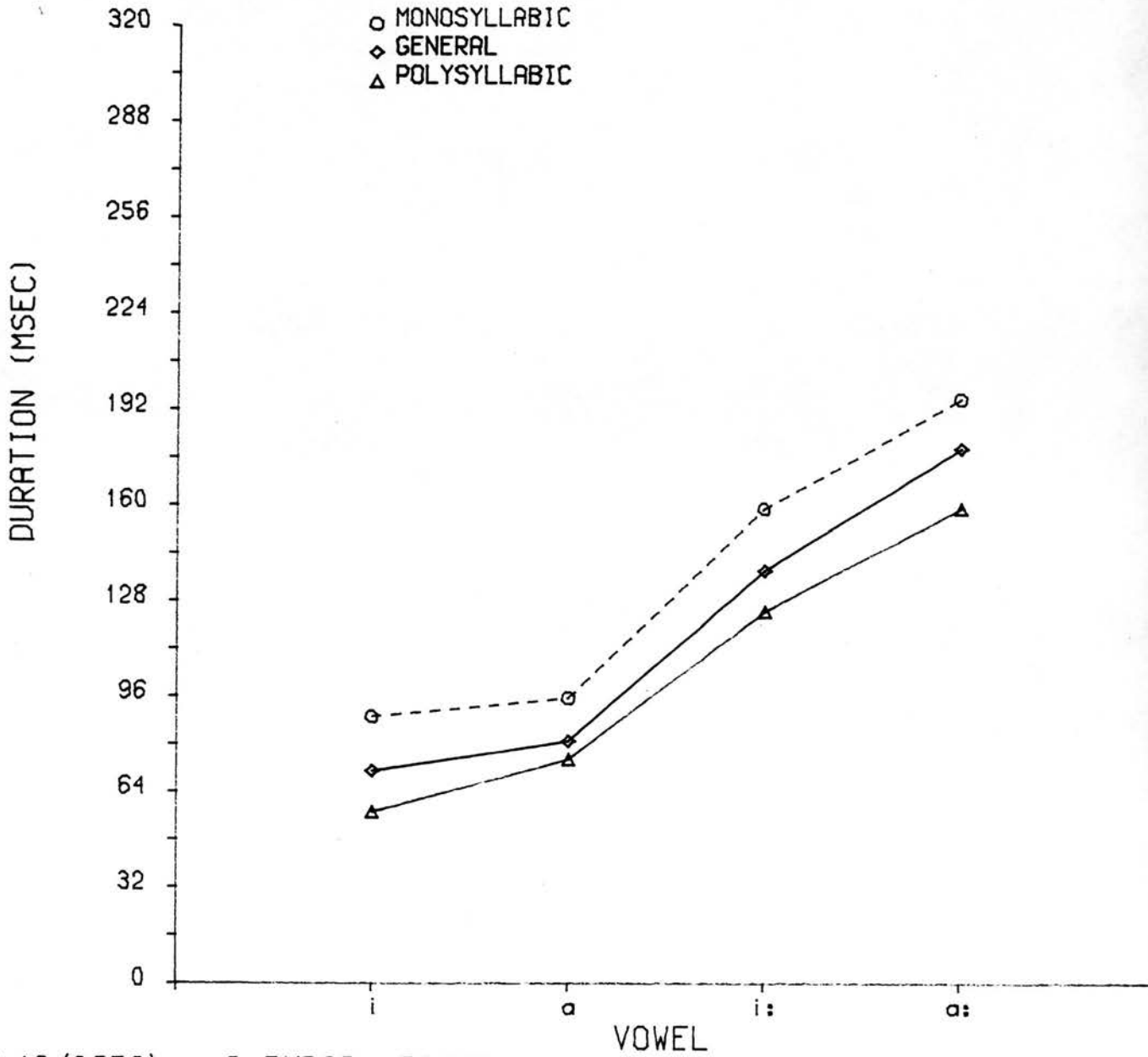
Figure 6.3.1.c

average duration of 184 msec and 218 msec respectively, the ratio between the two values is 0.84. The durational difference between the two means is very significant (t224=4.20,p<0.001). In phrase (in words embedded in the context of the carrier phrase) /i/ is 71 msec long and /a/ is 81 msec long and the ratio between them is o.87 and the difference is reached a highly significant level (t337=4.10,p<0.001) ; /i:/ is 138 msec long and /a:/ is 179 msec long, the ratio between them is 0.77, and the difference is very significant (t221=7.04,p<0.001).

The durational difference between high and low vowels seems to be only phonetically significant as it hovers around the just-noticeable differences value (JND´s) suggested by Lehiste (1970) "the just-noticeable differences in duration are between 10 and 40 msec." (p.13). Thus it is not likely to have any perceptual effect.

Attempts to explain the acoustic durational differences between open and close vowels resulted in two hypotheses: the ´energy expenditure´ hypothesis and the ´the articulatory distance´ hypothesis. The ´energy expenditure´ hypothesis was first suggested by Meyer (1903) who is quoted in Lindblom (1968) as follows "the temporal organization of speech sounds is determined by the amount of physiological energy that is consumed in producing them. During a close vowel more energy is expended than during an opener one. If the energy per

vowel were kept constant [i] would be shorter than [a]" (p.22). Thus this hypothesis claim that high vowels require more energy than low vowels because of the elevation of the tongue and that this compensation of energy causes a shortening of the vowel. The 'articulatory distance' hypothesis was first suggested by Jespersen (1926) who was quoted by Lindblom as saying that "the duration of a vowel is a function of its articulatory 'distance' to the adjacent consonants" (p.23). This hypothesis provides a plausible interpretation for the variations in vowel duration as a function of tongue height. Thus the longer articulatory movement the tongue has to make to achieve a certain conFiguration for the following consonant, the more time it takes. The longer movement required for the open vowel takes more time to achieve, thus causing the lengthening of its duration. This hypothesis was substantiated by House & Fairbanks (1953), Maack (1953), Fischer-Jørgensen (1964) and Lindblom (1968) who examined the open-close dimension of vowels not in terms of tongue height, but in terms of jaw opening and he found that "when vowel duration in the context of bilabial stops is plotted against mandibular position a positive correlation can be observed...the lower the jaw the longer the vowel" (p.25).

6.3.2. The effect of vowel length

Vowel length is another factor which influences the acoustic duration of vowels. It has been reported in the literature that in languages where there is a phonemic distinction between short and long vowels, the long vowels are twice as long as their corresponding short vowels and that in general the ratio of short to long vowels is about 50%. Fischer-Jørgensen (1955) reports that in Danish the average duration of the short vowels is 50.5% of that of the long vowels. Zwaardemaker & Eijkman (1928) found that the duration of short vowels in Dutch to be 40-50% of that of long vowels. Abramson (1962) study of Thai revealed that the ratios of short to long vowels are in the range of 28-50%. Absi's (1966) study of Arabic showed that the average ratio of i/i: to be 52.8%, a/a: 50.7% and u/u: 52.7%.

Tables 6.3.2.a and b show that in QA long vowels are very significantly longer than their short counterparts. In isolated words /i/ has an average duration of 87 msec and /i:/ is 184 msec. The ratio between them is 0.47 and the difference (97 msec) is very significant (t208=-15.97, p<0.001). /a/ has a mean duration of 106 msc and /a:/ 218 msec. The ratio between the two means is 0.48 and the difference (112 msec) is highly significant (t354=-24.65, p<0.001). In phrase /i/ is on average 71 msec long and /i:/ is 138 msec long. The ratio between the two values is 0.51 and the difference (67 msec is very significant (t206=-17.08, p<0.001). /a/ has an average duration of 81

Table 6.3.2.a

Average durations in msec and ratios of short to long vowels when
all the consonant environments are pooled. In isolated words.
Subject FB.

Vowel	Duration	Ratio	Significance
i	87	0.47	$p < 0.001$
i:	184		
a	106	0.48	$p < 0.001$
a:	218		

Table 6.3.2.b

Average durations in msec and ratios of short to long vowels when
all the consonant environments are pooled. In phrase. Subject FB.

Vowel	Duration	Ratio	Significance
i	71	0.51	$p < 0.001$
i:	138		
a	81	0.45	$p < 0.001$
a:	179		

msec and /a:/ 179 msec. The ratio between them is 0.45 and the difference (98 msec) is very significant ($t352=-29.12$, $p<0.001$). Thus the result of our investigation is in agreement with those studies reported in the literature. The durational difference between long and short vowels is much bigger than the JND´s value, as long vowels are double the length of the short vowels. Thus it is expected to be perceptually and phonologically significant. This durational difference is not physiologically determined, it is not inherent in the physiological process, but "it is a language-specific phenomenon planned at a higher linguistic level and deliberately maintained by the speaker for phonological objectives" (Al-Jazary 1981, p.357).

6.4. Extrinsic Factors Influencing Vowel Duration

6.4.1. Segmental Factors

The effect of the preceding consonants on the durations of the following vowels has been investigated in a few languages: in English by Meyer (1903) and Peterson and Lehiste (1960), in Hungarian by Meyer & Gombocz (1909) and in Norwegian by Fintoft (1961). The results of all these studies showed that the preceding consonants did not exhibit any clear or significant

influence on the duration of the following vowels. Therefore, in this study we will be investigating the influence of the immediately following consonants on the duration of the immediately preceding vowels only, as it has proved to have a considerable effect.

6.4.1.a The effect of voicing

The lengthening effect of a following voiced consonant on the preceding vowel has been observed and investigated in many languages: In English by House & Fairbanks (1953), Lisker (1957), Peterson & Lehiste (1960), House (1961), Sharf (1962), Delattre (1962), Umeda (1975), Klatt (1973 & 1976), and Chen (1970); in French by Belasco (1953), Mack (1982); in Spanish by Zimmerman & Sapon (1958); in Norwegian by Fintoft (1961); in Icelandic by Einarsson (1927); in German by Meyer (1904); in Polish by Keating (1979); in Czech by Keating (1984); in Italian by Metz (1914); in Hungarian by Meyer & Gombocz (1909); in Kurdish by Aziz (1976); in standard Arabic by Absi (1966); in Jordanian Arabic by Mitleb (1981); in Iraqi Arabic by Al-Jazary (1981); in Saudi Arabian Arabic by Fle ge (1979) and Fle ge & Port (1981).

House and Fairbanks's (1953) study of the influence of consonant environments upon the duration of vowels in American English revealed that a vowel is significantly longer when it is followed by a voiced consonant than

when it is followed by a voiceless one; they state that a "comparison of voiceless environments with their voiced cognate environments reveals larger values for the voiced environments in every case...when all responses are pooled with respect to this characteristic...there is a statistically significant difference of 0.79 sec between the two means" (p.108). Their results also showed that a vowel is longer when followed by a voiced fricative than when followed by a voiced plosive. They propose the following interpretation for the lengthening effect of voicing "the voicing of a vowel in a voiceless environment, in contrast to a voiced environment is withheld until the physiological vowel 'target' is more clearly approximated, and terminated sooner in the transition to the following consonant." (p.108). Peterson & Lehiste's (1960) study confirmed the result of House & Fairbanks study. In their investigation of the consonantal environment on the duration of stressed vowels and diphthongs in American English they found that the duration of a vowel is considerably shorter before a voiceless consonant than before a voiced consonant and that the "ratio of vowel before voiceless consonant to vowel before voiced consonant is approximately 2:3" (p.700). On the whole their results showed that vowels become longer in the following order: voiceless stop < voiceless fricative < voiced stop < voiced fricative as they report that the "average

durations of the syllable nuclei, in ascending order, were: 18.4 csec before the voiceless plosive, 22.8 csec before the voiceless fricative, 28.0 csec before the voiced plosive, and 37.6 csec before the voiced fricative." (p.700). In his percentage change model for American English, Klatt (1973) proposes the following rule for the effect of voicing "if a vowel is followed by a voiceless consonant within the same word, shorten the vowel by 25% (relative to its duration when followed by a voiced consonant within the same word)" (p.1102).

This articulatory investigation of the effect of the voicing of the postvocalic consonant in English is confirmed by an auditory investigation. Denes (1955) investigated the effectiveness of vowel duration as a cue for the voicing characteristic of the following consonant. His result clearly showed that "the relative durations of vowel and final consonant can be used as a cue for hearing the final sound as voiced or unvoiced" (p.76). Raphael's 1972 experiment confirmed the results of Denes as he found that "all final consonants and clusters were perceived as voiceless when preceded by vowels of short durations and as voiced when preceded by vowels of long duration" (p.1298).

In his cross-language study of the effect of voicing in English, French, Russian and Korean, Chen (1970) found that, in general, in all the languages studied the duration of the vowel was longer before voiced plosives than

before voiceless plosives. But the difference was more marked for English than for the other languages. He reports the following ratios of the duration of vowels before voiceless and voiced consonants: French 0.87, Spanish 0.86, Russian and Norwegian 0.82, Korean 0.78 and English 0.61. Thus he concludes that "voicing of the adjacent consonant influences its preceding vowel to different degrees in different languages" (p.138). Chen arrives at two tentative conclusions to explain the phenomenon of voicing effect "(a) it is presumably a language universal phenomenon that vowel duration varies as a function of the voicing of the following consonant, and (b) the extent, however, to which an adjacent voiced or voiceless consonant affects its preceding vowel duration is determined by the language-specific phonological structure" (p.139).

The investigation of the effect of voicing in Arabic revealed a contradictory result. Absi's (1966) study of Standard Arabic showed that vowels before voiced consonants are longer in duration than vowels before voiceless consonants as the average duration of the short vowels was 143 msec before voiced consonants and 127 msec before voiceless consonants (the ratio is 0.88), and the average duration of the long vowels was 282 msec and 249 msec before voiced and voiceless consonants respectively (the ratio is 0.88). AL-Jazary's (1981) study of Iraqi Arabic also revealed that vowels are significantly

longer when preceding voiced consonants than when preceding voiceless consonants, but with the ratio being 0.74 for fricatives and 0.90 for plosives. Thus the difference between the effect of voiced and voiceless fricatives is more significant than the difference between the effect of voiced and voiceless plosives. The findings of the above two studies of Arabic support the claim for the universality of voicing effects.

Fledge's (1979) cross-language study of the temporal correlate of voicing in Saudi Arabian Arabic and American English revealed that in Arabic the durational differences between vowels preceding voiced versus voiceless consonants are very small (6 msec) and non-significant while in English the differences are much bigger (40 msec) and very significant. Thus voicing has no effect on vowel duration in Arabic. This temporal correlate of voicing is found to be used by Arabs when speaking English as Fledge found that in Arabic-accented English "the difference in duration of vowels before /k/ vs. /g/ and /t/ vs. /d/ is far smaller than produced by Americans" (p.173). Mitleb (1981) and (1984) investigated the effect of voicing of the following consonants on the duration of the preceding vowels in Jordanian Arabic, American English and Arabic-accented English. His results showed that in English vowels before voiced consonants were significantly longer than before voiceless consonants ($p < 0.001$); while in Arabic voicing did not show a

significant effect on preceding vowel duration. As for Arabic-accented English there was a durational difference, but the size of the effect was much smaller than that for English, and the difference between the Jordanians and Americans was significant at the level of p<0.001. Thus Mitleb concludes that voicing effect on vowel duration is not an absolute universal but rather a language-specific variable which "must be learned by second language learners to sound like speakers of the target language" (p.26).

Tables 6.4.1.a.1-4 and Graphs 6.4.1.a.1-4 reveal the result of our investigation of voicing effect in QA. FB's data exhibit the following average durations for /i/, /a/, /i:/ and /a:/ in isolated words: 93.02 msec, 100.92 msec, 179.25 msec and 220.85 msec respectively when followed by voiceless consonants; and 90.10 msec, 109.59 msec, 202.68 msec and 227.43 msec when followed by voiced consonants. The ratios of these four vowels when preceding voiceless to voiced consonants are 1.03, 0.92, 0.88 and 0.97 respectively. When all the four vowels are pooled they have a mean duration of 140.92 msec when followed by voiceless segments and 154.36 msec when followed by voiced segments. The durational difference is small (13.44 msec) and non-significant (t431=-1.93, p<0.10), and the ratio is 0.91. In phrase /i/ is 75.33 msec long, /a/ is 81.65 msec long, /i:/ is 136.08 msec long and /a:/

Table 6.4.1.a.1

Average durations in msec ratios of vowels when preceding voiceless
and voiced consonants. In Isolated words.   Subject FB

Vowel	Voiceless	Voiced	Ratio	Significance
i	93.02	90.10	1.03	$p > 0.20$
a	100.92	109.59	0.92	$p < 0.10$
i:	179.25	202.68	0.88	$p < 0.10$
a:	178.34	179.35	0.99	$p > 0.20$

Table 6.4.1.a.2

Average durations in msec ratios and significance levels of vowels
when preceding voiceless and voiced consonants. In phrase.
Subject FB.

Vowel	Voiceless	Voiced	Ratio	Significance
i	75.33	74.35	1.01	$p > 0.20$
a	81.65	87.21	0.93	$p < 0.10$
i:	136.08	148.81	0.91	$p < 0.20$
a:	178.34	179.35	0.99	$p > 0.20$

Table 6.4.1.a.3

Mean durations in msec , ratios and significance levels of vowels
preceding voiceless and voiced consonants. In isolated words.
Subject HJ.

Vowel	Voiceless	Voiced	Ratio	Significance
i	146.90	143.85	1.02	p > 0.20
a	133.37	127.49	1.04	p > 0.20
i:	199.84	183.19	1.09	p < 0.20
a:	212.61	211.48	1	p > 0.20

Table 6.4.1.a.4

Mean durations in msec , ratios and levels of significance of
vowels preceding voiceless and voiced consonants. In phrase.
Subject HJ.

Vowel	Voiceless	Voiced	Ratio	Significance
i	124.04	117.30	1.05	p > o.20
a	113.77	112.79	1	p > 0.20
i:	148.16	137.11	1.08	p < 0.10
a:	171.55	168.83	1.01	p > 0.20

Graph showing the mean durations of /i/
/a/, /i:/ and /a:/ when preceding voiced and
voiceless consonants. In isolation. Speaker FB.
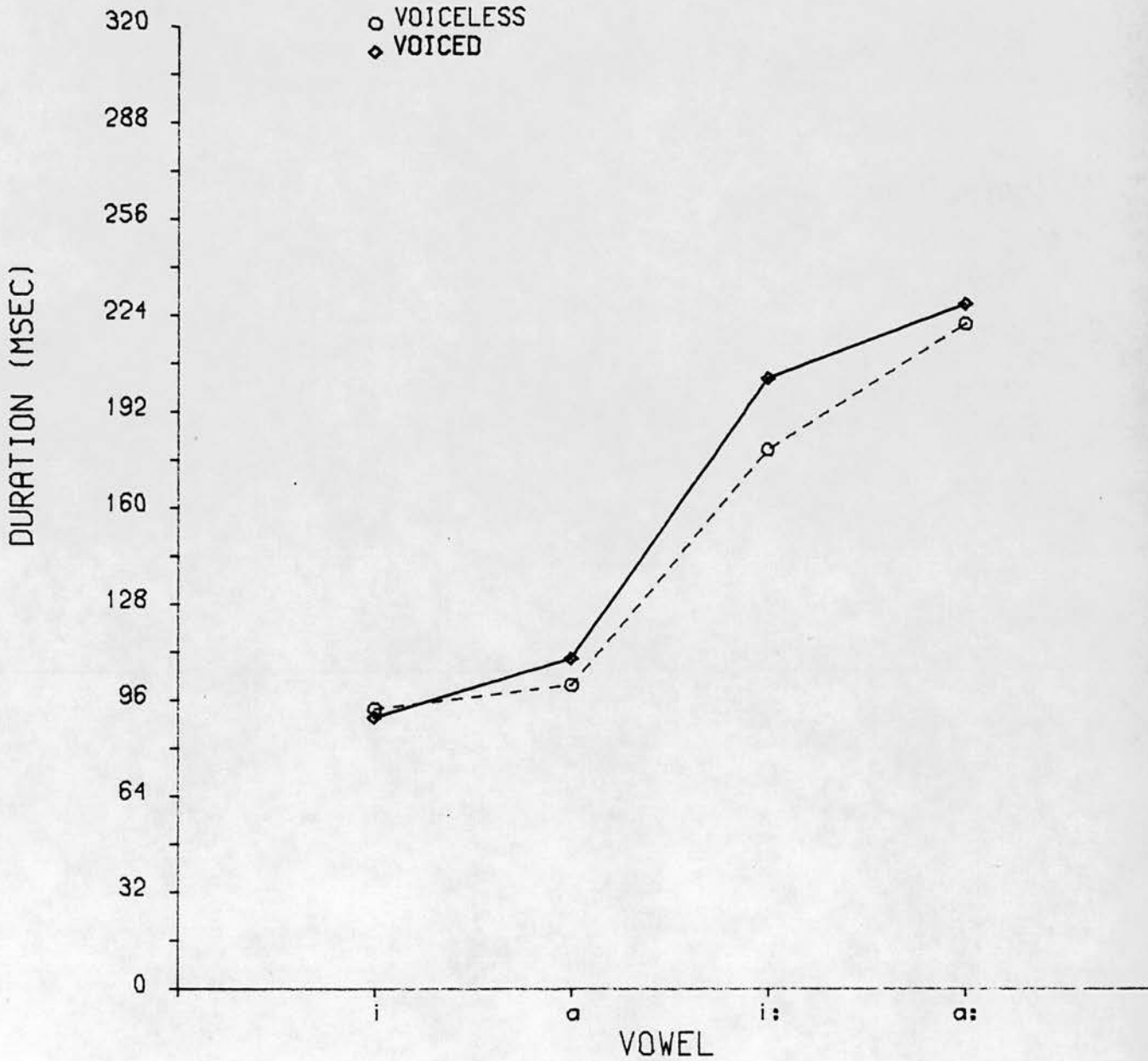
Figure 6.4.1.a.1

Graph showing the mean duration of /i/, /a/,
/i:/ and /a:/ when preceding voiced and voiceless
consonants. In phrase. Speaker FB.
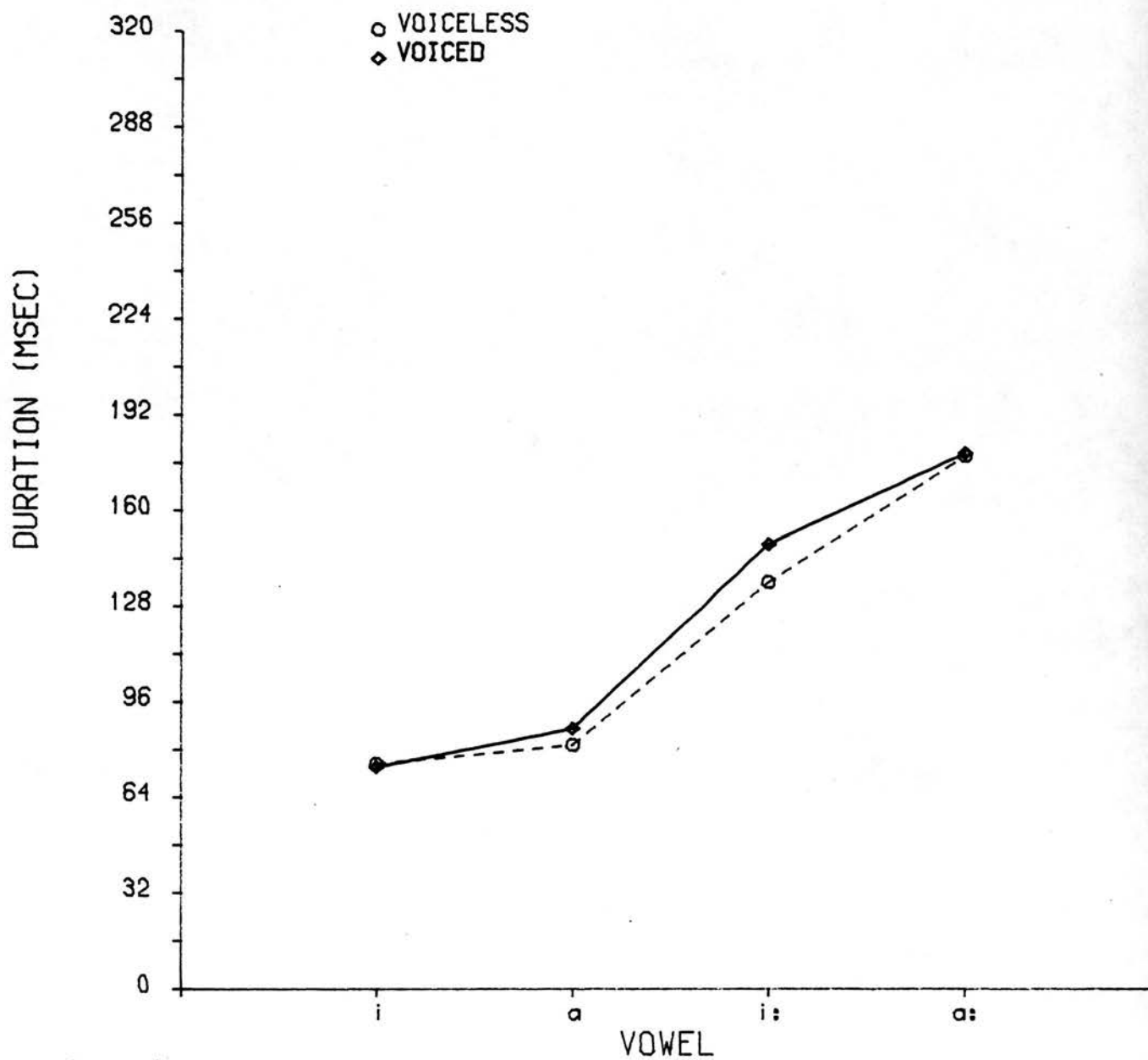
Figure   6.4.1.a.2

Graph showing the mean durations of /i/, /a/, /i:/
and /a:/ when preceding voiced and voiceless consonants.
In isolation. Subject HJ.
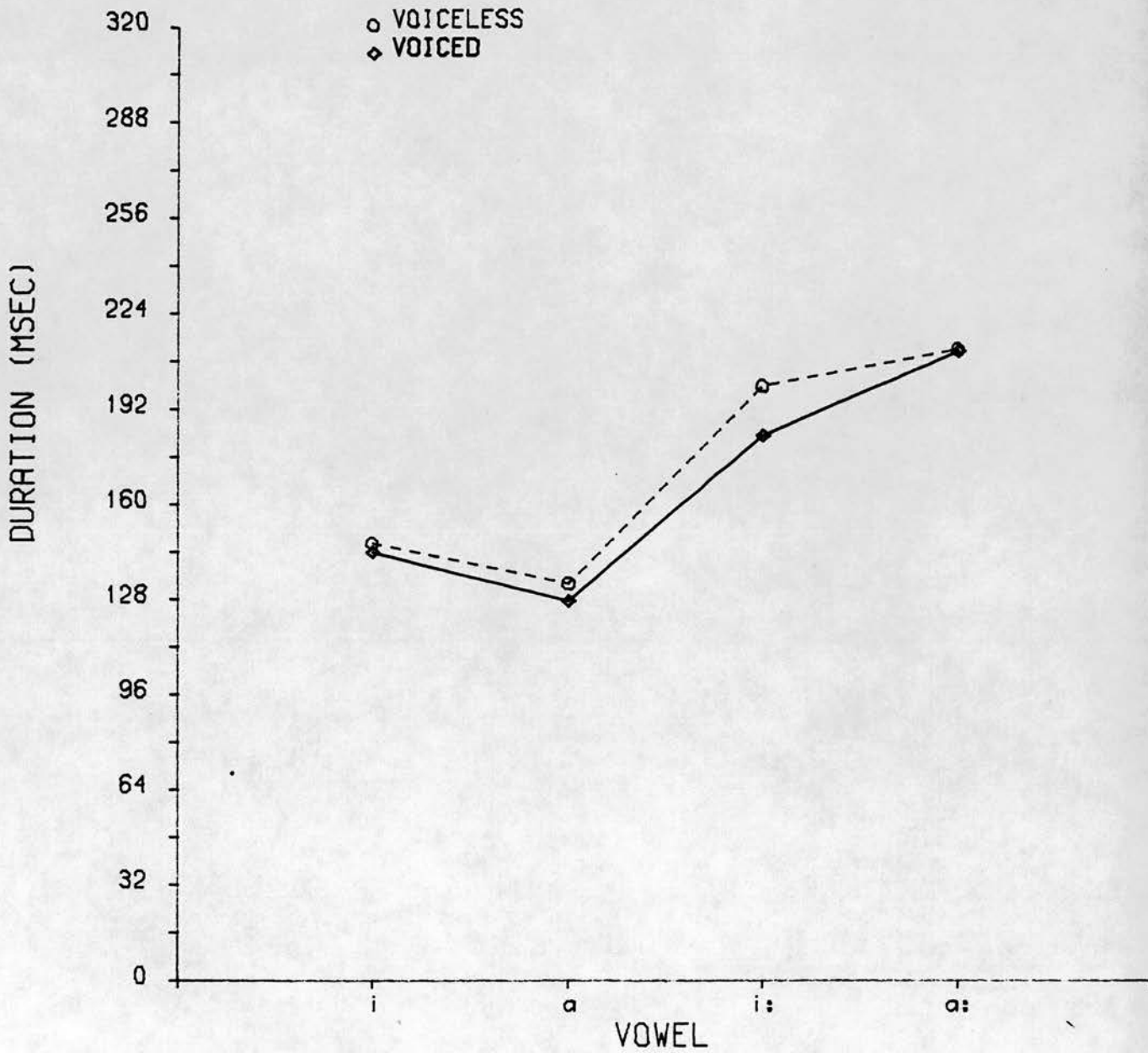
Figure   6.4.1.a.3

Graph showing the average durations of /i/, /a/, /i:/
and /a:/ when preceding voiced and voiceless consonants.
In phrase. Speaker HJ.
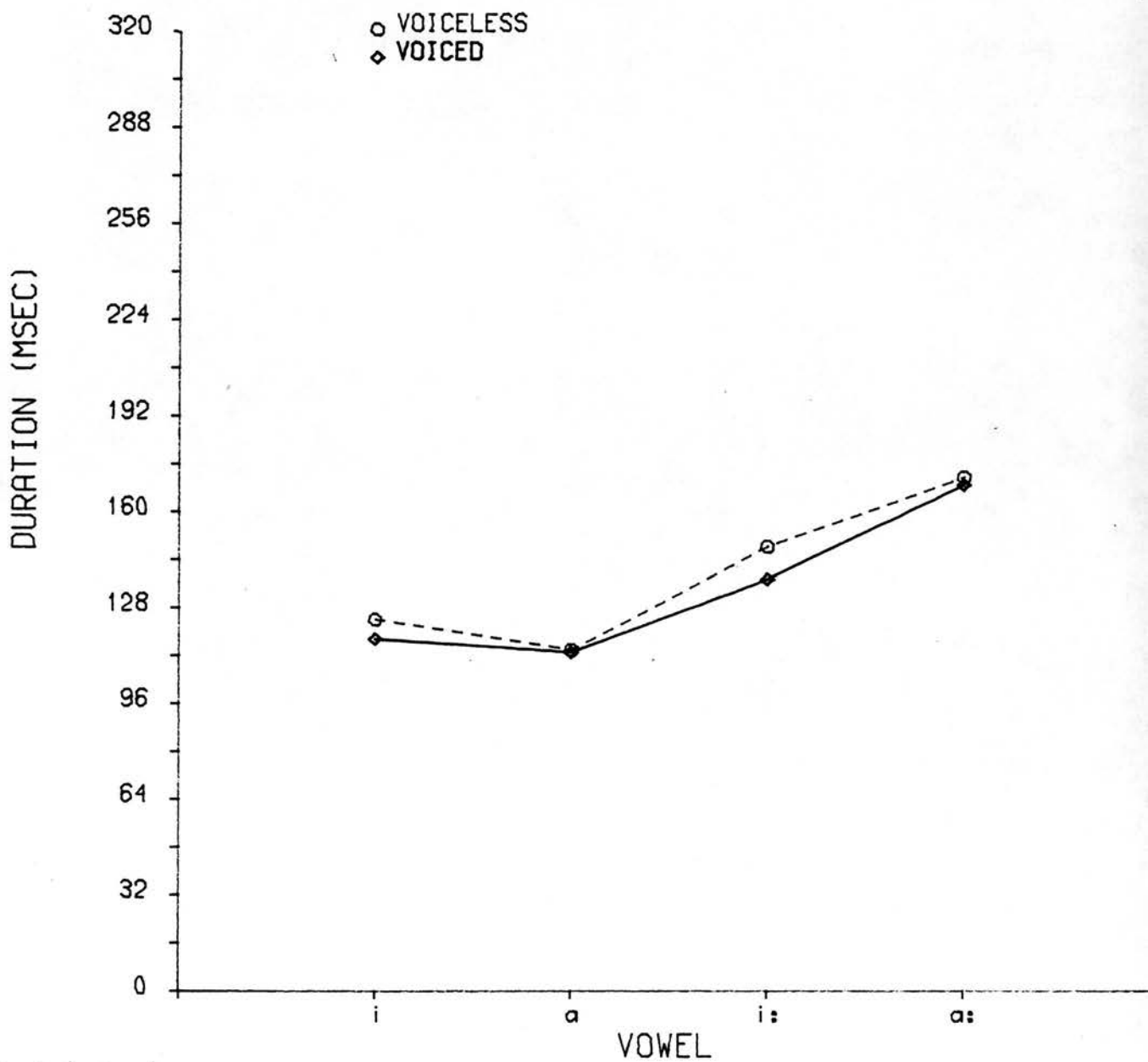
Figure 6.4.1.a.4

is 178.34 msec long before voiceless consonants; and 74.35 msec, 87.21 msec, 148.81 msec and 179.35 msec respectively before voiced consonants. The ratio of the two sets of means are as follows: 1.01, 0.93, 0.91 and 0.99. When all the four vowels are pooled they have an average duration of 112.74 msec when preceding voiceless consonants and 120.35 msec when preceding voiced consonants. The durational difference between the vowels in the two contexts is very small (7.61 msec) and is non significant (t428= -1.48, p<0.20). In isolated words HJ´s data show that the duration of /i/ is 146.90 msec, /a/ 133.37 msec, /i:/ 199.84 msec and /a:/ 212.61 msec before voiceless segments; and 143.85 msec, 127.49 msec, 183.19 msec and 211.48 msec respectively before voiced segments. The difference between vowels in voicless and voiced contexts is very slight and insignificant and the ratios between them are 1.02, 1.04, 1.09 and 1 respectively . Thus vowels preceding voiceless consonants are even slightly longer than when preceding voiced consonants. When the durations of all four vowels are pooled they have an average length of 166.17 msec in the voiceless context and 163.78 msec in the voiced context. The ratio between the two means is 1.01 and the difference is very small (2.39 msec) and non significant (t548=0.48, p>o.20). In phrase, /i/, /a/, /i:/ and /a:/ have the following mean durations: 124.01 msec, 113.77 msec, 148.16 msec and 171.55 msec respectively before voiceless consonants; and

117.30 msec, 112.79 msec, 137.11 msec and 168.83 msec respectively before voiced consonants. The ratios between the two sets of means are 1.05, 1, 1.08 and 1.01 respectively. When the durations of all four vowels are pooled they exhibit the following values: 136.29 msec when adjacent to voiceless consonants and 133 msec when adjacent to voiced consonants. The ratio between the two values is 1.02 and the difference is very small (3.29 msec) and highly insignificant ($t548=0.97$, $p>0.20$).

Thus, the result of our investigation of the effect of voicing in QA disagrees with the findings of Absi's (1966) and Al-Jazary's (1981) studies, but it agrees with the findings of Fledge's (1979), Fledge & Port's (1981) and Mitleb's (1981 & 1984). Our findings also in agreement with Keating's (1979) results for Polish where she found that voicing has no effect on the durations of vowels as the ratio of vowels before voiceless and voiced consonants was 0.99. Keating (1984) also found a similar result for Czech where the ratio of /a/ before voiceless to voiced consonants was 0.95 and was not significant ($t30=-0.37$, $p>o.20$). We may conclude that the effect of voicing is not automatic and not language-universal as it does not occur universally across languages. It is a language-specific phenomenon as it operates in some languages like English, French and Russian while it does not operate in other languages like Arabic, Polish and Czech.

There are a number of hypotheses which have been offered to explain the differences in vowel duration as a function of the voicing of the following consonant, like the "laryngeal adjustment" hypothesis which was first suggested by Halle & Stevens (1967) who claim that the abduction of the vocal folds in voiceless consonants takes less time to achieve than the adjustment needed in the adduction position required for the voiced consonants and hence "the longer laryngeal adjustment time required for a voiced consonant would necessitate an increased duration of the preceding vowel; the consonantal constriction cannot be effected before the vocal cords are positioned in a way that will guarantee uninterrupted vocal cord vibration during the constricted interval" (pp.269-270). This hypothesis has been rejected by Fisher-Jørgensen (1968), Chen (1970) and Lisker (1974) as neither electromyographic nor fiberoptic investigaion confirmed such laryngeal adjustment for voiced consonants. The "temporal compensation" hypothesis was first suggested by Kozhevnikov & Chistovich (1967) to provide an interpretation for the difference in the acoustic durations of vowels preceding voiced versus voiceless consonants as they state that the "difference in the interval of the intervocalic consonants (the closure for ´p´ should be longer than the closure for ´b´) should be accompanied by a compensating change of the duration of the adjacent vowel." (p.106). Thus the closure

intervals of the following consonants vary as a function of voicing. Voiced consonants are shorter in duration than voiceless consonants and thus they are inversely related to the durations of the vowels. The shorter duration of the vowel is compensated for by the longer duration of the following voiceless consonant closure and vice versa. This hypothesis may only explain the voicing effects in languages like English where there is a correlation between vowel length and the voicing of the following consonants. It does not explain the absence of variation in vowel duration even though there is a variation in the consonant duration, between voiced and voiceless consonants like Arabic and Polish where the durations of voiceless consonants are much longer than voiceless consonants, but this variation in consonant duration does not affect the duration of the preceding vowels. This "indicates that the vowel shortening effect, in those languages where it occurs, is not physiologically determined by the closure duration effect" (Keating 1984, p.40).

Thus the effect of voicing is not a phonetic universal nor it is automatic and predictable. It is a language-specific phenomenon. Keating (1984) states that this "example of extrinsic vowel duration patterning shows that a supposed phonetic universals not in fact universally attested. Because of this fact, and because the extent and level of duration differences varies across

those languages with the pattern, the pattern cannot be automatic or predictable. Each language must specify its own phonetic facts by rule." (p.41).

6.4.1.b.

The effect of manner of articulation

The influence of the manner of articulation of a following consonant upon the duration of a preceding vowel is not as intensively investigated as the effect of voicing. But in general, most of the studies have revealed that vowels are longer in duration before fricatives than before plosives. House and Fairbanks (1953) and Peterson and Lehiste (1960) found that in English the duration of a vowel increases in the following order when the postvocalic consonants are voiceless stops< voiceless fricatives< nasals< voiced stops< voiced fricatives. Thus vowels are longest before voiced fricatives and shortest before voiceless stops. In Swedish, Elert (1964) found that vowels are shortest before nasals and longest before voiced fricatives and that the length of a vowel increases in the following order: nasals< voiceless plosives< voiceless fricatives< voiced plosives< voiced fricatives. Absi's 1966 study revealed that in Arabic plosives have the most shortening

effect while liquids have the most lengthening effect on preceding vowels and that the duration of a vowel increases in the following order: stops< nasals< fricatives< liquids. Al-Jazary´s 1981 study of Iraqi Arabic showed that vowel length increases in the following order when preceding voiceless plosives< voiceless fricatives< voiced plosives< voiced fricaives.

Tables 6.4.1.b.1-4 and Graphs 6.4.1.b.1-4 show the influence of the manner of articulation of the postvocalic consonants on the preceding vowels in QA (VDF=voiced fricative, VSF=voiceless fricaive, N=nasal, VDP=voiced plosive, VSP=voiceless plosive and PHZD= pharyngealized). FB´s data show that vowels, in the isolated words, have the tendency to decrease in their duration value in the following order as an effect of manner of articulation of the following consonants:

/i/ Voiced fricatives> voiceless fricatives> emphatics> nasals> voiced plosives> voiceless plosives.

/a/ voiced fricatives> voiced plosives> nasals> emphatics> voiceless fricatives> voiceless plosives.

/i:/ voiced plosives> voiced fricatives> nasals> voicesless fricatives> emphatics> voiceless plosives.

/a:/ voiced fricatives> voiced plosives> voiceless plosives> nasals> emphatics> voiceless plosives.

In the phrase condition the tendency is that

/i/ voiced fricaives> voiceless fricaives> emphatics>

Table 6.4.1.b.1

Mean durations of vowels when preceding voiced fricatives,
voiceless fricatives, nasals, voiced plosives and pharyngealized
consonants. In isolated words. Subject FB.

Vowel	VDF	VSF	N	VDP	VSP	PHZD
i	101.42	99.03	87.88	80.70	79.71	97.84
a	113.52	101.67	109.88	111.07	98.48	108.08
i:	201.55	186.13	196	208.36	167.77	171.50
a:	238	226.94	210	237.18	204.92	208.66

Table 6.4.1.b.2

Mean durations of vowels when preceding voiced fricatives,
voiceless fricatives, nasals, voiced plosives, voiceless
plosives and pharyngealized consonants. In phrase.
Subject FB.

Vowel	VDF	VSF	N	VDP	VSP	PHZD
i	81.42	79.40	71.88	68.70	66.14	77.07
a	91.75	81.94	84.11	89.55	81.20	87.82
i:	141.25	138.80	152	144	131.55	127.75
a:	179.90	180.35	165.36	187.50	173.07	172.80

Table 6.4.1.b.3

Mean durations in msec of vowels when preceding voiced fricatives voiceless fricatives, nasals, voiced plosives, voiceless plosives and pharyngealized consonants. In isolated words. Subject HJ.

Vowel	VDF	VSF	N	VDP	VSP	PHZD
i	148.25	159.54	147.57	137.26	123.79	131.04
a	140.53	141.02	122.33	121.35	121.58	120.57
i:	185.77	205.76	186.84	180.60	187.25	174.22
a:	227.91	223.05	189.23	212.64	193.71	223

Table 6.4.1.b.4

Mean durations in msec of vowels when preceding voiced fricatives, voiceless fricatives, nasals, voiced plosives, voiceless plosives and pharyngealized consonants. In phrase. Subject HJ.

Vowel	VDF	VSF	N	VDP	VSP	PHZD
i	123.16	134.18	113.78	118.93	105.51	114
a	125.88	119.51	100.33	112.28	104.91	110.76
i:	144.88	155.76	133.61	139.20	132	133.55
a:	173.41	176.47	155.14	176.16	162.66	183.87

Graph showing the effect of manner of articulation of the
following consonant on the duration of vowels.
In isolation, speaker FB
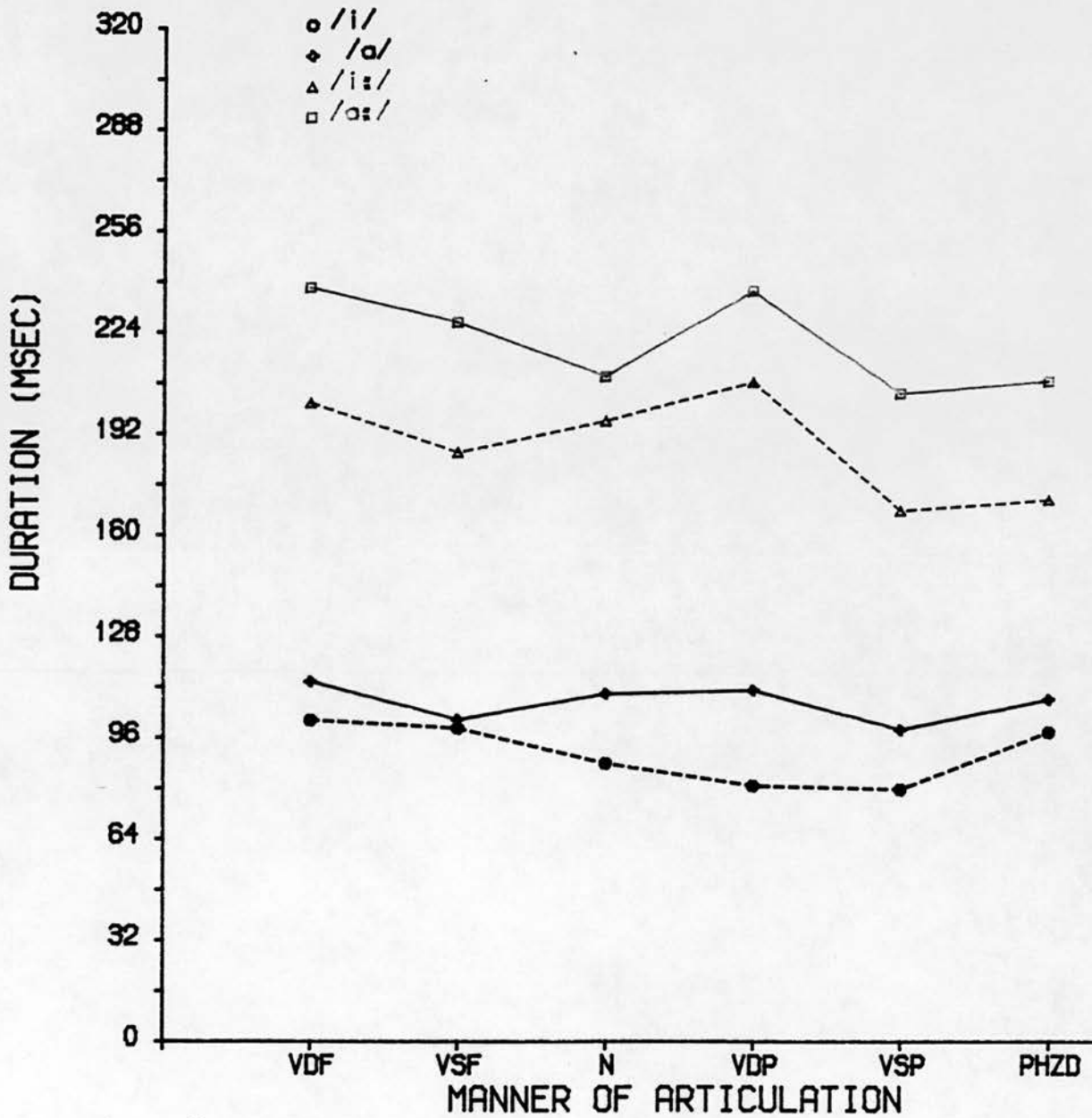
Figure 6.4.1.b.1

Graph showing the effect of manner of articulation of the
following consonant on the duration of vowels.
In phrase, speaker FB
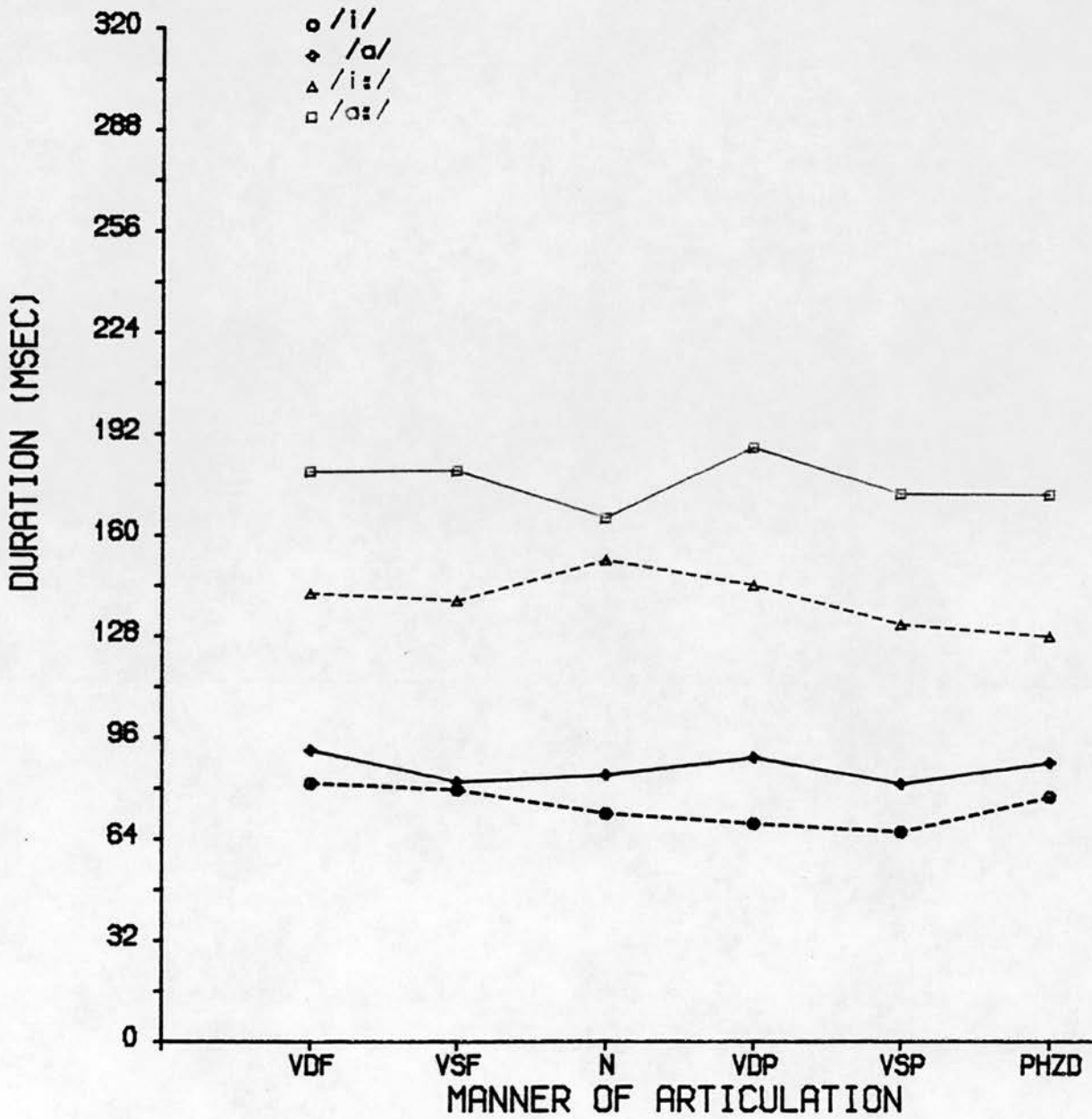
Figure 6.4.1.b.2

Graph showing the effect of manner of articulation of the
following consonant on the duration of vowels.
In isolation, speaker HJ.
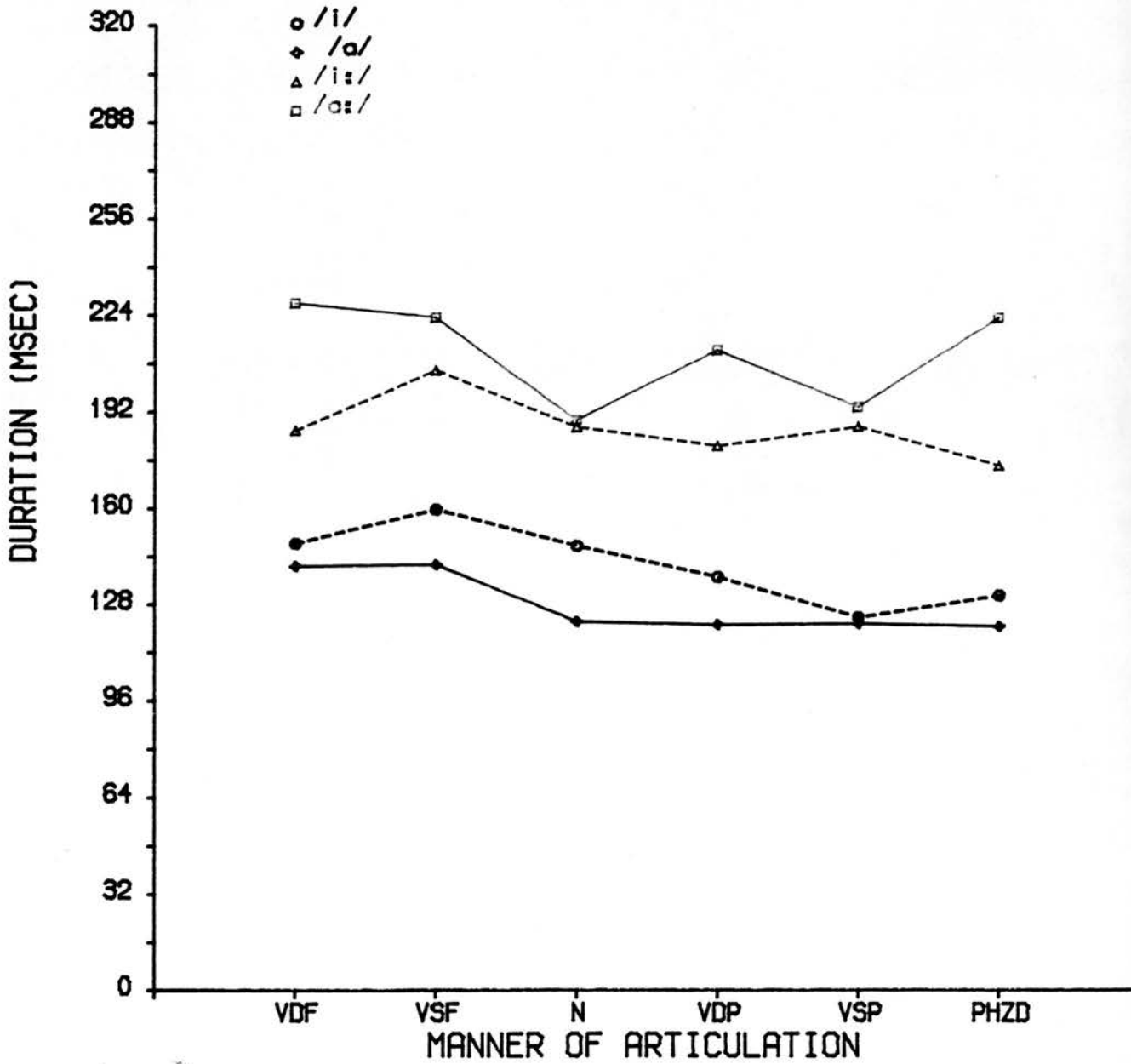
Figure   6.4.1.b.3

Graph showing the effect of manner of articulation of the following consonant on the duration of vowels.
In phrase, speaker HJ.
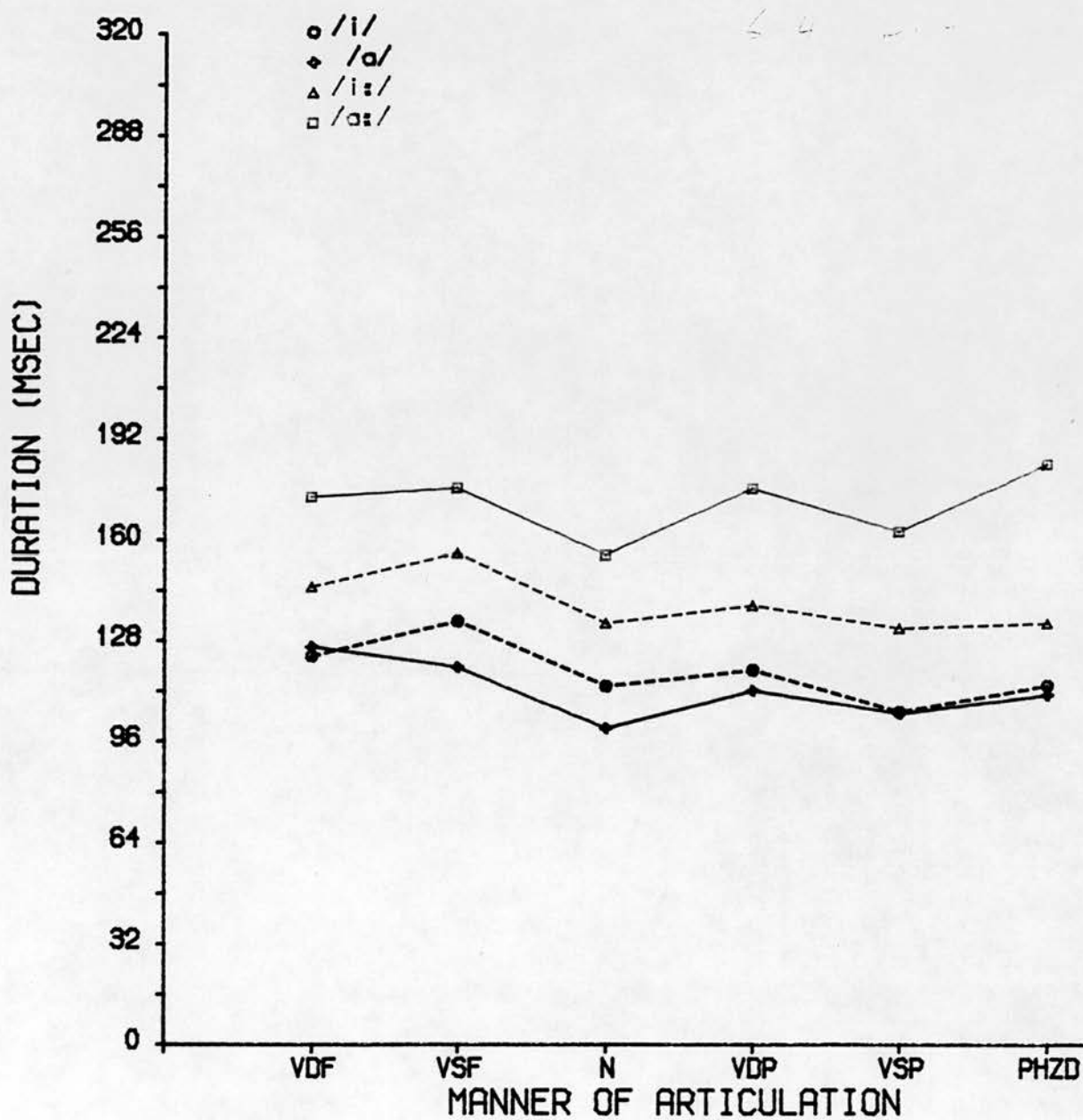
Figure   6.4.1.b.4

nasals> voiced plosives> voiceless plosives.

/a/ voiced fricatives> voiced plosives> emphatics> nasals> voiceless fricatives> voiceless plosives.

/i:/ nasals> voiced plosives> voiced fricatives> voiceless fricatives> voiceless plosives> emphatics.

/a:/ voiced plosives> voiceless fricatives> voiced fricatives> voiceless plosives> emphatics> nasals.

Thus the short vowels /i/ and /a/ are longest when preceding voiced fricatives and shortest when preceding voiceless plosives in both the isolation and phrase conditions. /i:/ is longest before voiced plosives and shortest before voiceless plosives in isolation, and longest before nasals and shortest before emphatics in phrase. /a:/ is longest before voiced fricatives and shortest before voiceless plosive in isolation , and longest before voiced plosives and shortest before nasals in phrase.

HJ´s data reveal that in isolated words vowels have the tendency to decrease in their duration in the following order:

/i/ voiceless fricatives> voiced fricatives> nasals> voiced plosives> emphatics> voiceless plosives.

/a/ voiceless fricatives> voiced fricatives> nasals> voiceless plosives> voiced plosives> emphatics.

/i:/ voiceless fricatives> voiceless plosives> nasals> voiced fricatives> voiced plosives> emphatics.

/a:/ voiced fricatives> voiceless fricatives> emphatics>

voiced plosives> voicesless plosives> nasals.

In phrase vowels have the following tendency:

/i/ voiceless fricatives> voiced fricatives> voiced plosives> nasals> emphatics> voiceless plosives.

/a/ voiced fricatives> voiceless fricatives> voiced plosives> emphatics> voiceless plosives> nasals.

/i:/ voiceless fricatives> voiced fricatives> voiced plosives> nasals> emphatics> voiceless plosives.

/a:/ emphatics> voiceless fricatives> voiced plosives> voiced fricatives> voiceless plosives> nasals.

Thus /i/ is longest when preceding voiceless fricatives and shortest when preceding voiceless plosives in both the isolated word and phrase conditions. /a/ is longest before voiceless fricatives and shortest before emphatics in the isolated words condition, and longest before voiced fricatives and shortest before nasals in the phrase condition. /i:/ is longest before voiceless fricatives in both conditions, whiles it is shortest before emphatics in the isolation and before voiceless plosives in phrase. /a:/ is longest before voiced fricatives and shortest before nasals in isolated words, while it is longest when preceding emphatics and shortest when preceding nasals in phrase.

In general, we may say that vowels are longest before voiced fricatives and shortest before voiceless plosives for subject FB. While for subject HJ vowels are

longest before voiceless fricatives and shortest before voiceless plosives. The statement that vowels are longer in duration when preceding fricatives than when preceding plosives proved to be true for only one of the two subjects. Tables 6.4.1.b.5-6 and Graphs 6.4.1.b.5-6 show HJ data which reveal that vowels are on average longer before fricatives than before plosives. In isolated words /i/, /a/, /i:/ and /a:/ have the following mean durations before plosives: 130.64 msec, 121.46 msec, 183.55 msec and 204 msec respectively; before fricatives they have the following means: 156.02 msec, 140.82 msec, 198.84 msec and 224.93 msec respectively. The ratio of the means before plosives to before fricatives are 0.83 for /i/, 0.86 for/a/, 0.92 for /i:/ and 0.90 for /a:/. The durational differences proved to be significant for all the vowels except for /i:/: $p < 0.01$ for /i/, $p < 0.02$ for /a/, $p > 0.20$ for /i:/ and $p < 0.05$ for /a:/. When all the four vowels are pooled they have an average length of 152.64 msec before plosives and 175.44 msec before fricatives. The ratio of the two means is 0.87 and the difference between them (22.8 msec) is highly significant ($t401 = -3.91$, $p < 0.001$).

In phrase /i/, /a/, /i:/ and /a:/ have the following lengths when preceding plosives: 112.33 msec, 108.88 msec, 136 msec and 170 msec respectively; and 136.75 msec, 122.14 msec, 152 msec and 175.29 msec respectively when preceding fricatives. The ratio of the means in the two

Table 6.4.1.b.5

Mean durations in msec and ratios of vowels preceding plosives to vowels preceding fricatives. In isolated words. Subject HJ.

Vowel	Plosive	Fricative	Ratio	Significance
i	130.64	156.02	0.83	$p < 0.01$
a	121.46	140.82	0.86	$p < 0.02$
i:	183.55	198.84	0.92	$p > 0.20$
a:	204	224.93	0.90	$p > 0.05$

Table 6.4.1.b.6

Mean durations in msec and ratios of vowels preceding plosives to vowels preceding fricatives. In phrase. Subject HJ.

Vowel	Plosive	Fricative	Ratio	Significance
i	112.33	136.75	0.82	$p < 0.01$
a	108.88	122.14	0.89	$p < 0.02$
i:	136	152	0.89	$p < 0.05$
a:	170	175.29	0.96	$p > 0.20$

Graph showing the mean durations of /i/, /a/, /iː/
and /aː/ when preceding plosives and fricatives.
In isolation. Speaker HJ.
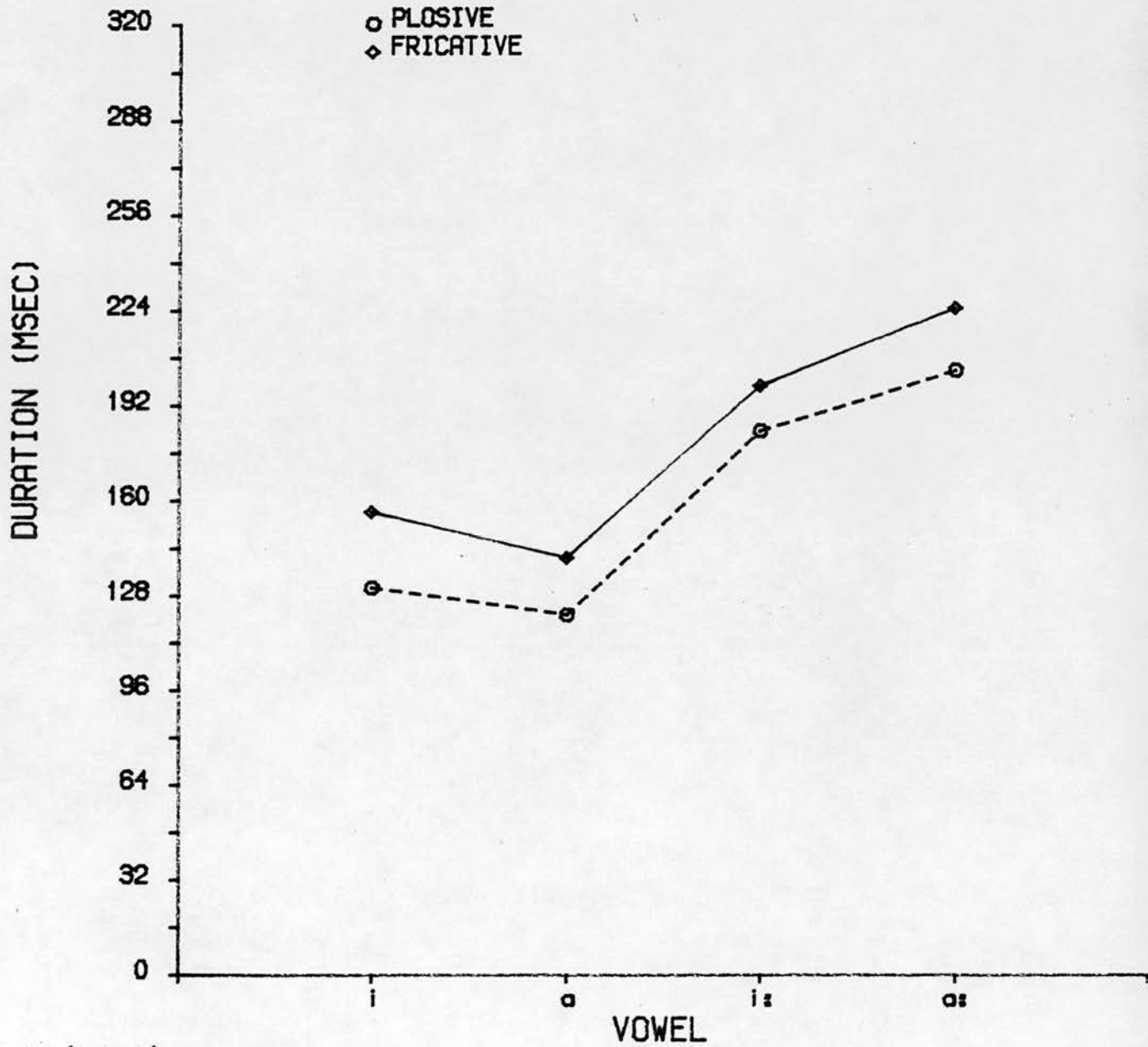
Figure   6.4.1.b.5

Graph showing the mean durations of /i/, /a/, /i:/
and /a:/ when preceding plosives and fricatives.
In phrase. Speaker HJ.
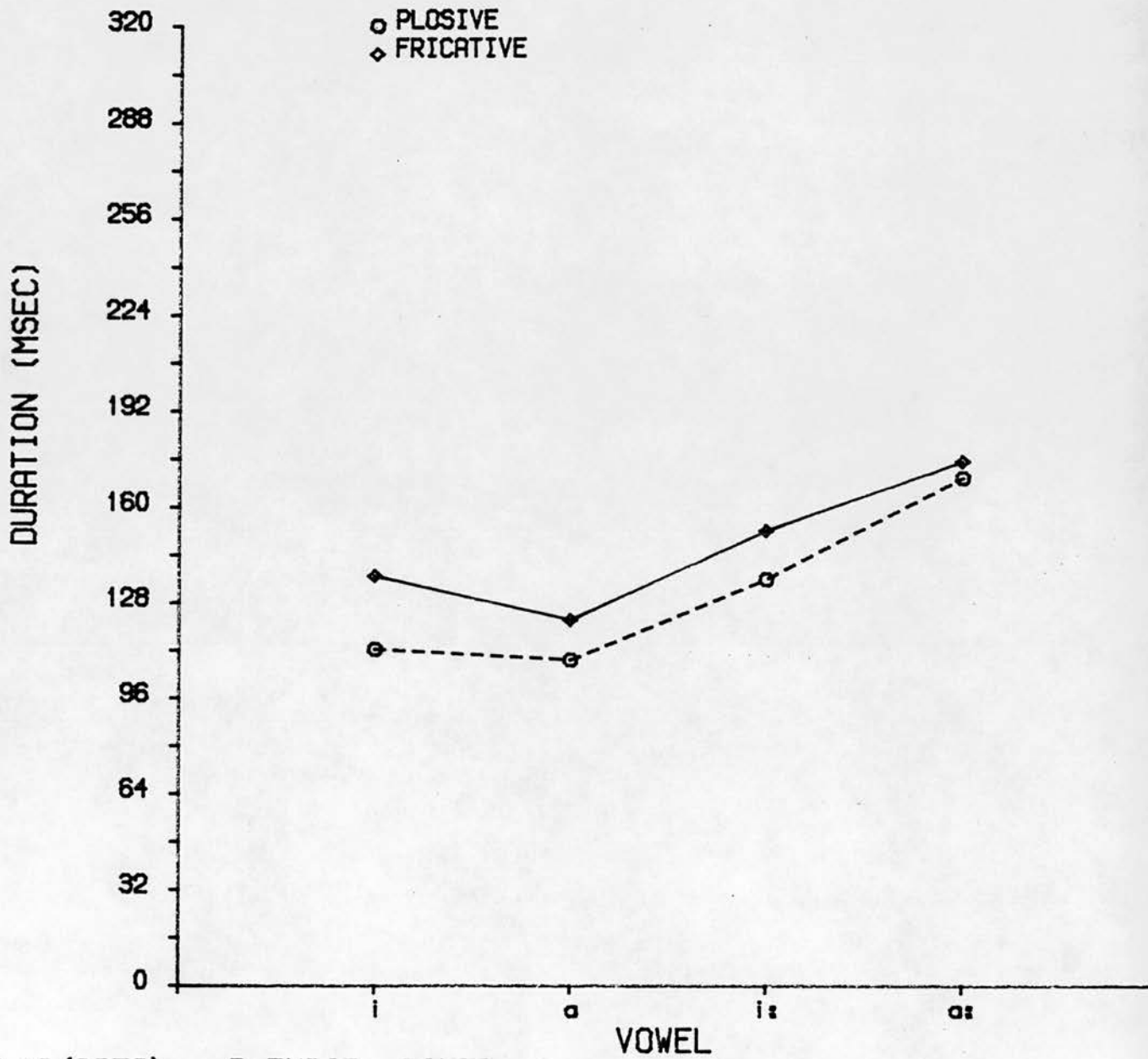
Figure   6.4.1.b.6

invironments are 0.82 for/i/, 0.89 for /a/, 0.89 for /i:/ and 0.96 for /a:/. These ratio reached a significant level for all the vowels except /a:/: p<0.01 for /i/, p<0.02 for /a/, p<0.05 for /i:/ and p>0.20 for /a:/. When all the vowels are pooled they have an average duration of 128.90 msec before plosives and 142.90 msec before fricatives. The ratio between the two means is 0.90, and the difference between them (14 msec) is highly significant (t401= -3.52, p<0.001).

Tables 6.4.1.b7-8 and Graphs 6.4.1.b7-8 represent FB data. In isolated words /i/, /a/, /i:/ and /a:/ have the following mean durations when preceding plosives: 80.29 msec, 104.90 msec, 190.10 msec and 225.20 msec respectively; and when preceding fricatives 99.77 msec, 106.45 msec, 191.91 msec and 231.16 msec respectively. The ratio of the means in the two contexts are 0.80, 0.98, 0.99 and 0.97 respectively. The durational difference between them reached a significant level for only /i/ at the level of p<0.02. When all the vowels are pooled they have an average duration of 141.17 msec before plosives and 152.74 msec before fricatives. The ratio of the two means is 0.92 and the difference between them (11.57 msec) is non-significant (t324=-1.43, p<0.20).

In phrase, /i/, /a/, /i:/ and /a:/ have the following average durations before plosives: 67.64 msec, 85.53 msec, 138.10 msec and 182.14 msec respectively; and before fricatives: 80.08 msec, 85.80 msec, 139.65 msec and 180.18

Table 6.4.1.b.7

Mean durations in msec and ratios of vowels preceding plosives
to vowels preceding fricatives. In isolated words. Subject FB.

Vowel	Plosive	Fricative	Ratio	Significance
i	80.29	99.77	0.80	p < 0.02
a	104.90	106.45	0.98	p > 0.20
i:	190.10	191.91	0.99	p > 0.20
a:	250.20	231.16	0.97	p > 0.20

Table 6.4.1.b.8

Mean durations in msec and ratios of vowels preceding plosives
to vowels preceding fricatives. In phrase. Subject FB.

Vowel	Plosive	Fricative	Ratio	Significance
i	67.64	80.08	0.84	p < 0.02
a	85.53	85.80	0.99	p > 0.20
i:	138.10	139.65	0.98	p > 0.20
a:	182.14	180.18	1.01	p > 0.20

Graph showing the mean durations of /i/, /a/, /i:/
and /a:/ when preceding plosives and fricatives.
In isolation. Speaker FB.
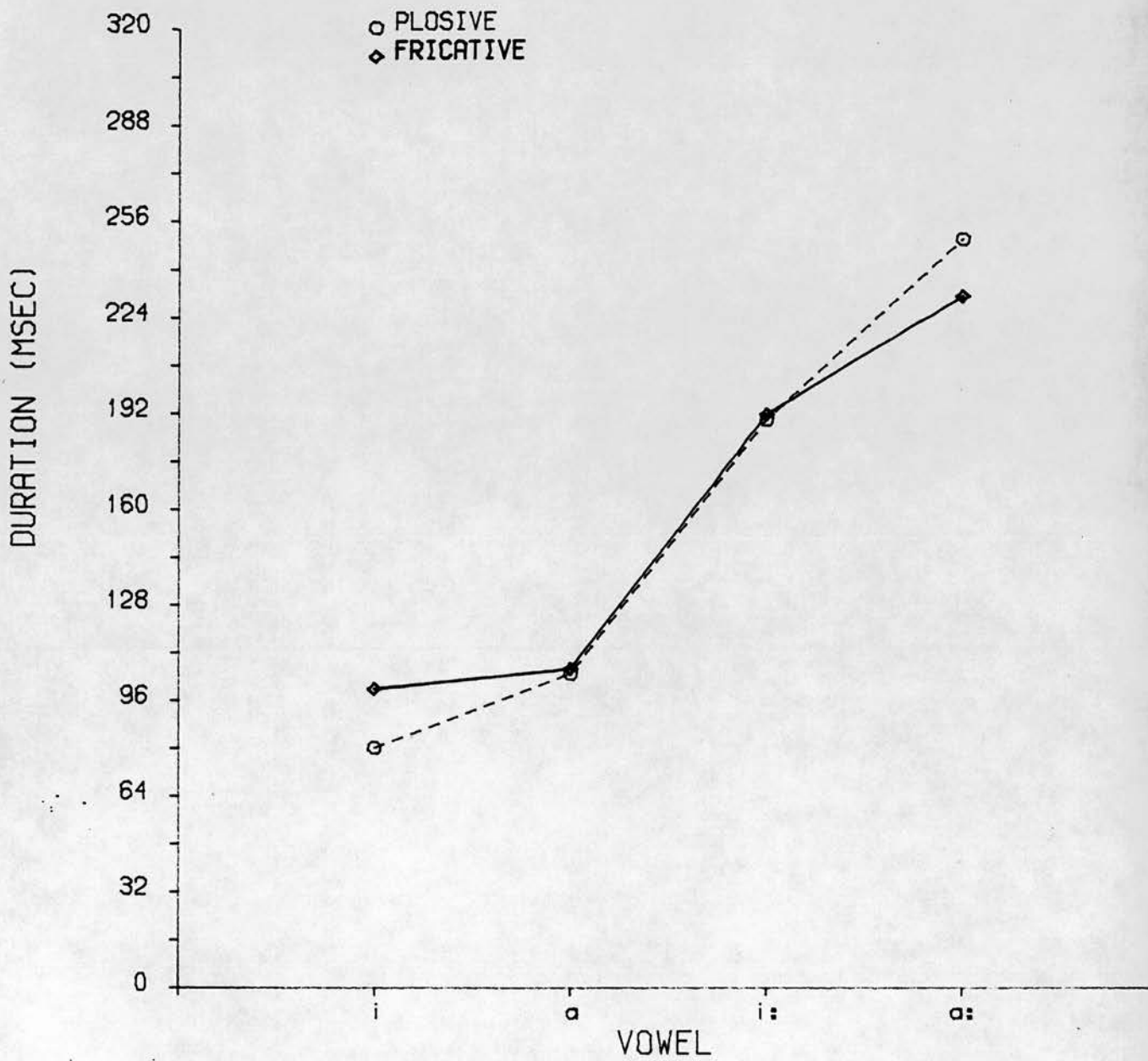
Figure 6.4.1.b.7

Graph showing the mean durations of /i/, /a/, /i:/
and /a:/ when preceding plosives and fricatives.
In phrase. Speaker FB.
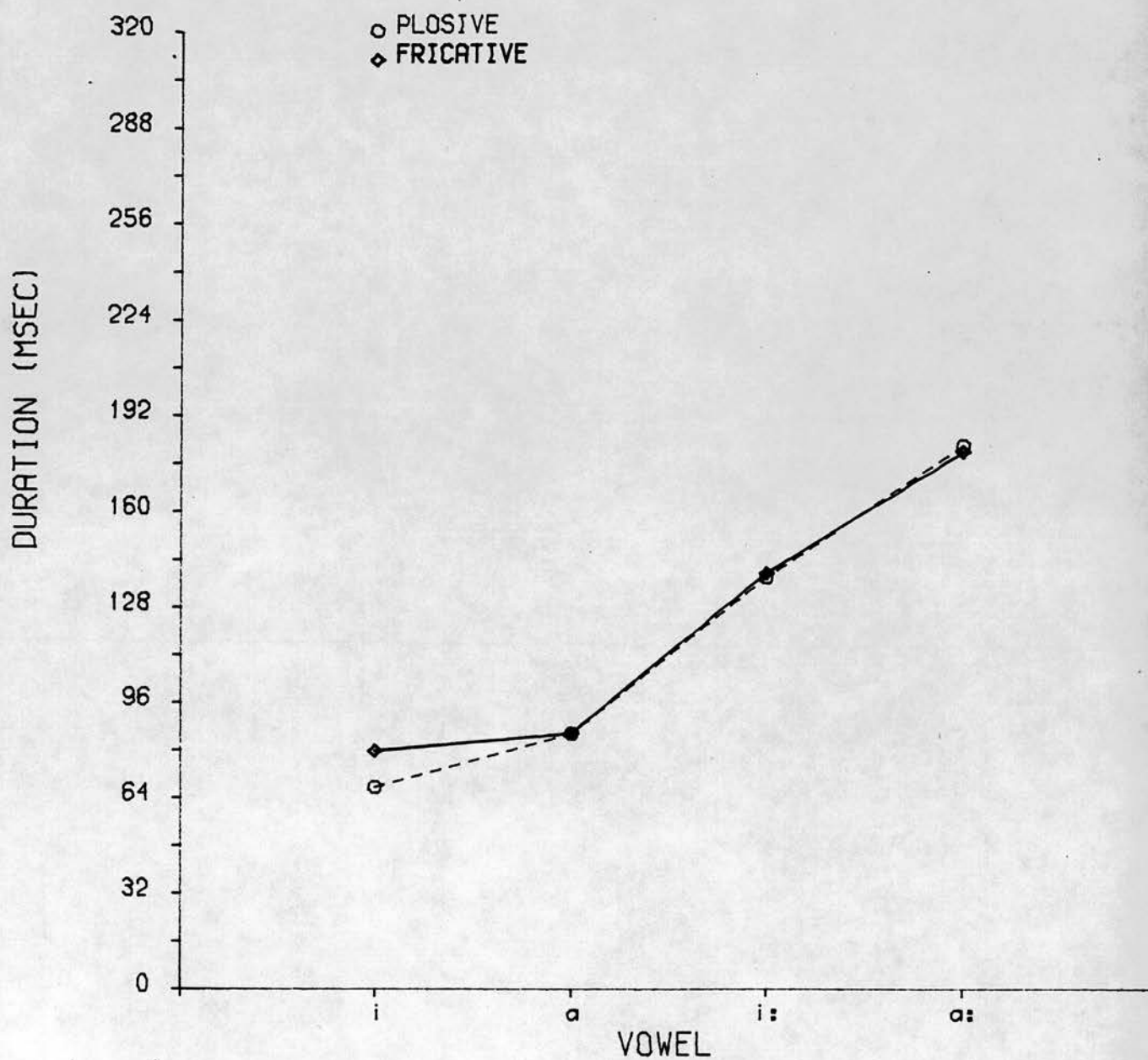
Figure 6.4.1.b.8

msec respectively. The ratio between the means in the two contexts are 0.84, 0.99, 0.98 and 1.01, and the differences are only significant for /i/ at the level of p<0.02. When the four vowels are pooled they have an average length of 112.47 msec when preceding plosives and 119.34 msec when preceding fricatives. The ratio between these two means is 0.94, and the difference (6.87 msec) is non-significant (t322=-1.16, p>0.20).

Thus the fricativeness of the following consonant is found to have a significant lengthening effect on the preceding vowels for HJ, while it has a very slight and non-significant effect for FB.

6.4.1.c.

The effect of pharyngealization

Tables 6.4.1.c.1-2 show the pooled value for all the vowels when adjacent to emphatic and non-emphatic consonants. They reveal that a vowel is lengthened when adjacent to a pharyngealized consonant as compared to when adjacent to a non-pharyngealized counterpart. The average durations of the vowels in the emphatic context is 163.40 msec and in the non-emphatic context is 144.93 msec for FB. The ratio the two means is 0.88, and the durational difference (18.46 msec) is highly significant

Table 6.4.1.c.1

Average durations in msec and ratio of vowels adjacent to non-emphatic and emphatic consonants. Subject FB.

Non-emphatic	Emphatic	Ratio	Signifcance
144.93	163.40	0.88	p < 0.001

Table 6.4.1.c.2

Average durations in msec and ratio of vowels adjacent to non-emphatic and emphatic consonants. Subject HJ.

Non-emphatic	Emphatic	Ratio	Significance
187.55	209.33	0.89	p < 0.02

Table 6.4.1.c.3

Average durations and ratio of vowels adjacent to non-emphatic and emphatic consonants. Subject AS.

Non-emphatic	Emphatic	Ratio	Significance
199.15	220.07	0.90	p < 0.05

(p<0.001). HJ data show that vowels have a mean duration of 187.55 msec in the non-emphatic environment and 209.33 msec in the emphatic environment. The ratio between the two means is 0.89 and the durational difference is significant at the level of p<0.02. The acoustic data of a third subject AS (see Table 6.4.1.c.3) is also in agreement with the results of the above two subjects. In the non-emphatic context vowels are on average 199.15 msec long and in the emphatic context are 220.07 msec long. Thus on average vowels are 20.92 msec shorter in the non-emphatic context than in the emphatic context. This durational difference reached a significant level (p<0.05).

When the data of all the three subjects are pooled, vowels have an average duration of 174.35 msec in the non-pharyngealized context and 194.48 msec in the pharyngealized context. The ratio between the two means is 0.89, and durational difference (20.12 msec) proved to be highly significant (p<0.001).

This result is in agreement with that of Al-Jazary (1981) for Iraqi Arabic as he found that vowels are significantly longer when preceding emphatic consonants than when preceding non-emphatic consonants.

The durational difference between vowels next to pharyngealized and non-pharyngealized consonants hover around the JND's value and therefore it is only phonetically and not phonologically or perceptually

significant, though it might contribute to the other phonetic exponent of the pharyngealization feature to bring about the phonological distinction between the emphatic and its non-emphatic counterpart.

It was observed that vowels are lengthened when they are next to an emphatic consonant, whether they precede or follow it. Compare the duration of /i:/ in the following examples: /ti:n/ (Figure 6.4.1.c.1) (202 msec) and /ƫi:n/ (Figure 6.4.1.c.2) (238 msec); and of /a:/ in /ba:t/ (Figure 6.4.1.c.3) (244 msec) and in /ba:ƫ/ (Figure 6.4.1.c.4) (262 msec). But the effect of a following emphatic consonant on the preceding vowel is more prominent than the effect of a preceding emphatic consonant on a following vowel, that is to say that vowels are longer when they precede than when they follow emphatic consonants. Compare the duration of /a/ in /baṣ/ (Figure 6.4.1.c.5) (140 msec) and in /ṣab/ (Figure 6.4.1.c.6) (112 msec), and /a:/ in /ba:ṣ/ (Figure 6.4.1.c.7) (252 msec) and in /ṣa:b/ (Figure 6.4.1.c.8) (236 msec). It was also noticed that /ṣ/ has the most lengthening effect on the adjacent vowel and /ƫ/ has the least. Comparing the duration of /i/ in the following words: /giṣ/, /giẓ/ and /giƫ/ we find that it is 160 msec long before /ṣ/, 114 msec before /ẓ/ and 108 msec before /ƫ/ (see Figures 6.4.1.c.9-11 FB). The airflow records of the second subject (HJ) exhibit a similar pattern: /i/ in /giṣ/ is 180 msec long, in /giẓ/ 164 msec and in /giƫ/ 152 msec (Figures 6.4.1.c.12-14).
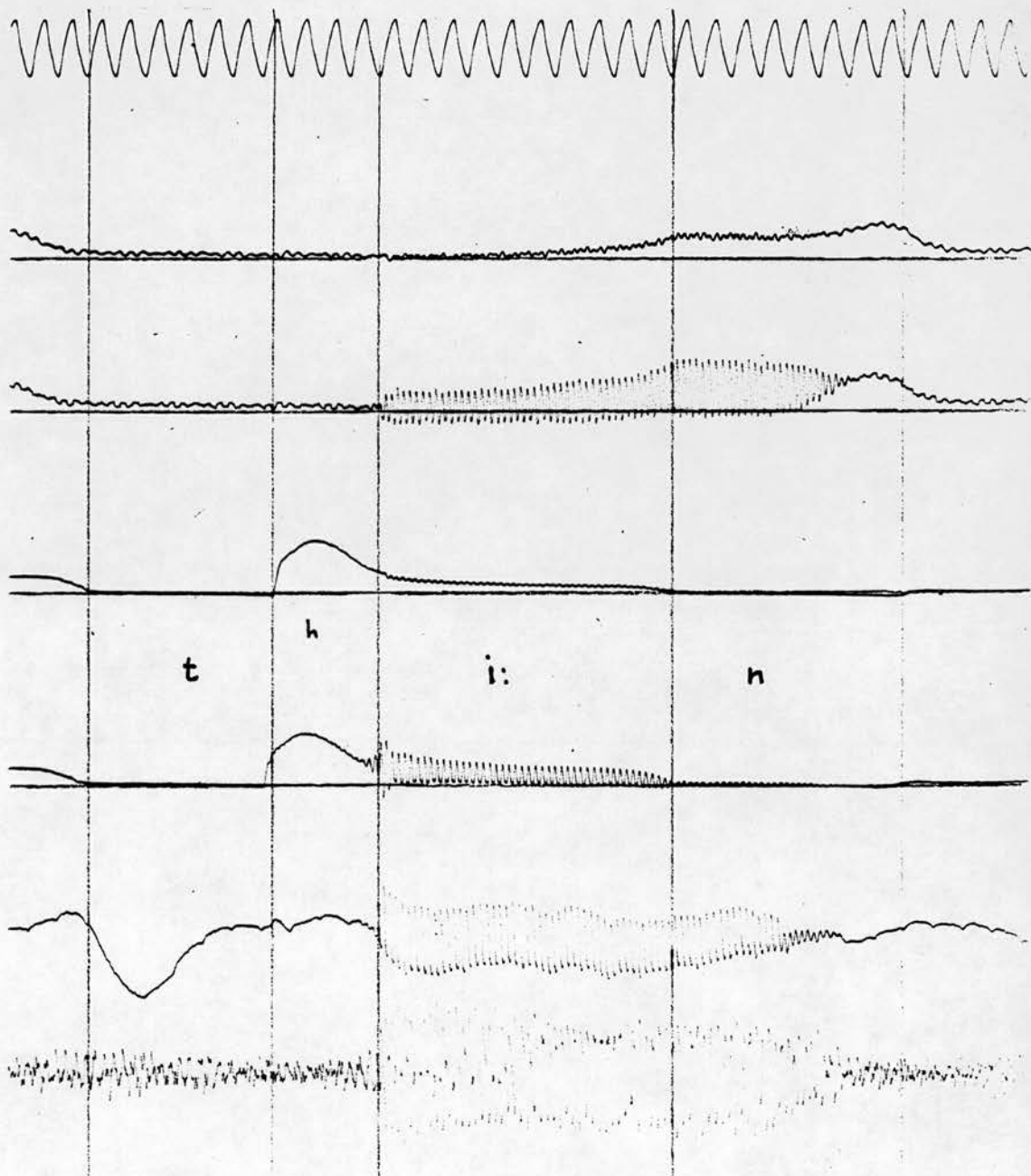
Figure 6.4.1.c.1
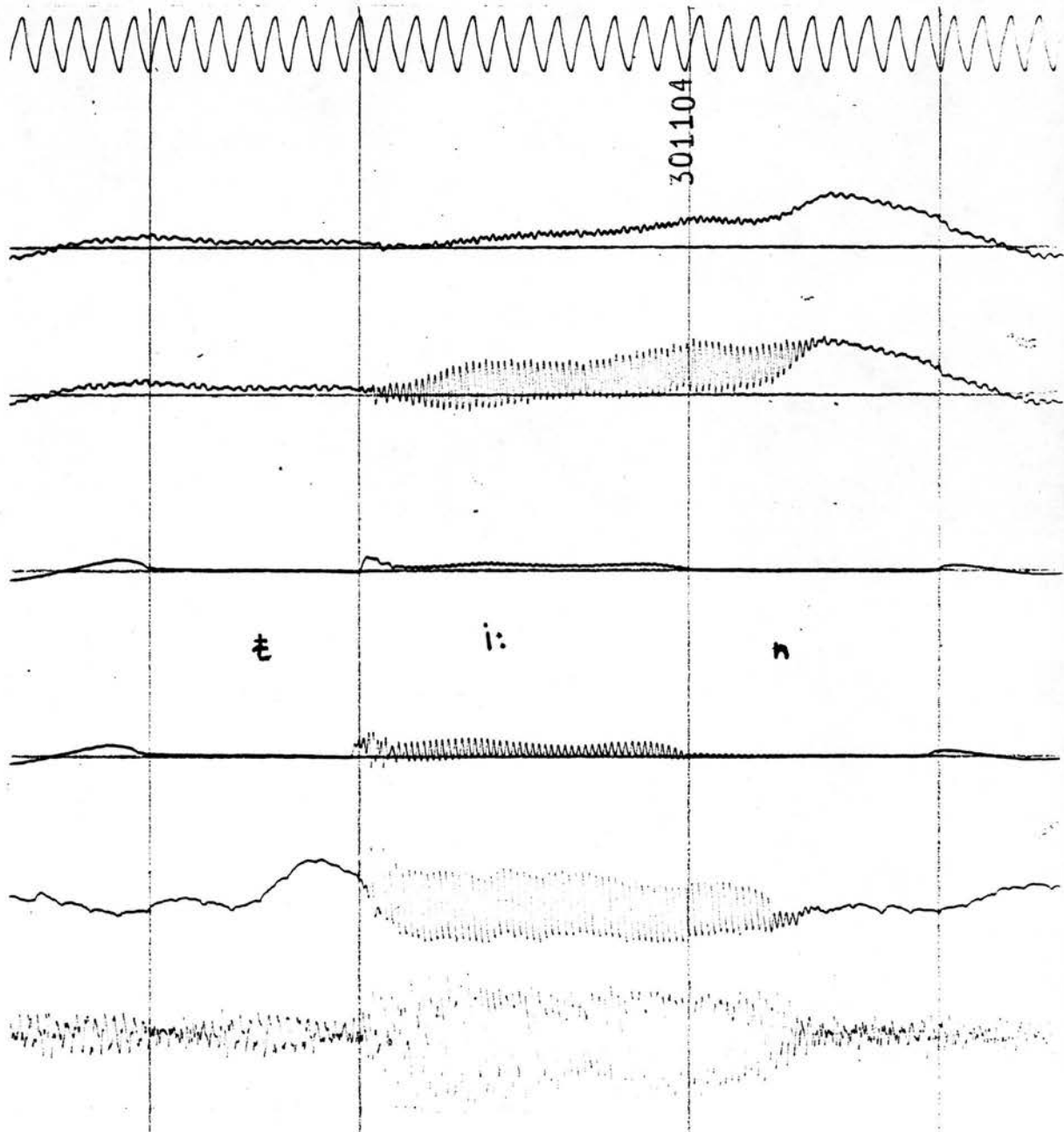
Figure 6.4.1.c.2

Figure 6.4.1.c.3
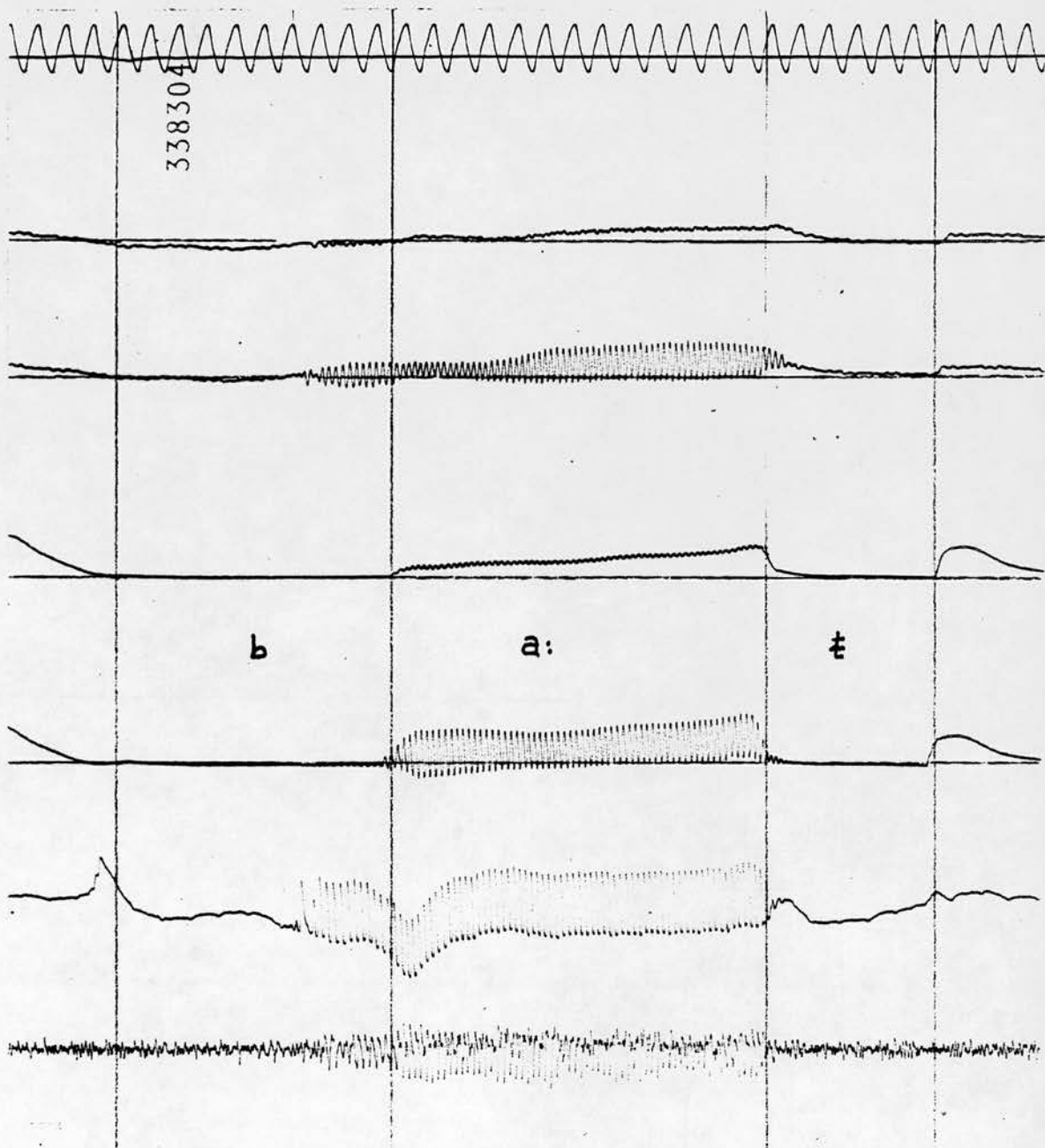
Figure   6.4.1.c.4
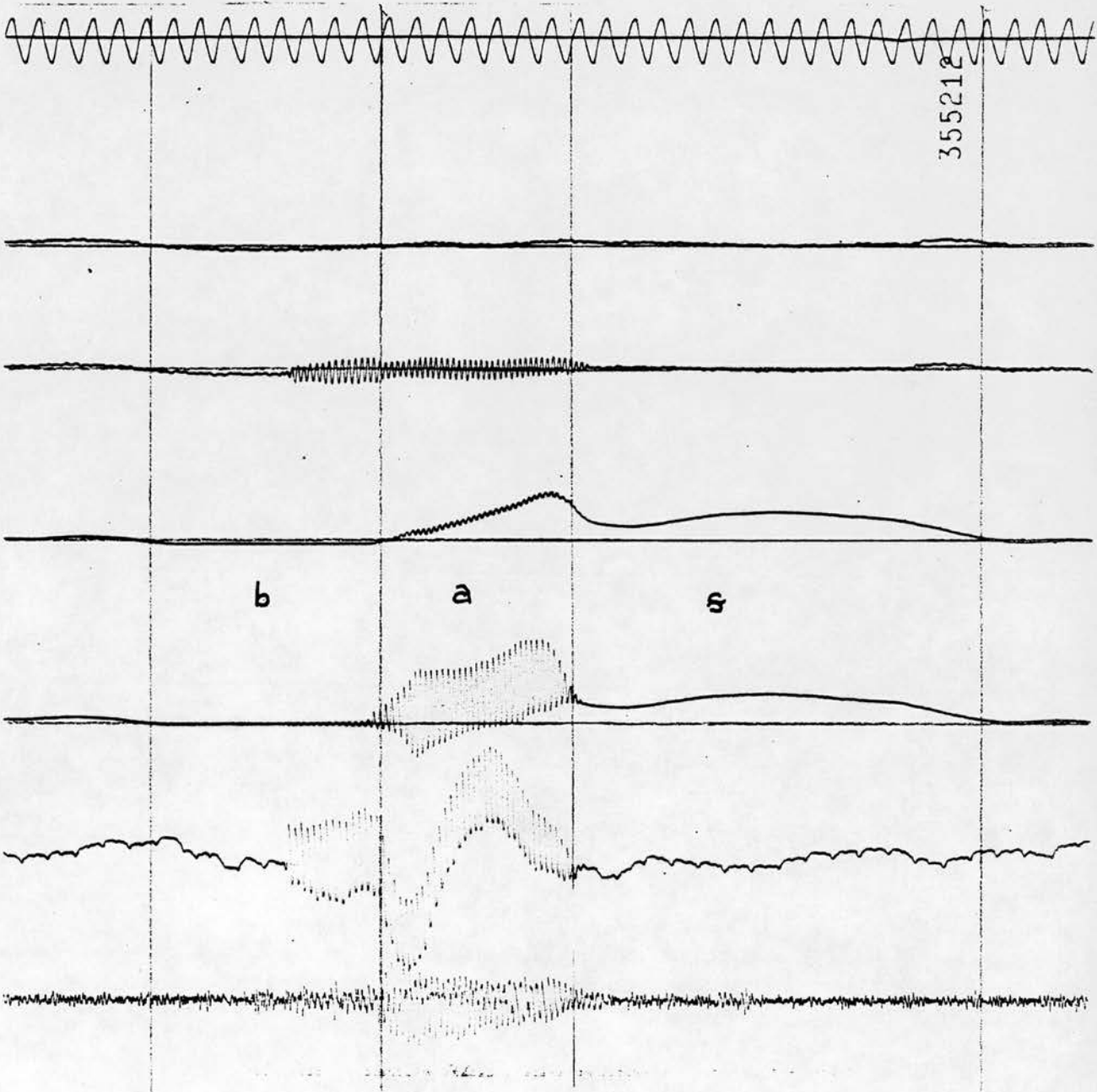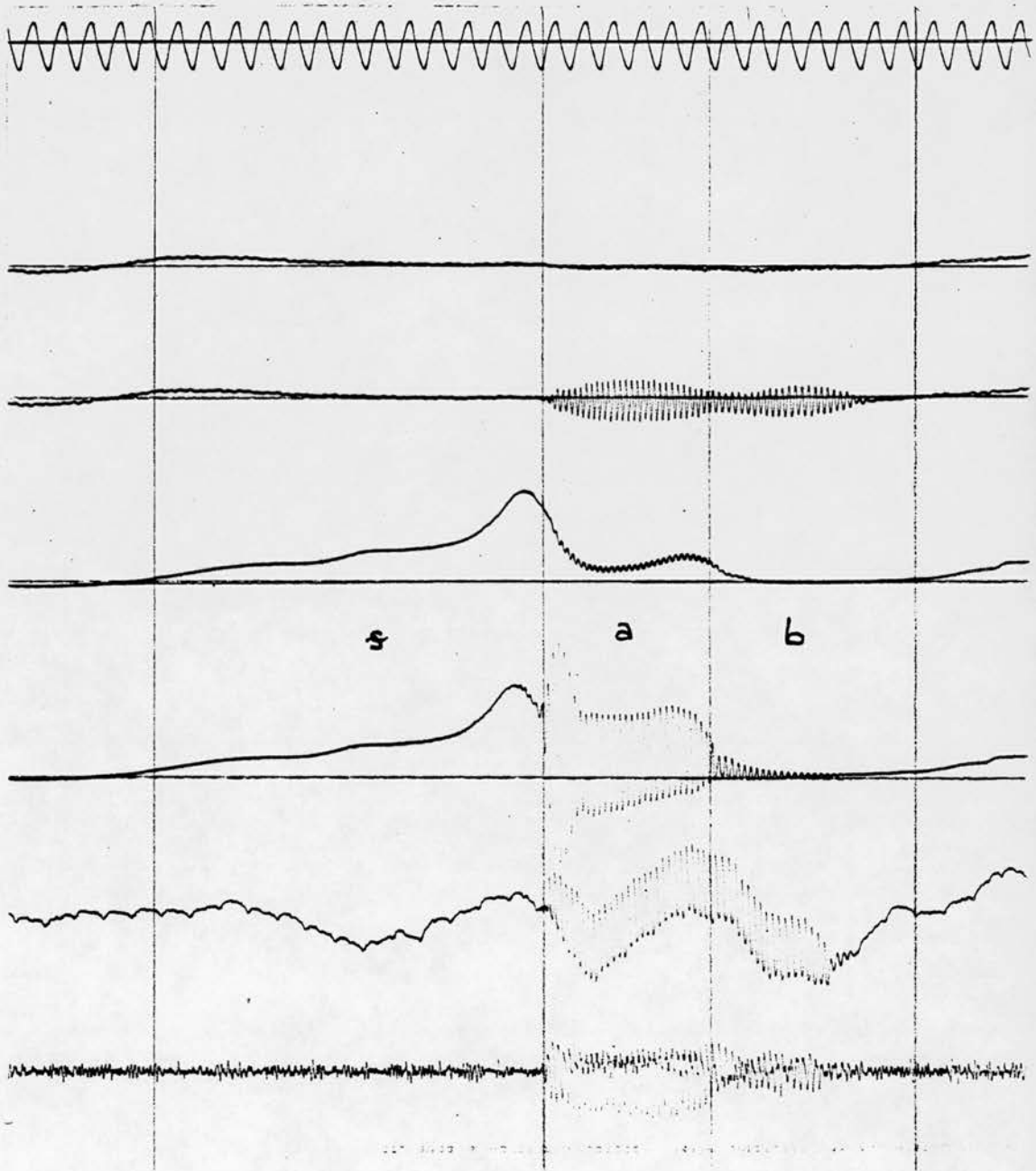
Figure 6.4.1.c.5

Figure 6.4.1.c.6
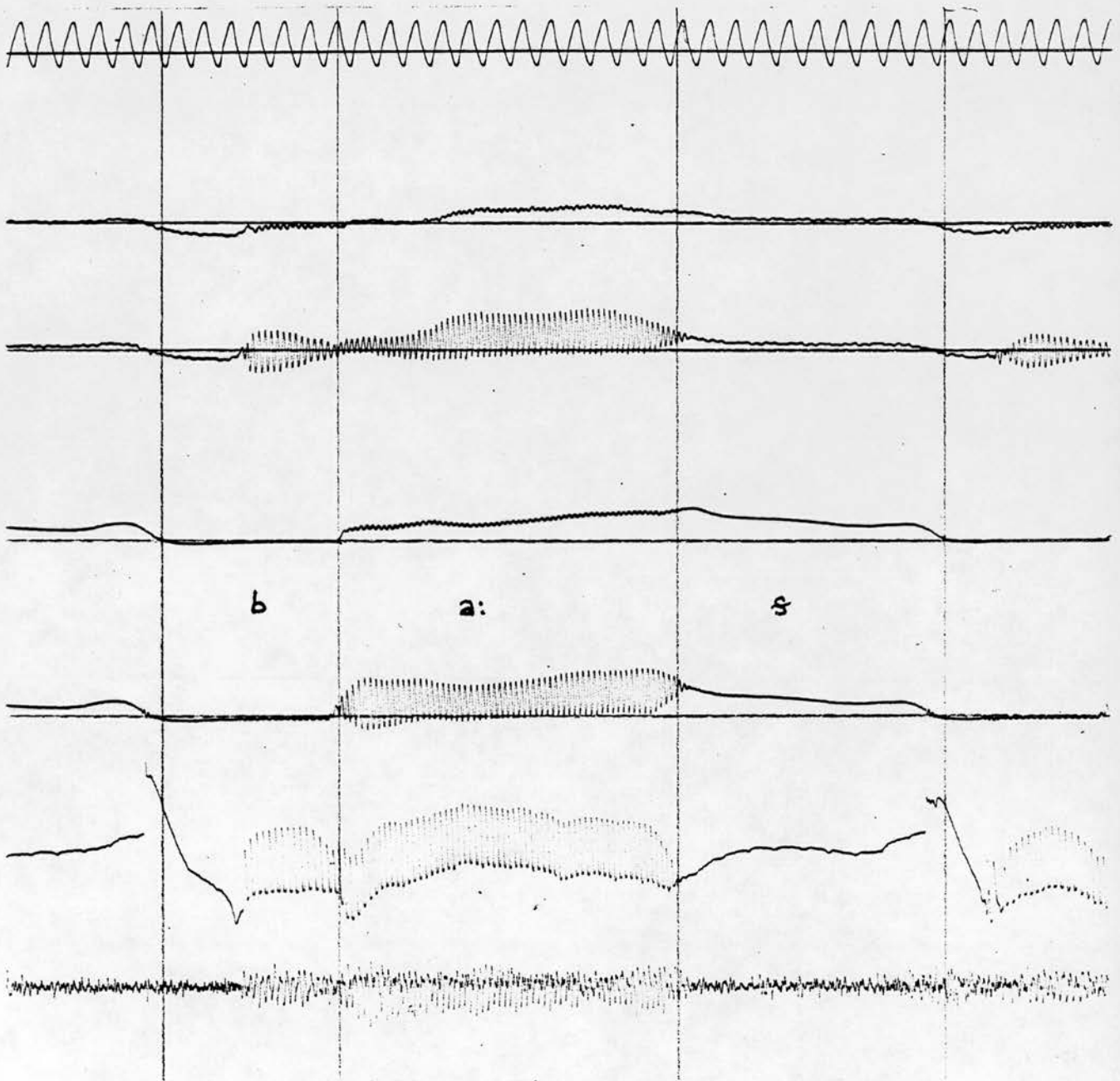
Figure 6.4.1.c.7
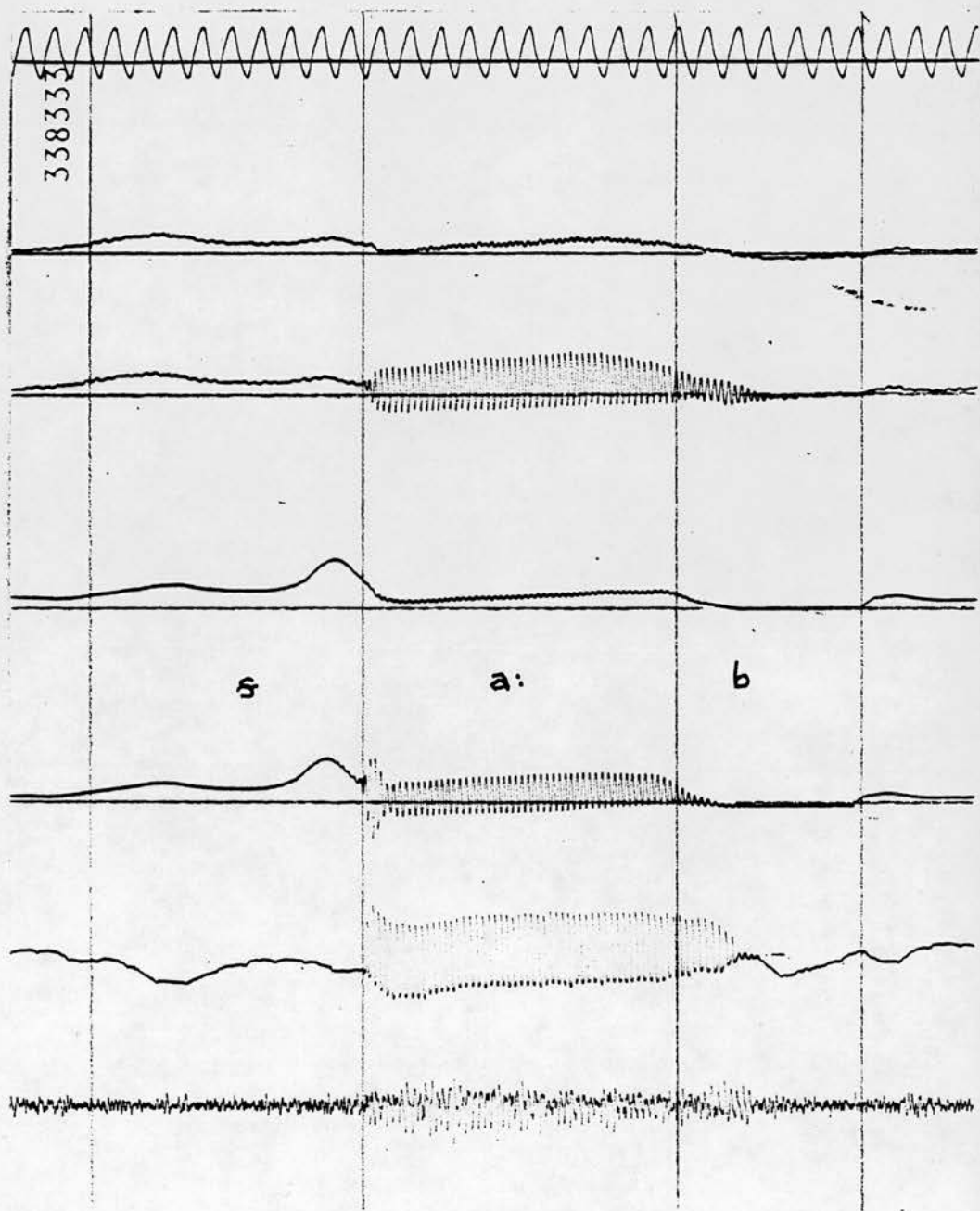
Figure   6.4.1.c.8
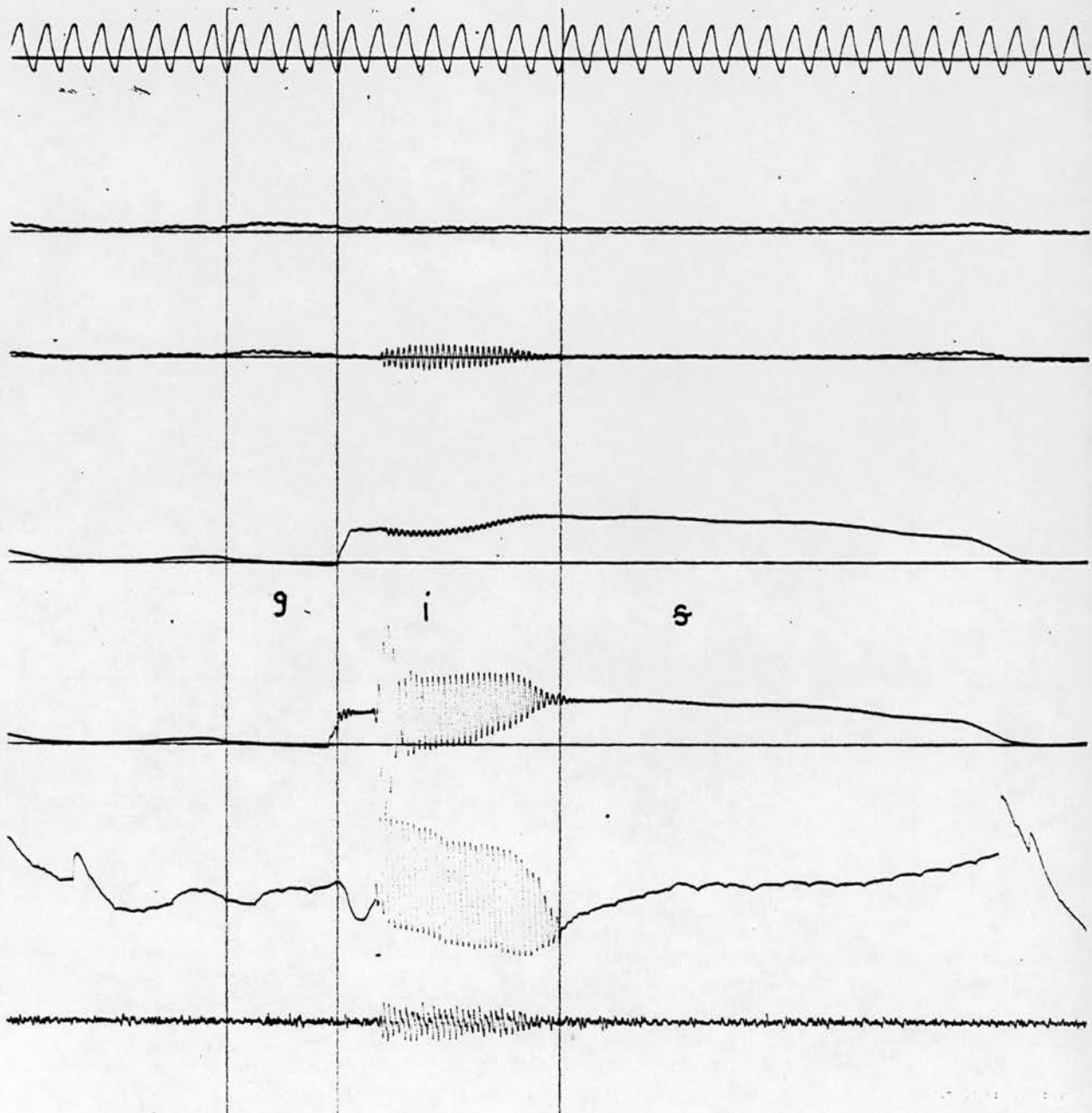
Figure 6.4.1.c.9
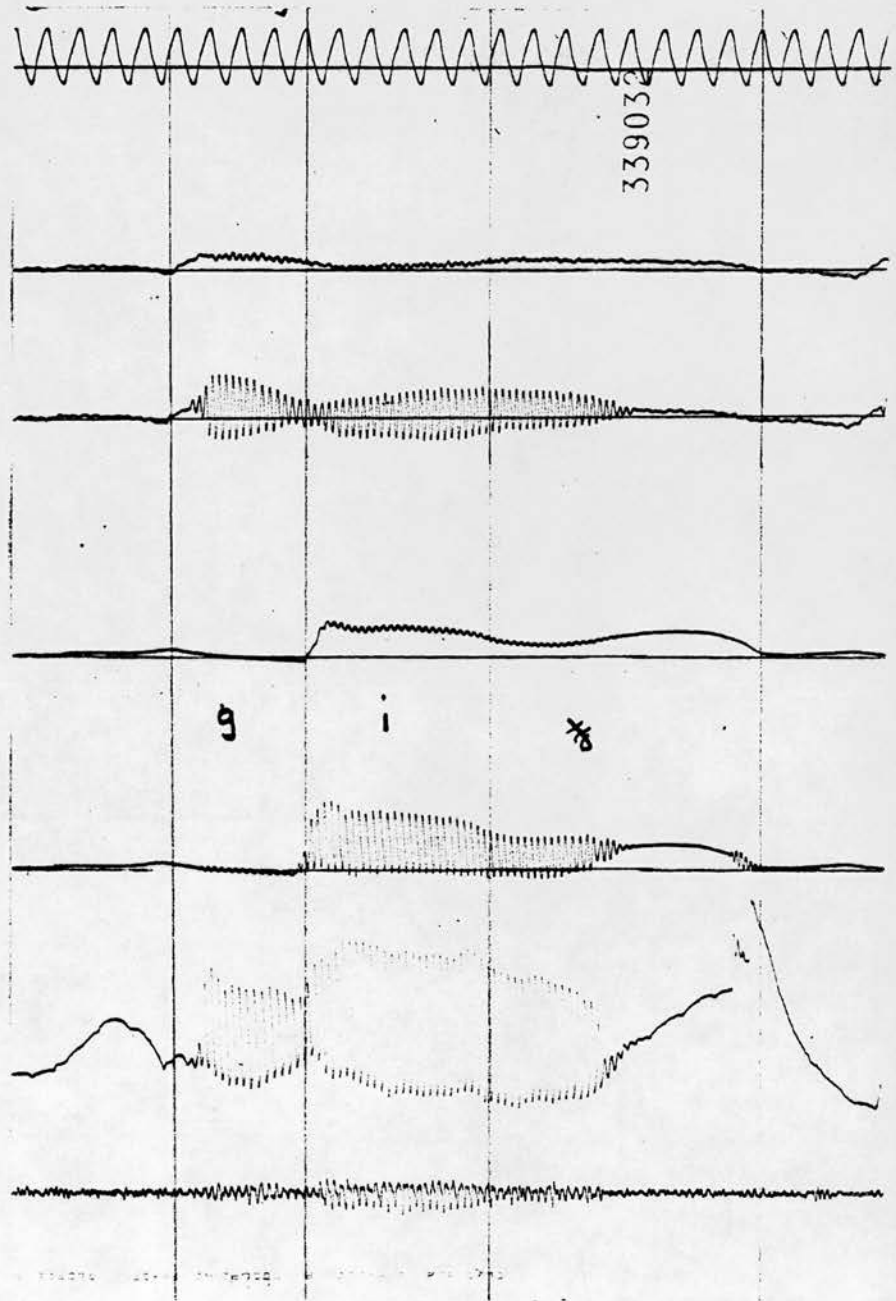
Figure   6.4.1.c.10
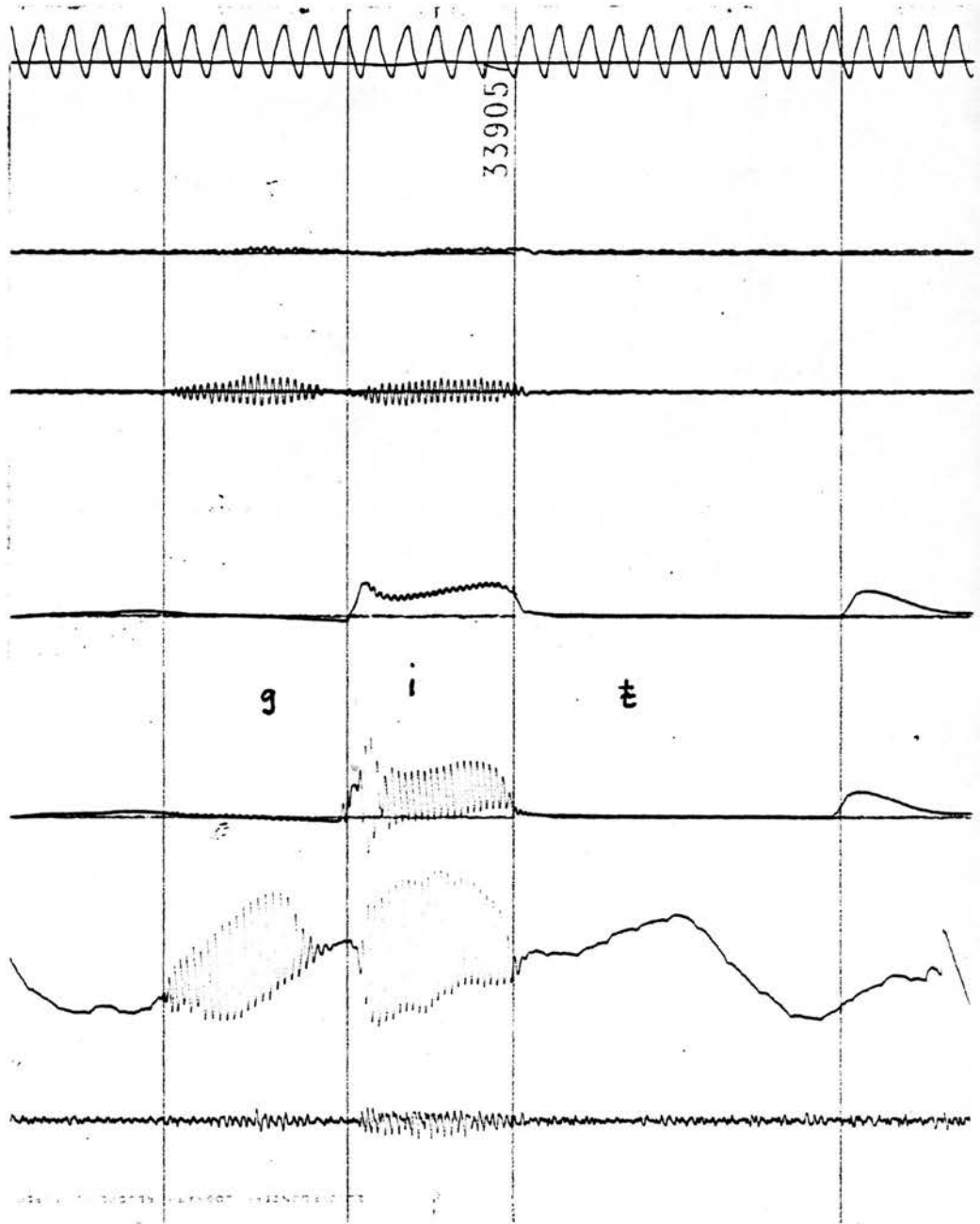
Figure   6.4.1.c.11
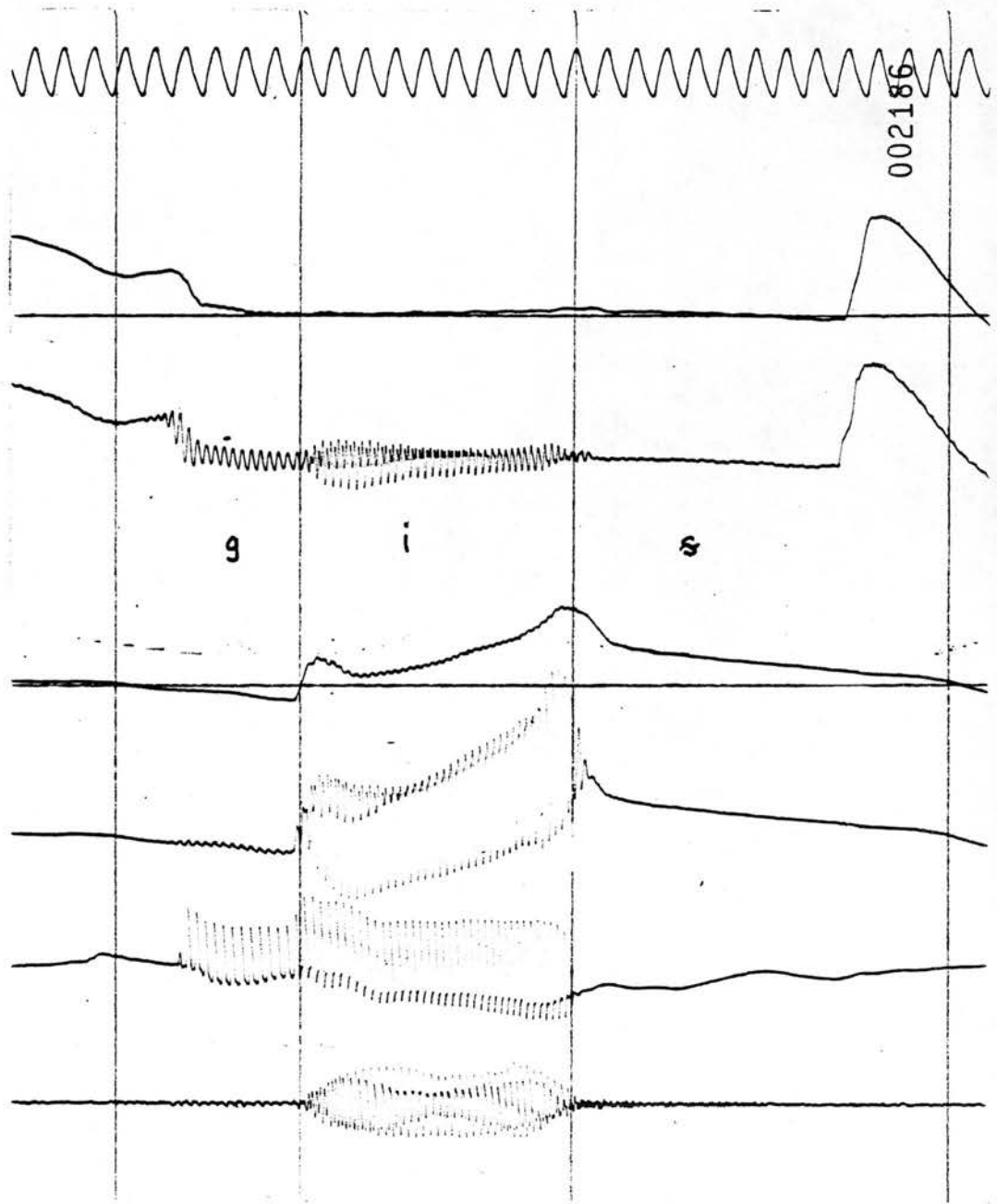
Figure 6.4.1.c.12
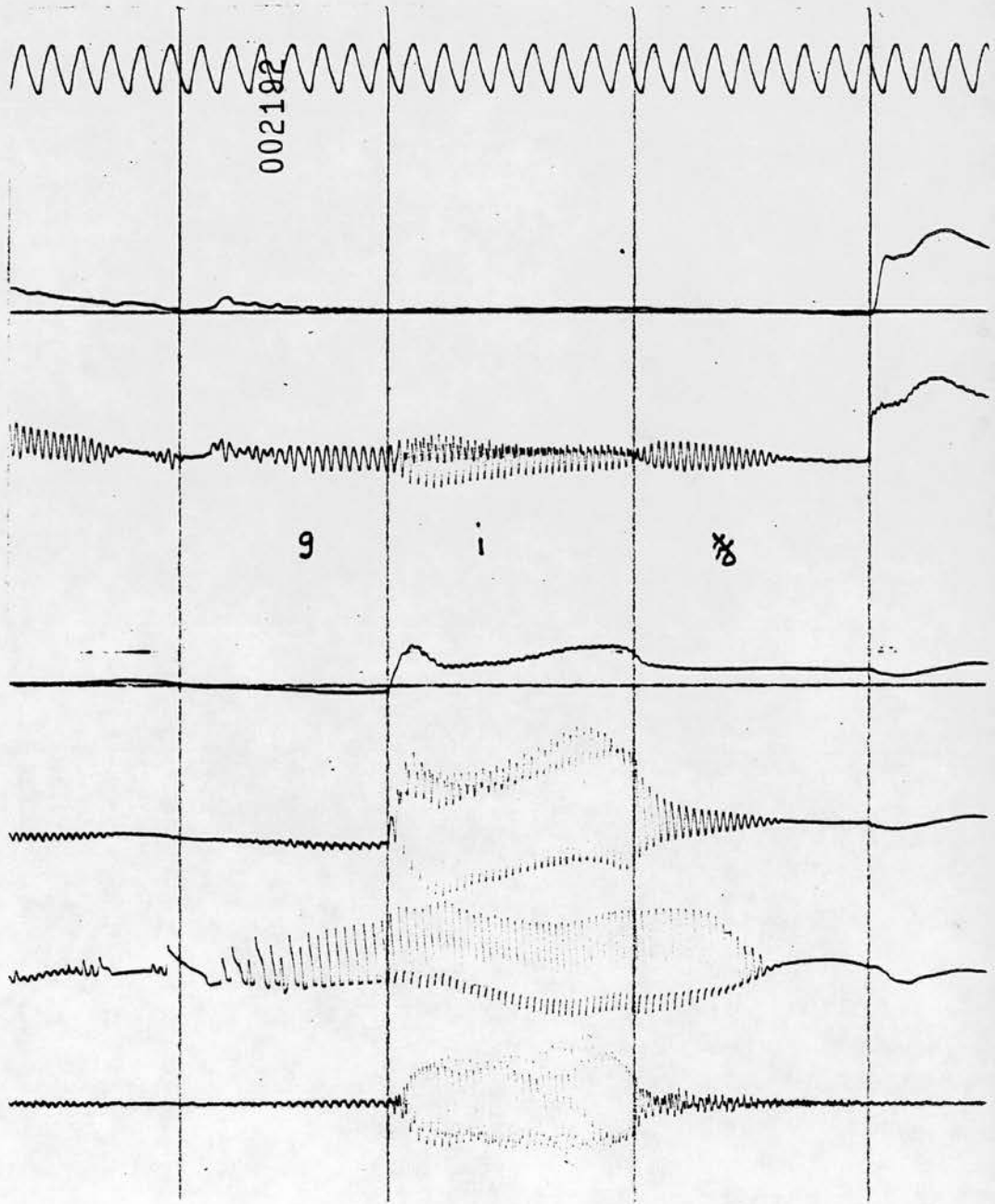
Figure 6.4.1.c.13
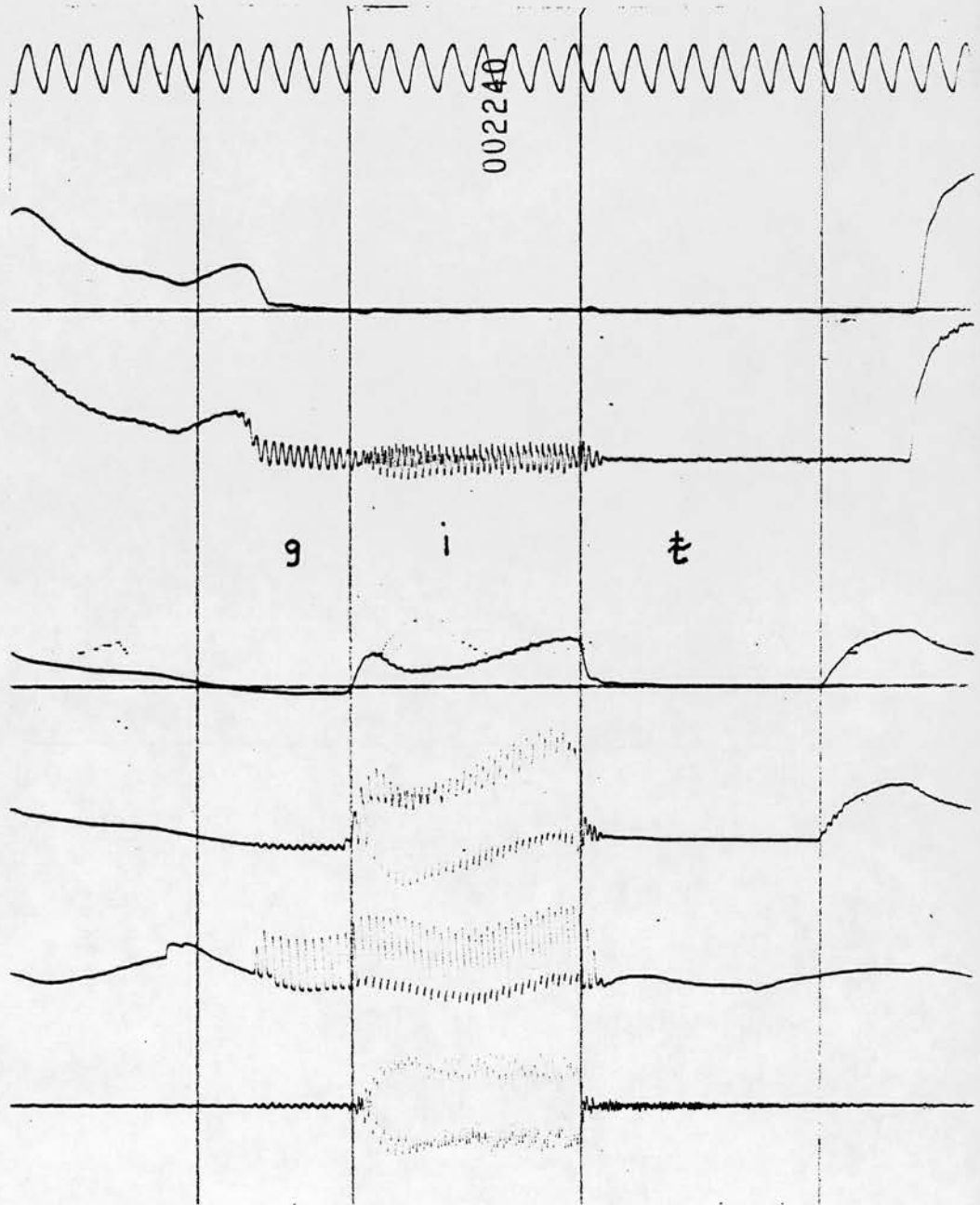
Figure 6.4.1.c.14

Thus we may say that the effect of s>⅛>ŧ, and that vowels before emphatic fricatives are longer in duration than vowels before emphatic plosives. This lengthening effect of the pharyngealized consonants on the preceding vowels can be ascribed to the fact that execution of these consonants is delayed as a result of the rearward movement of the back of the tongue towards the pharyngeal wall, a movement required for pharyngealization before the execution of the primary configuration.

6.4.1.d.

The effect of consonant duration

The effect of gemination and consonant clusters is considered is this section. A geminate consonant is realized here as two identical abutting consonants. And when they occur in intervocalic position, within word boundaries, the first member closes the first syllable and the second member releases the second syllable. Thus the syllable boundary falls in between the two members of the geminate.

Delattre (1971) investigated the effect of gemination across word boundaries in four languages: English, German, Spanish and french. He found that vowels

are only slightly shorter before geminates than before sing le consonants. He gives the following average ratios of vowels before geminates to those before non geminates: 0.94 to 1 for Spanish, 0.96 to 1 for English, 0.96 to 1 for French and 0.97 to 1 for German. While in his (1962) study, Delattre found that vowels are shorter in duration when followed by consonant clusters than when followed by single consonants. He states that the vowel [a] in /pakt/ is shorter in duration than in /pak/ due to the "anticipation of a greater effort for the articulation of the cluster [kt] shortens vowels more than the anticipation of the single consonant [k]." (p.96).

Nooteboom & Slis (1972) found that in Dutch consonants following short vowels are consistently longer in duration than consonants following long vowels. Al-Jazary (1981) found that vowels are very significantly longer when they precede non-geminates than when they precede geminates in Iraqi Arabic. He also states that geminate consonants are longer in duration, have a higher intra-oral pressure and shorter time when compared to their non-geminate counterparts. Thus there seems to be an inverse relation between the duration of the consonant and its preceding vowel; long consonants (geminates or clusters) are preceded by, relatively, shorter vowels and short or single consonants are preceded by a relatively longer vowels.

Table 6.4.1.d.1 reveal the results for FB data. The

Table 6.4.1.d.1

Average durations in msec and ratio of vowels preceding
geminates to vowels preceding non-geminates. Subject FB.

Geminate	Non-Geminate	Ratio	Significance
93.40	105.80	0.88	$p < 0.01$

Table 6.4.1.d.2

Average durations in msec and ratio of vowels preceding
geminates to vowels preceding non-geminates. Subject HJ.

Geminate	Non-Geminate	Ratio	Significance
84.28	87.14	0.96	$p > 0.20$

average duration of short vowels before geminates is 93.40 msec and before non-geminate counterparts is 105.80 msec. The ratio between the two means is 0.88 and the difference (12.40 msec) is significant (p<0.01). Table 6.4.1.d.2 represents the results for the second subject (HJ). It reveals that the difference in duration between vowels before geminate and non-geminate consonants is very slight and non-significant (p>0.20) and the ratio between them is 0.96.

The influence of initial and final clusters on adjacent vowels was also investigated. The results revealed that vowels are significantly shorter in duration when adjacent to consonant clusters than when adjacent to single consonants. Table 6.4.1.d.3 show that for FB vowels are on average 144 msec long next to clusters and 158.66 msec long next to single consonants. The ratio between the two means is 0.88 and the difference is siginificant (p<0.01). Table 6.4.1.d.4 reveals that for HJ vowels are on average 166.2 msec long when adjacent to clusters and 190.2 msec when adjacent to single consonants. The ratio between the two means is 0.87 and the difference proved to be highly significant (p<0.001).

The durational difference between vowels preceding geminates or clusters and single consonants hover around the JND´s value and therefore we expect it to be only phonetically significant. While the durational difference between a geminate and non-geminate counterpart is

Table 6.4.1.d.3

Average durations in msec and ratio of vowels adjacent to
consonant clusters to vowels adjacent to single consonants.
Subject FB

Cluster	Single	Ratio	Significance
144	158.66	0.88	$p < 0.01$

Table 6.4.1.d.4

Average durations in msec and ratio of vowels adjacent to
consonant clusters to vowels adjacent to single consonants.
Subject JH.

Cluster	Single	Ratio	Significance
166.2	190.2	0.87	$p < 0.001$

much longer than JND´s value, hence, it is expected to be both perceptually and phonologically significant. However the shorter acoustic duration of vowels before geminates is not compensated for by the longer duration of the geminates as the overall durations of the words containing geminates are much longer than the words containing single counterparts. Compare the duration of the following words: /başar/ (558 msec) and /başşar/ (606 msec), /siħar/ (542 msec) and /siħħar/ (644 msec) /ħasan/ (734 msec) and /ħassan/ (766 msec). Thus there is no indication of a temporal compensatory adjustment between the preceding vowel and the following geminate/non-geminate consonant.

6.4.1.e. The effect of place of articulation

The influence of consonants with different places of articulation on the preceding vowel has been extensively investigated. The result of these investigations did not seem to have any cosistent pattern. Meyer (1903) did not find that the duration of English vowels varied according to the place of articulation of the following consonant, while House & Fairbanks (1953) found that vowels preceding labio-dentals and post-dentals are generally longer than those preceding bilabials and velars in American English and they come to the conclusion that

place of articulation is the least important of the consonant characteristics as it has the least effect. Peterson & Lehiste (1960) study of American English found that alveolars and palatoalveolars have a greater lengthening effect on the preceding vowel than labials and velars. Maack (1953) found that in German, front vowels are longer before labials and velars than before dentals; and back vowels are longest before labials and shortest before velars. According to Fintoft (1961) vowels before labials are shorter than those before dentals in Norwegian. Fischer-Jørgensen (1964) conducted an extensive investigation of the effect of place of articulation in Danish. She found that there are three factors of place which influence the duration of a vowel "a) the place of articulation of the vowel itself: u is on the whole longer than i. b) The place of articulation of the following consonant: vowels are, on the whole, shorter before b than before d and g. c) The specific vowel-consonant combination: There is an evident tendency u(d) > u(g) > u(b), a weaker tendency y (g) > y(d) > y(b) and a slight tendency i(g) > i(b) > i (d)." (p.191). In Swedish, Elert (1964) found that the duration of vowels decreases in the following order when preceding retroflex > dental > labial > palatal-velar. Absi (1966) arranges the consonants which differ in their place of articulation according to their shortening effect on preceding vowels in the following order for Arabic: dental < velars <

pharyngeals < labials < palatals. While Al-Jazary (1981) study showed that all vowels preceding back consonants (glottal and pharyngeal) are very sig nificantly shorter than those preceding front and central consonants. The duration of the preceding vowel decreased in the following order: denti-alveolars > palato- alveolars > labio-dentals > uvulars > pharyngeals. Delattre (1962) claims that the duration of vowels increases as the place of articulation of the postvocalic consonant gets further back in the vocal tract, i.e. that vowels are longest before back consonants and shortest before front consonants. Delattre bases his rule on the study of Spanish and English vowel duration by Zimmermann and Sapon (1958).

Tables 6.4.1.e.1-4 and Graphs 6.4.1.e.1-8 reveal that in QA both the short front high vowel /i/ and the long front high vowel /i:/ are longest when preceding palato-alveolar and pharyngeal consonants, and shortest when preceding velar consonants (LB=labial, DT=dental, AV=alveolar, PAV=palato-alveolar, VL=velar and PHGL=pharyngeal). The duration of /i/ decreases in the following order according to the place of articulation of the following consonants:

- palato-alveolar> alveolar> dental> pharyngeal> labial> velar (one word list, FB)

- palato-alveolar> alveolar= pharyngeal> labial> dental> velar (phrase, FB.)

Table 6.4.1.e.1

Average durations in msec of vowels preceding labial,
dental, alveolar, palato-alveolar, velar and pharyngeal
consonants. In isolated words.   Subject FB.

Vowel	LB	DT	AV	PAV	VL	PHGL
i	114.5	119.5	120.5	127.5	93.5	118.5
a	125	123	133	130	132.5	142
i:	247	239	229	232	199.5	262
a:	260.5	255.5	246	274.5	258	258

Table 6.4.1.e.2

Average durations in msec of vowels preceding labial,
dental, alveolar, palato-alveolar, velar and pharyngeal
consonants. In phrase. Subject FB.

Vowel	LB	DT	AV	PAV	VL	PHGL
i	88	87.5	90.5	102.5	77.5	90.5
a	92.5	90	95	88	100	103
i:	160	159	157	172	146	174.5
a:	203	178.5	199	201.5	188	178.5

Table 6.4.1.e.3

Average durations in msec of vowels preceding labial,
dental, alveolar, palato-alveolar, velar and pharyngeal
consonants. In isolated words. Subject HJ.

Vowel	LB	DT	AV	PAV	VL	PHGL
i	172.5	166	178.5	208	160.5	178.5
a	154	188	152.5	204	166	167
i:	222	232	226.5	266	216	250
a:	234	268	247	256.5	243	254

Table 6.4.1.e.4

Average durations in msec of vowels preceding labial,
dental, alveolar, palato-alveolar, velar and pharyngeal
consonants. In phrase. Subject HJ.

Vowel	LB	DT	AV	PAV	VL	PHGL
i	137.5	130.5	148.5	154	135.5	137.5
a	136.5	142	145.5	156	137	137.5
i:	157.5	160	153.5	154	141.5	169
a:	187.5	187	192	186	178.5	183.5

Graph showing the effect of place of articulation of
the following consonant on the durations of the vowels
/i/ and /i:/ in monosyllabic position.
In isolation, speaker FB.
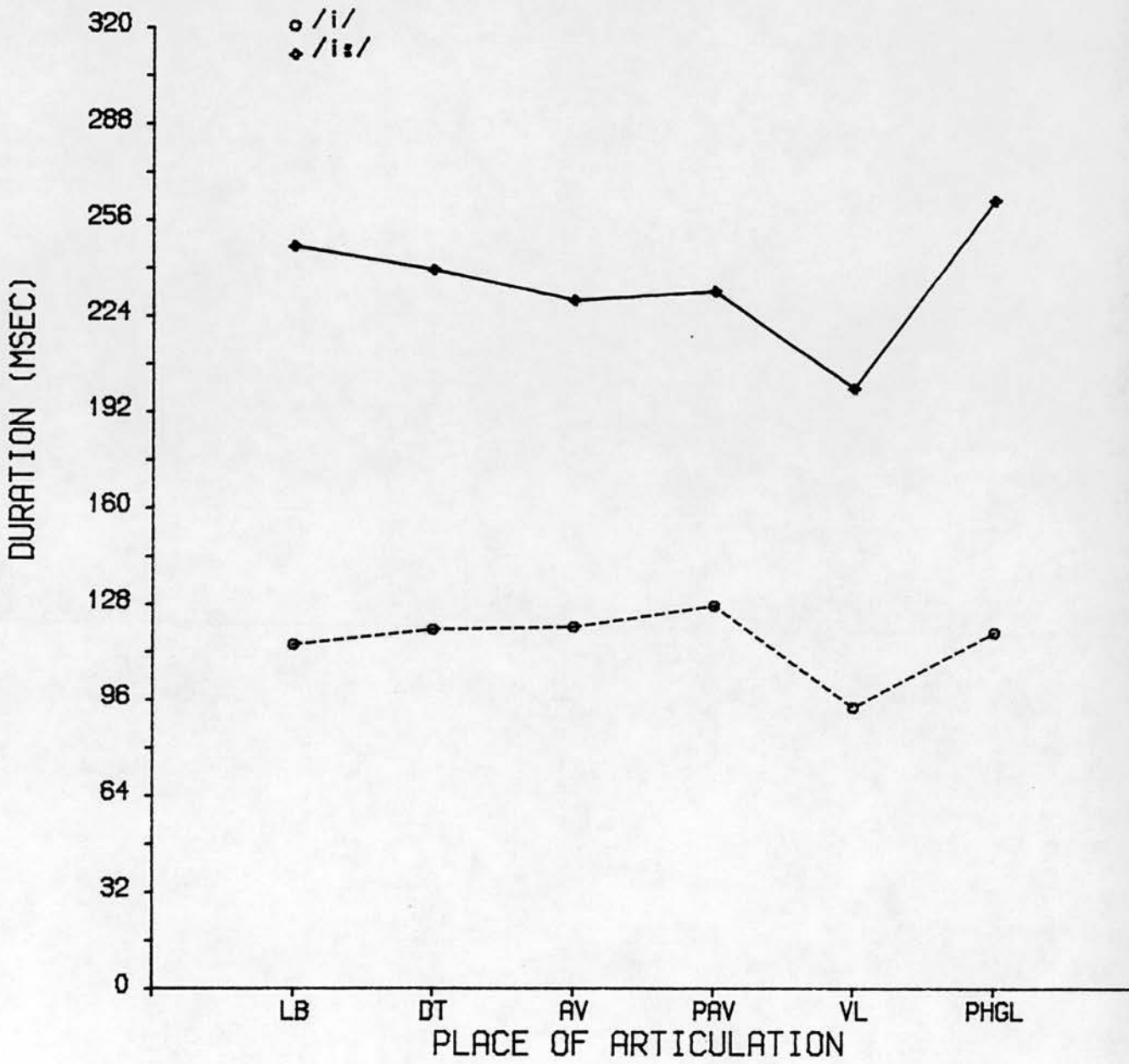
Figure 6.4.1.e.1

Graph showing the effect of place of articulation of the following consonant on the durations of the vowels /i/ and /i:/ in monosyllabic position. In phrase, speaker EB.
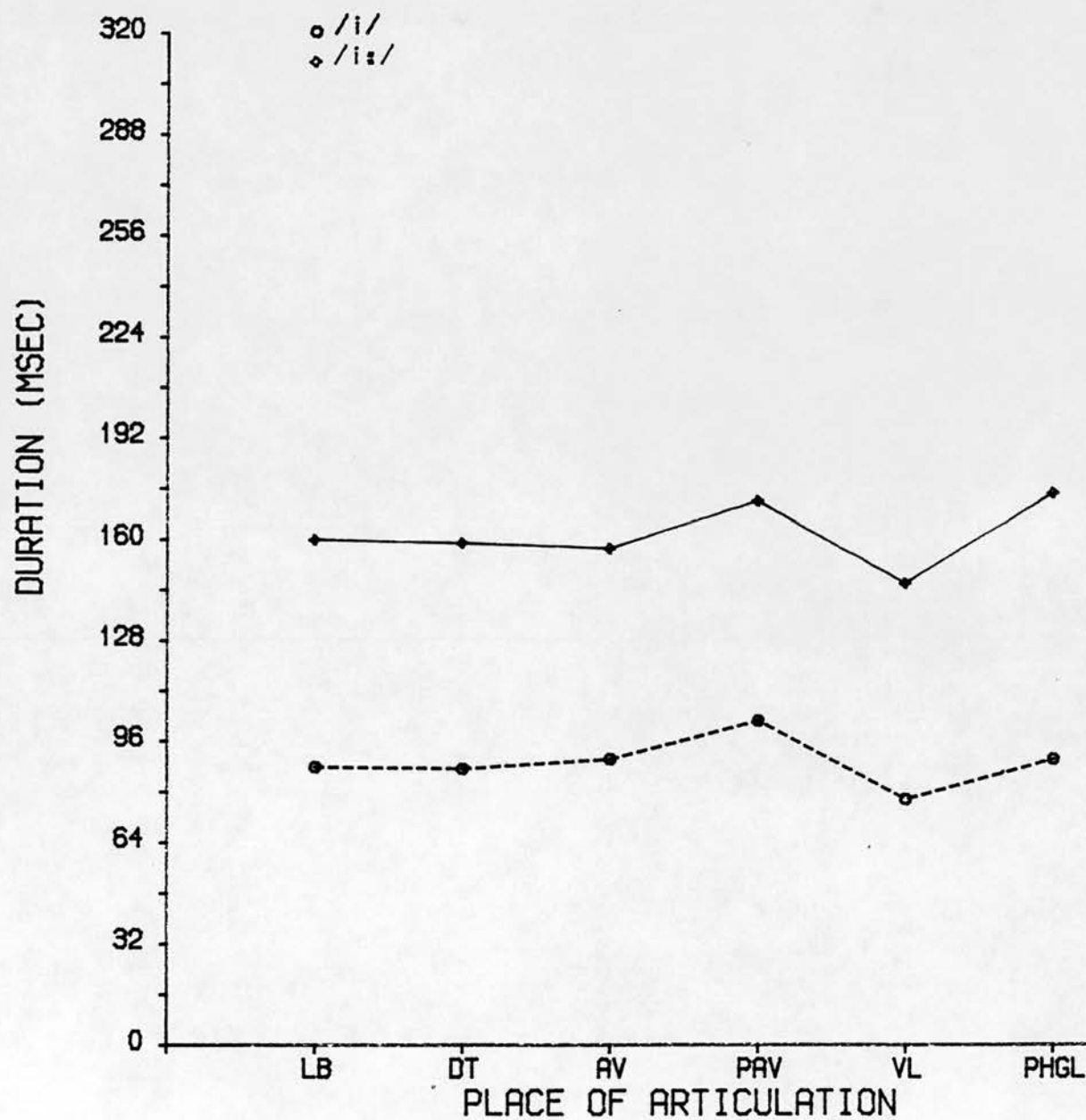
Figure 6.4.1.e.2

Graph showing the effect of place of articulation of
the following consonant on the durations of the vowels
/i/ and /iː/ in monosyllabic position.
In isolation, speaker HJ.
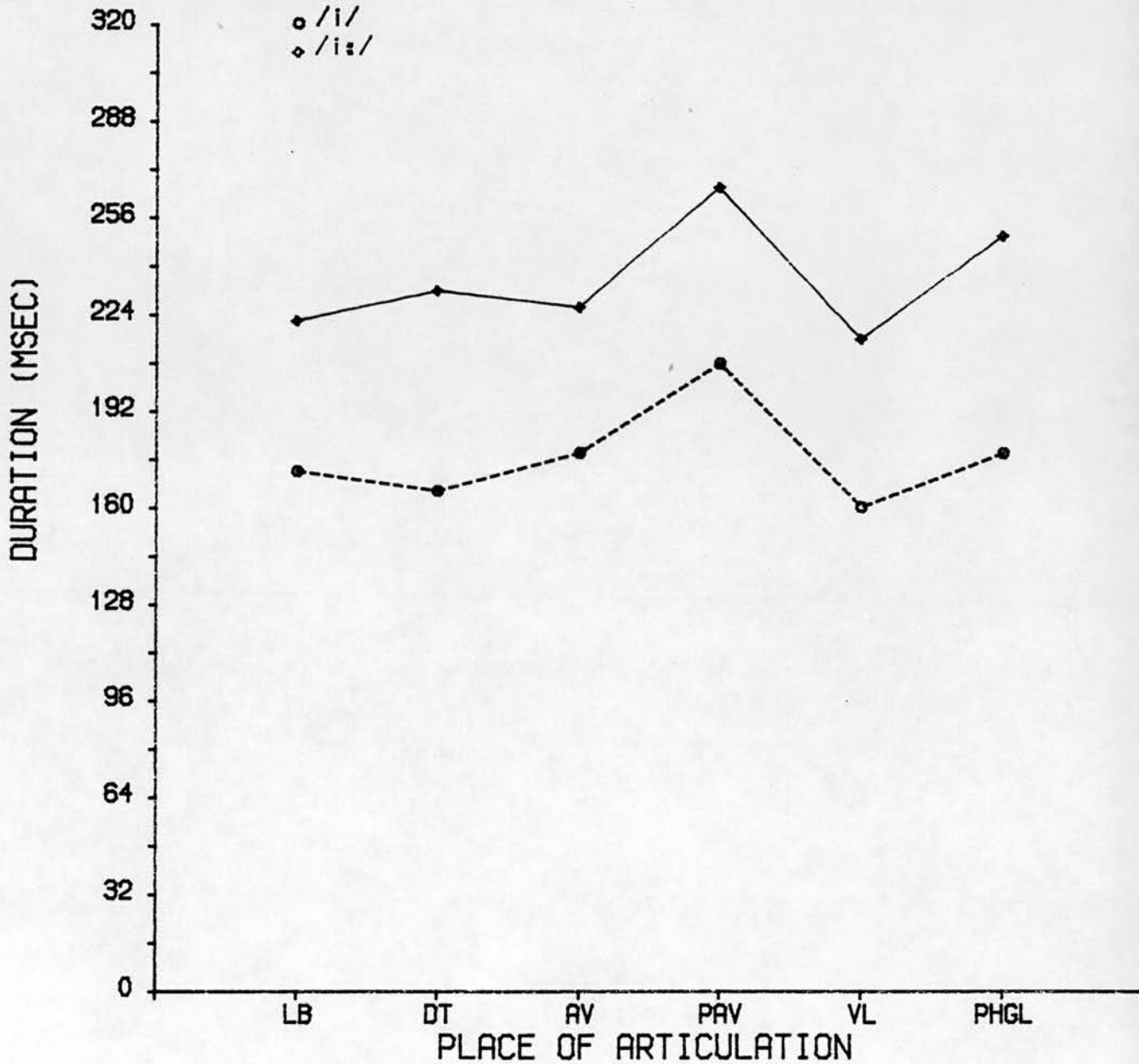
Figure 6.4.1.e.3

Graph showing the effect of place of articulation of
the following consonant on the durations of the vowels
/i/ and /i:/ in monosyllabic position.
In phrase, speaker HJ.
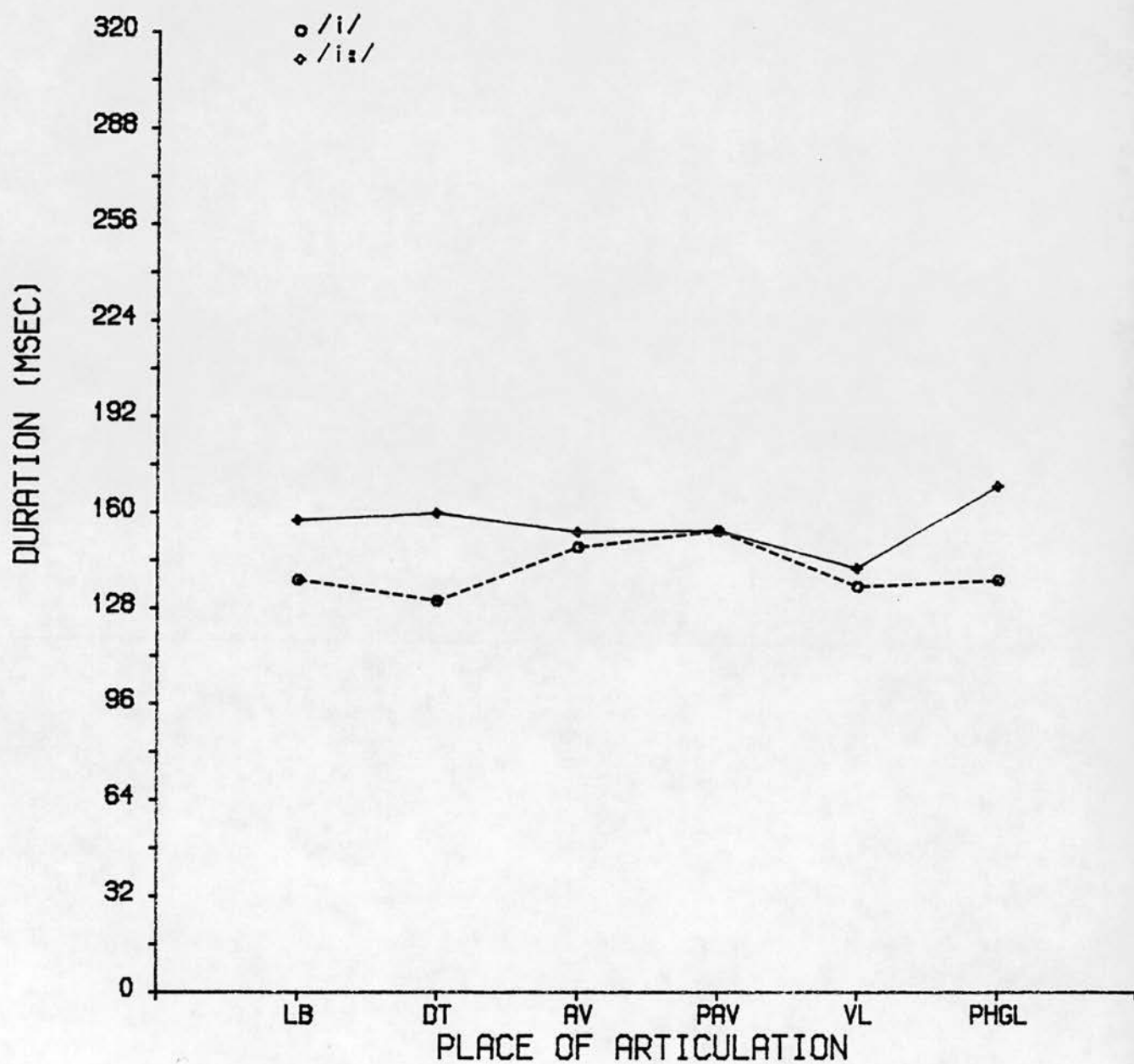
Figure 6.4.1.e.4

- palato-alveolar> alveolar= pharyngeal> labial> dental> velar (one-word list, HJ)

- palato-alveolar> alveolar> labial= pharyngeal> velar> dental (phrase, HJ)

The duration of /i:/ decreases in the following order as an effect of the place of articulation of the following consonants:

- pharyngeal> labial> dental> palato-alveolar> alveolar> velar (one- word list, FB)

- pharyngeal> palato-alveolar> labial> dental> alveolar> velar (phrase, FB)

- palato-alveolar> pharyngeal> dental> alveolar> labial> velar (one- word list, HJ)

- pharyngeal> dental> labial> palato-alveolar> alveolar> velar (phrase, HJ).

This result is in agreement with the findings of House and Fairbanks (1953) and Peterson and Lehiste (1960) for American English where they found that vowels are shortest before velars and longest before palato-alveolars and alveolars. It disagrees with Al-Jazary's results as he found that vowels are shortest before pharyngeals. The fact that vowels preceding velars are shortest while vowels preceding front and central consonants are longest contradicts Delattre's (1962) hypothesis that vowels are longest before back consonants and shortest before front consonants.

As for the open vowels /a/ and /a:/ the data do

not reveal a very regular pattern in the variation of their duration as a result of the variation in the place of articulation of the postvocalic consonants (see Tables 6.4.1.e.3-4 and Graphs 6.4.1.e.5-8).

The duration of /a/ decreases in the following order as aresult of point of articulation of the following consonant:

- pharyngeal> alveolar> velar> palato-alveolar> labial> dental (one-word list, FB)

- pharyngeal> velar> alveolar> labial> dental> palato-alveolar (phrase, FB)

- palato-alveolar> dental> pharyngeal> velar> labial> alveolar (one-word list, HJ)

- palato-alveolar> alveolar> dental> pharyngeal> velar> labial (phrase, HJ)

/a:/ gets shortened in the following order:

- palato-alveolar> labial> pharyngeal= velar> dental (one-word list, FB)

- labial> palato-alveolar> alveolar> velar> dental=pharyngeal (phrase, FB)

- dental> palato-alveolar> pharyngeal> alveolar> velar> labial (one -word list, HJ)

- alveolar> labial> dental> palato-alveolar> pharyngeal> velar (phrase, HJ)

The above patterns show that open vowels do not have as consistent a pattern as the close vowels, though

Graph showing the effect of place of articulation of
the following consonant on the durations of the vowels
/a/ and /aː/ in monosyllabic position.
In isolation, speaker FB.
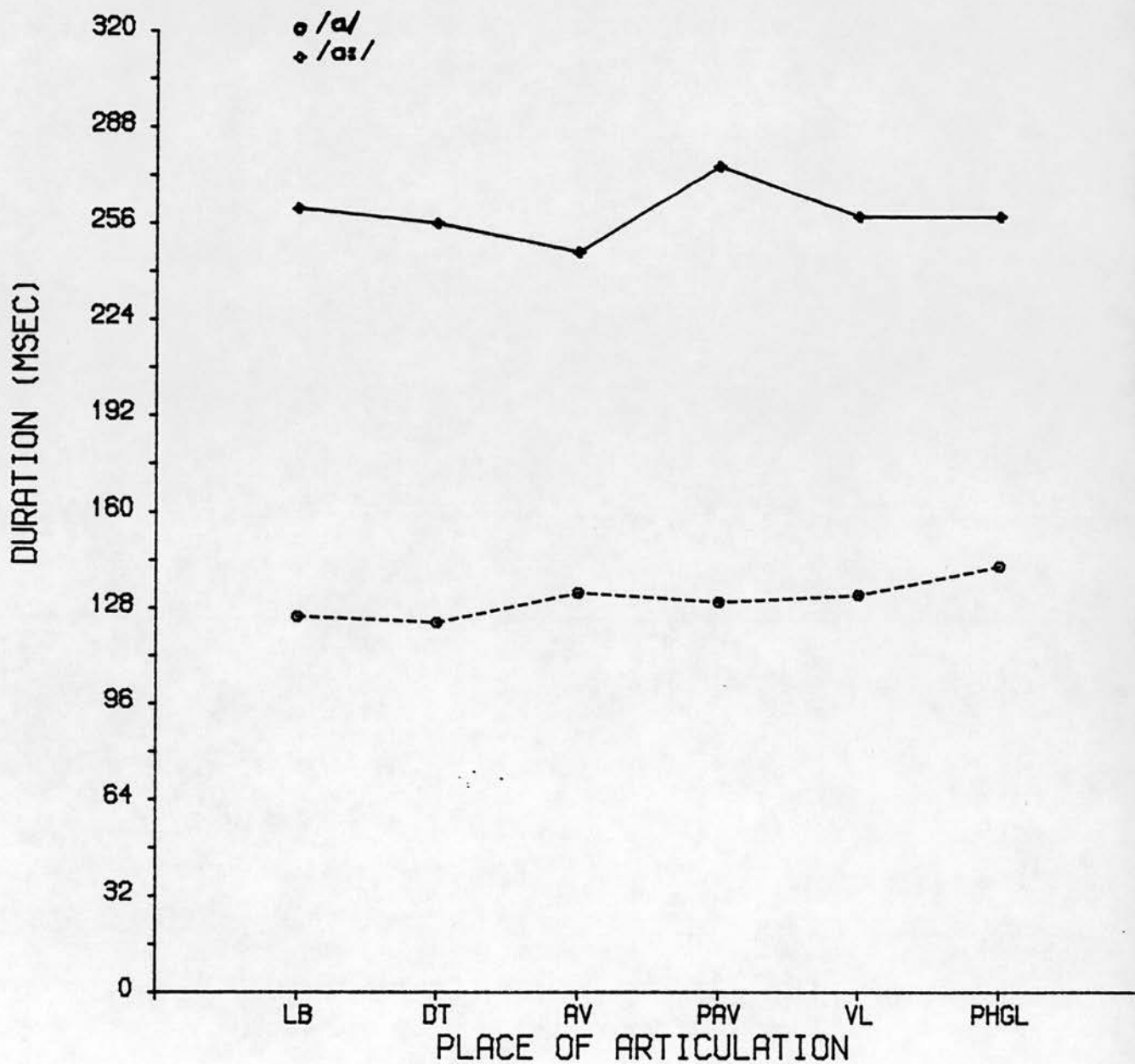
Figure   6.4.1.e.5

Graph showing the effect of place of articulation of
the following consonant on the durations of the vowels
/a/ and /aː/ in monosyllabic position.
In phrase, speaker FB.
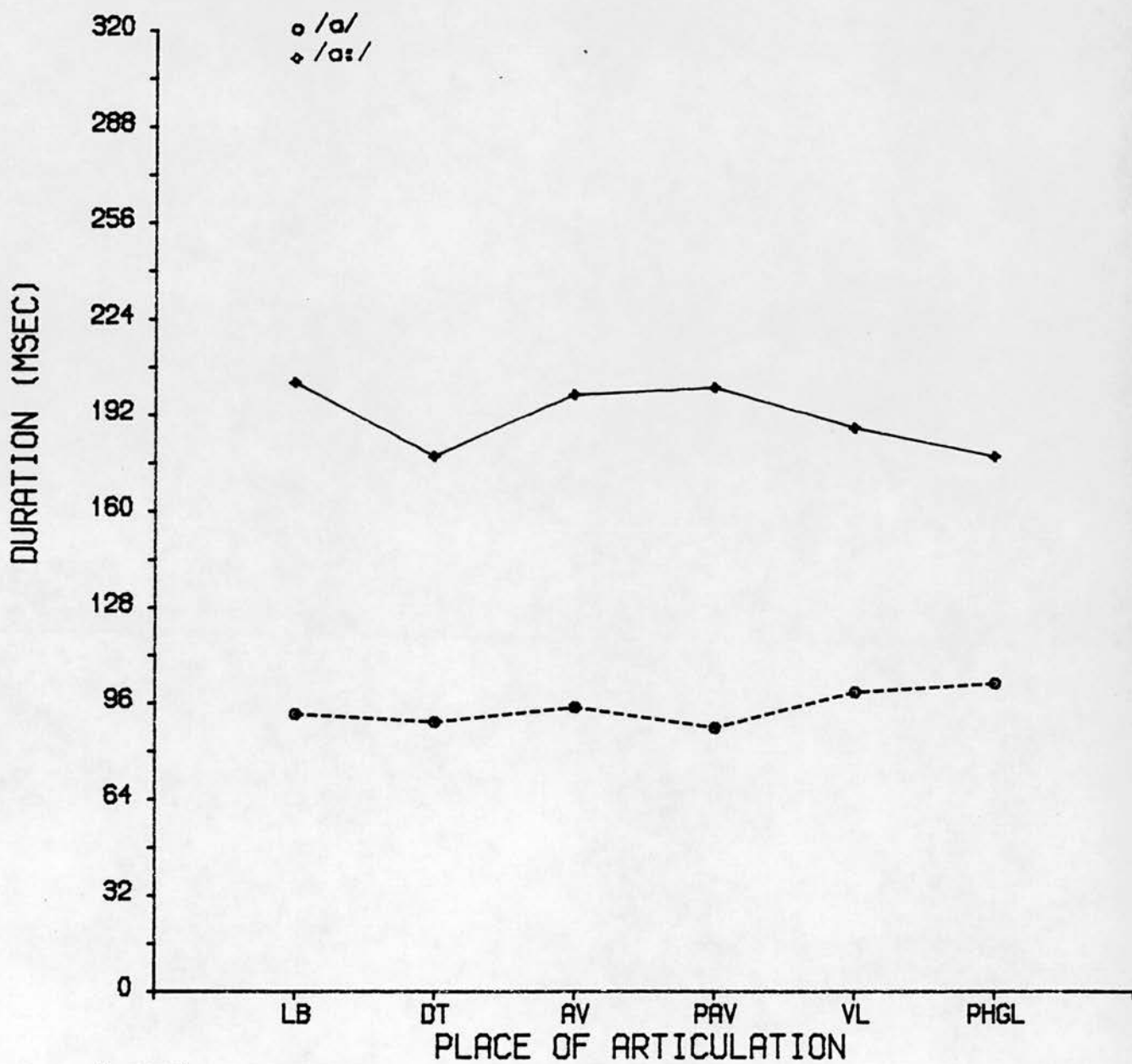
Figure 6.4.1.e.6

Graph showing the effect of place of articulation of
the following consonant on the durations of the vowels
/a/ and /a:/ in monosyllabic position.
In isolation, speaker HJ.
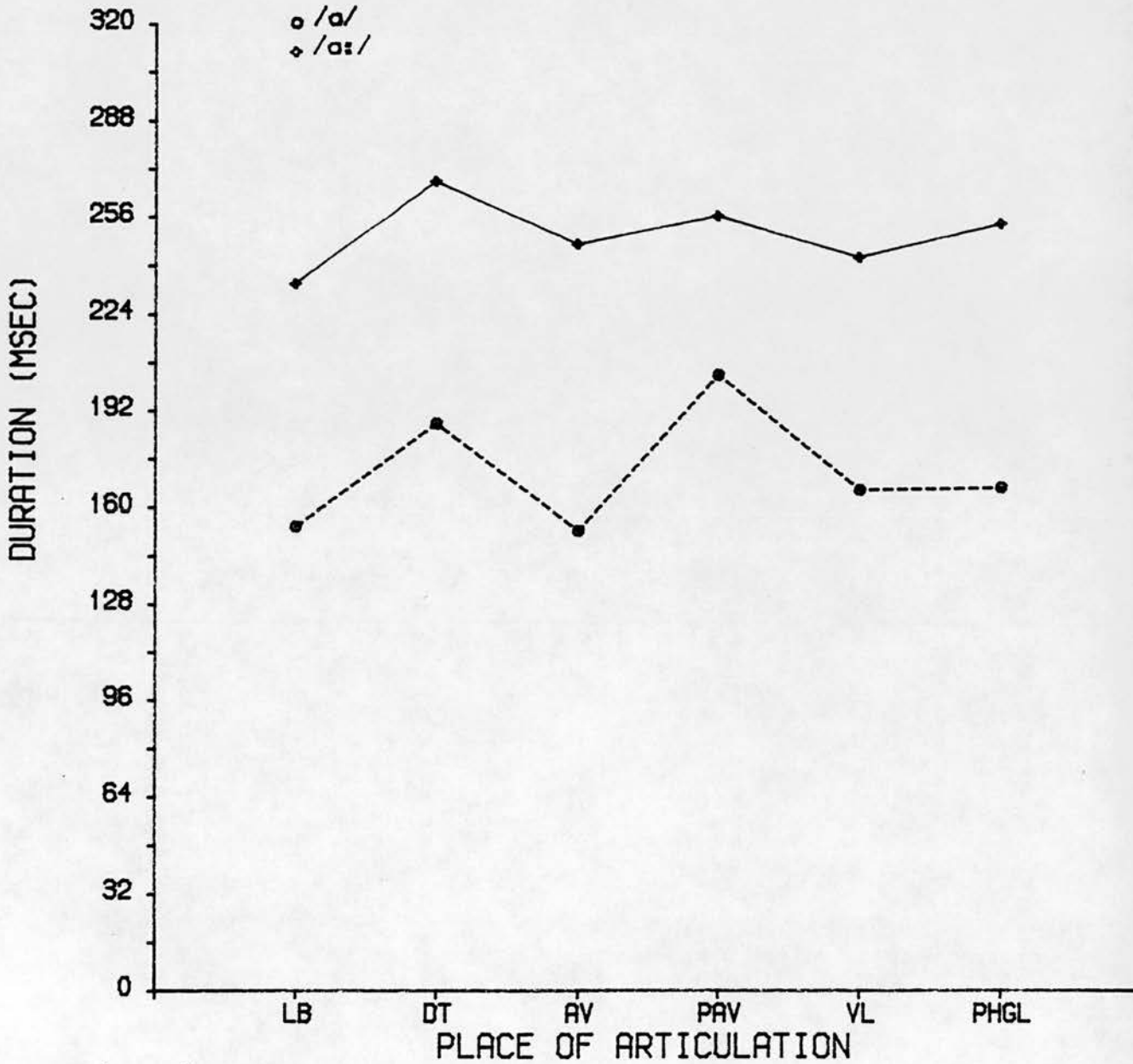
Figure 6.4.1.e.7

Graph showing the effect of place of articulation of the following consonant on the durations of the vowels /a/ and /aː/ in monosyllabic position.
In phrase, speaker HJ.
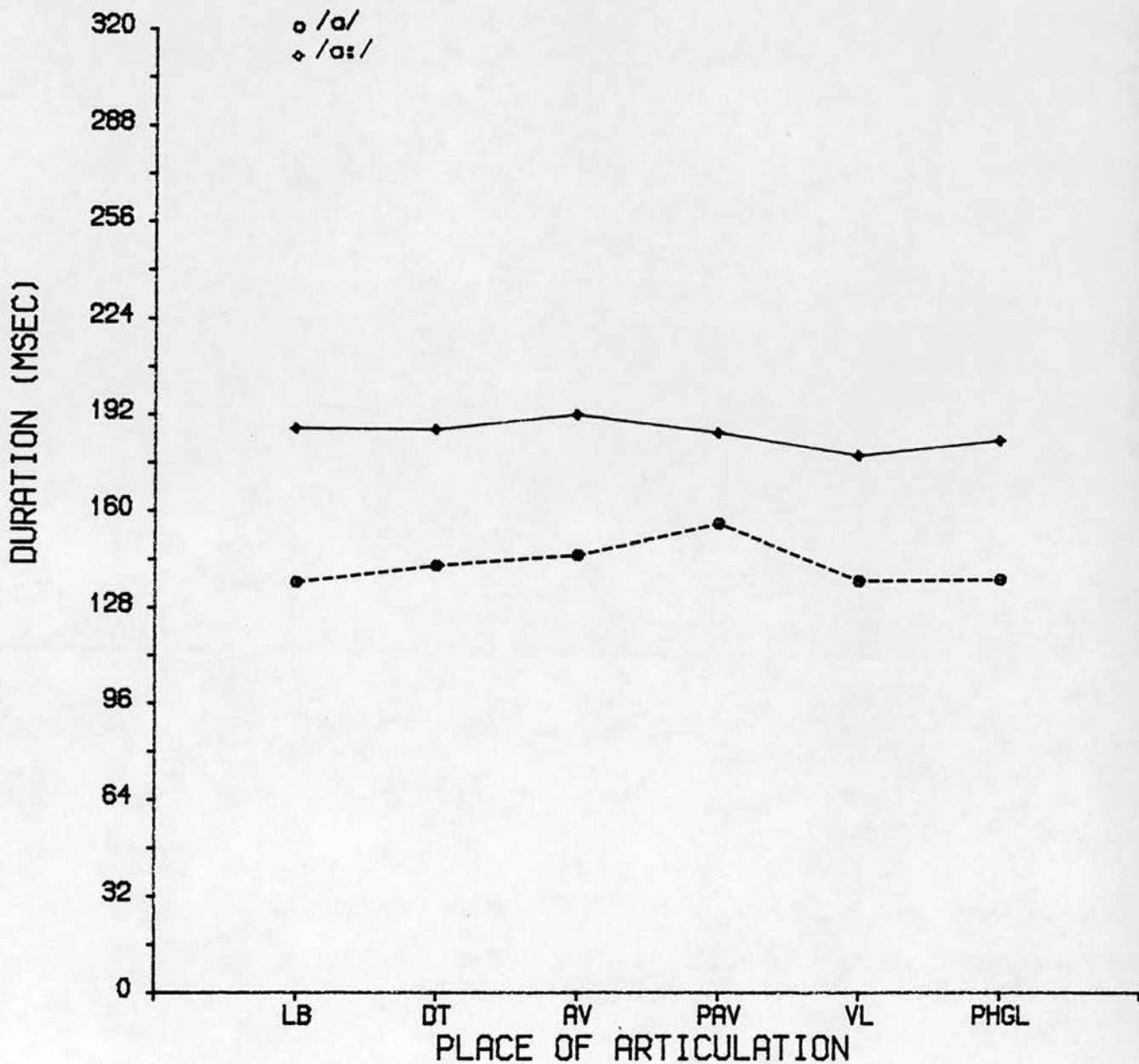
Figure 6.4.1.e.8

there is a slight tendency for them to be lengthened before central and pharyngeal consonants and to be shortened before velars, labials and dentals.

The fact that vowels are shorter in duration before velars and labials could be attributed to the coarticulatory effect. As the lips are not involved in the articulation of the vowels they are free to coarticulate in anticipation of the following labial consonant, thus causing the preceding vowel to end earlier. Also the front vowels involve only the front part of the tongue in their articulation, leaving the back of the tongue free to coarticulate and assume the position of the following velar consonant before the complation of the vowel itself, thus resulting in a relatively shorter duration.

The fact that high front vowels are longest before palato-alveolar and pharyngeal consonants may be ascribed to the lack of such coarticulatory effects. The pharyngeals require the retraction and lowering of the whole body of the tongue, a movement against the nature of the front high vowels, thus the articulation of the vowel has to be fully completed before the tongue starts taking the required configuration for the following pharyngeal consonant. The production of a following palato-alveolar consonant involves more or less the same articulators as those required for the production of the preceding front high vowel. But as the production of a

fricative requires a somewhat more complex and subtle adjustment than the preceding vowel, it takes a relatively longer time to achieve, resulting in lengthening the preceding vowel.

The above data revealed some rather consistent relations between the front high vowel's duration and place of articulation of the following consonants. The fact that some of these relations have been found in other languages, that vowels are shorter before labials and velars and longer before alveolars and palato-alveolars, makes us assume that they are language universal.

6.5. The effect of stress

Beside pitch and intensity, duration has been proved to be one of the important acoustic correlates of stress in some languages, and that the longer duration of vowels in stressed syllables is one of the phonetic manifistations of stress. Vowels are considerably longer in stressed than unstressed syllables, a fact proved to be true for several languages. In English, the average stressed vowel is approximately 50% longer than the average unstressed vowel, claim Parmenter and Trevino (1935). Fry (1955) made measurements of vowel duration in stressed and unstressed syllables in English and found

that vowel duration is considerably longer in stressed than in unstressed syllbles . Tiffany's (1959) study of American English showed a similar result as he found that vowel duration is significantly longer in stressed syllables than unstressed syllables. Delattre (1966) cross-linguistic study of the influence of stress on vowel duration in four languages (English, German, Spanish and French) revealed that stressed syllables are longer than unstressed syllables in all the four languages though the ratio is not equal for all of them "English has the widest ratio of syllable lengths from stressed to unstressed, German has a narrow ratio and Spanish the narrowest" (p189). Absi's (1966) study of Arabic showed that the ratio of unstressed to stressed vowel is 70.6%; he also reports the following ratios for some other languages: Swedish 65%, German 65%, Italian 56% and Danish 50%. Al-Jazary (1981) found that vowels in stressed syllables are considerably longer than vowels in unstressed syllables in Iraqi Arabic and that the difference between them is very significant.

But this lengthening effect of stress on vowel duration does not seem to be a language-universal phenomenon as there are languages in which stress does not affect the duration of its vowels or it has a very small effect as in Czech, Finnish and Estonian (Lehiste 1970).

The average durations of stressed and unstressed

vowels in polysyllabic words in the one-word list and the phrase list in QA are represented in Tables 6.5.1-4 and Graphs 6.5.1-4. The data show that stress has a significant effect on the duration of the long vowels /i:/ and /a:/ and that it has no or little effect on the duration of the short vowels /i/ and /a/.

FB's data reveal that in isolated words /i/ is 60.14 msec long in unstressed position and 65.11 msec in stressed position. The ratio of the two means is 0.95 and the difference between their duration (4.97 msec) is not significant ($t69=0.60$, $p>0.20$). In phrase, /i/ has an average value of 53 msec in unstressed syllables and 60 msec in stressed syllables. The ratio between the two values is 0.88 and difference (7 msec) is non-significant ($t69= 1.94$, $p<0.10$). /a/ has an average duration of 99.08 msec in unstressed syllables and 89.73 msec in stressed syllables in isolated words. The ratio between the two means is 1.10 and the difference (9.35 msec) is non-significant ($t152=-1.93$, $p<0.10$). In phrase /a/ is on average 72.87 msec in unstressed syllables and 80 msec in stressed syllables. The ratio between the two means is 0.91 and the difference proved to be significant ($t150=2.34$, $p<0.02$). In isolated words /i:/ is 130.90 msec long in unstressed position and 156 msec long in stressed position. The durational difference between the two means (25.1 msec) proved to be statistically significant ($t47=2.02$, $p=0.5$) and the ratio is 0.83. In phrase /i:/ has

Table 6.5.1

Average durations in msec and ratios of vowels in unstressed
to stressed position. In isolated words. Subject FB.

Vowel	Unstressed	Stressed	Ratio	Significance
i	60.14	65.11	0.95	$p > 0.20$
a	99.08	89.73	1.10	$p < 0.10$
i:	130.90	156	0.83	$p = 0.05$
a:	118.11	211.16	0.55	$p < 0.001$

Table 6.5.2

Average durations in msec and ratios of vowels in unstressed
to stressed position. In phrase. Subject FB.

Vowel	Unstressed	Stressed	Ratio	Significance
i	53	60	0.88	$p < 0.10$
a	72.87	80	0.91	$p < 0.02$
i:	101.63	130.89	0.77	$p < 0.02$
a:	108.44	174.67	0.62	$p < 0.001$

Table 6.5.3

Average durations in msec ratios of vowels in unstressed to
stressed position.   In isolated words.   Subject HJ.

Vowel	Unstressed	Stressed	Ratio	Significance
i	99.13	88.24	1.12	$p < 0.20$
a	126.18	102.08	1.23	$p < 0.001$
i:	127.40	160.59	0.79	$p < 0.01$
a:	129.22	198.43	0.65	$p < 0.001$

Table 6.5.4

Average durations in msec and ratios of vowels in unstressed
to stressed position.   In phrase.   Subject HJ.

Vowel	Unstressed	Stressed	Ratio	Significance
i	81.90	81.67	1	$p > 0.20$
a	99.37	99.53	0.99	$p > 0.20$
i:	119.60	129.86	0.92	$p < 0.20$
a:	122.58	168.19	0.72	$p < 0.001$

Graph showing the mean durations of /i/, /a/, /i:/
and /a:/ in stressed and unstressed positions.
In isolation. Speaker FB.
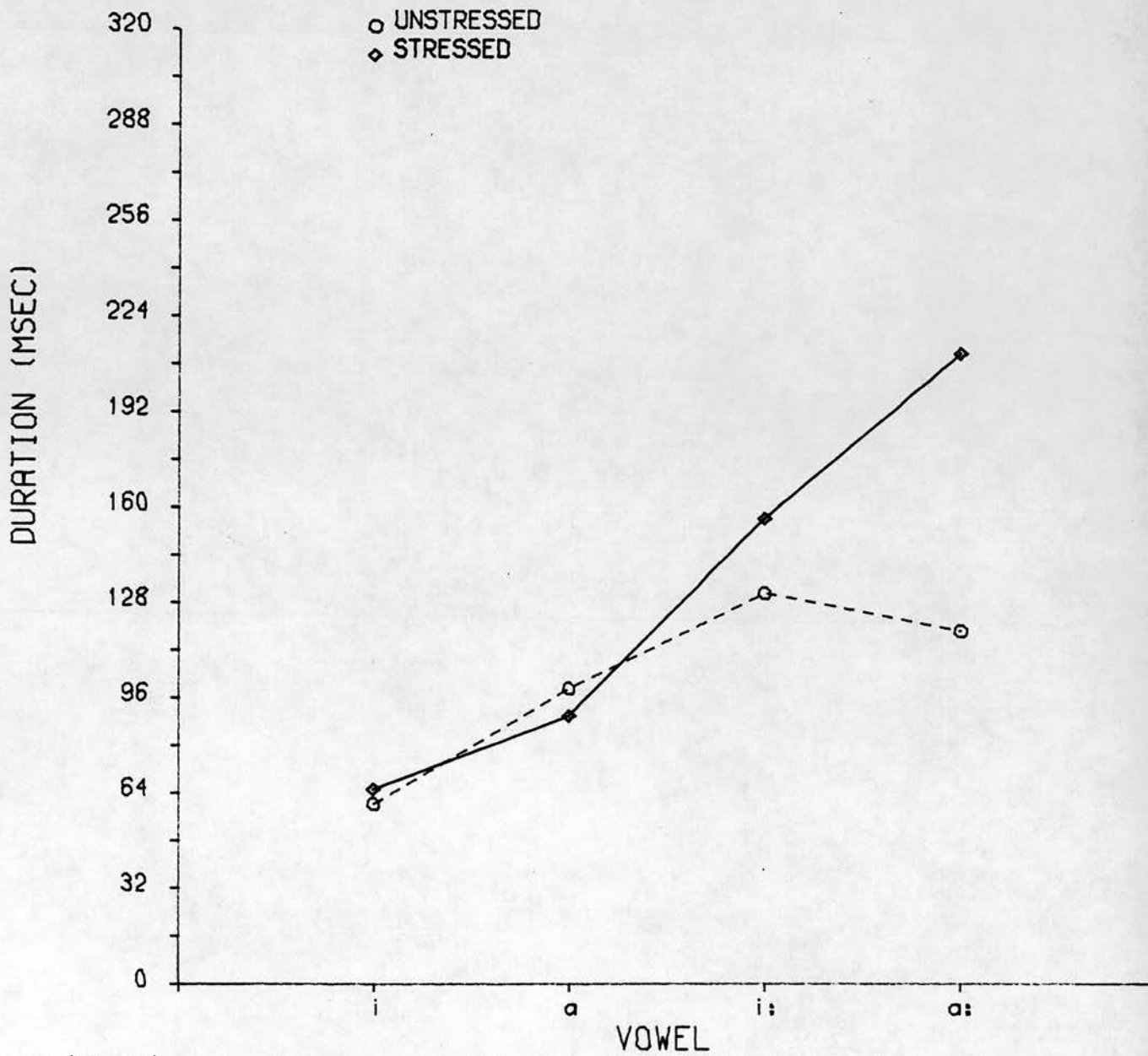
Figure 6.5.1

Graph showing the mean durations of /i/, /a/, /i:/ and /a:/ in stressed and unstressed positions. In phrase. Speaker FB.
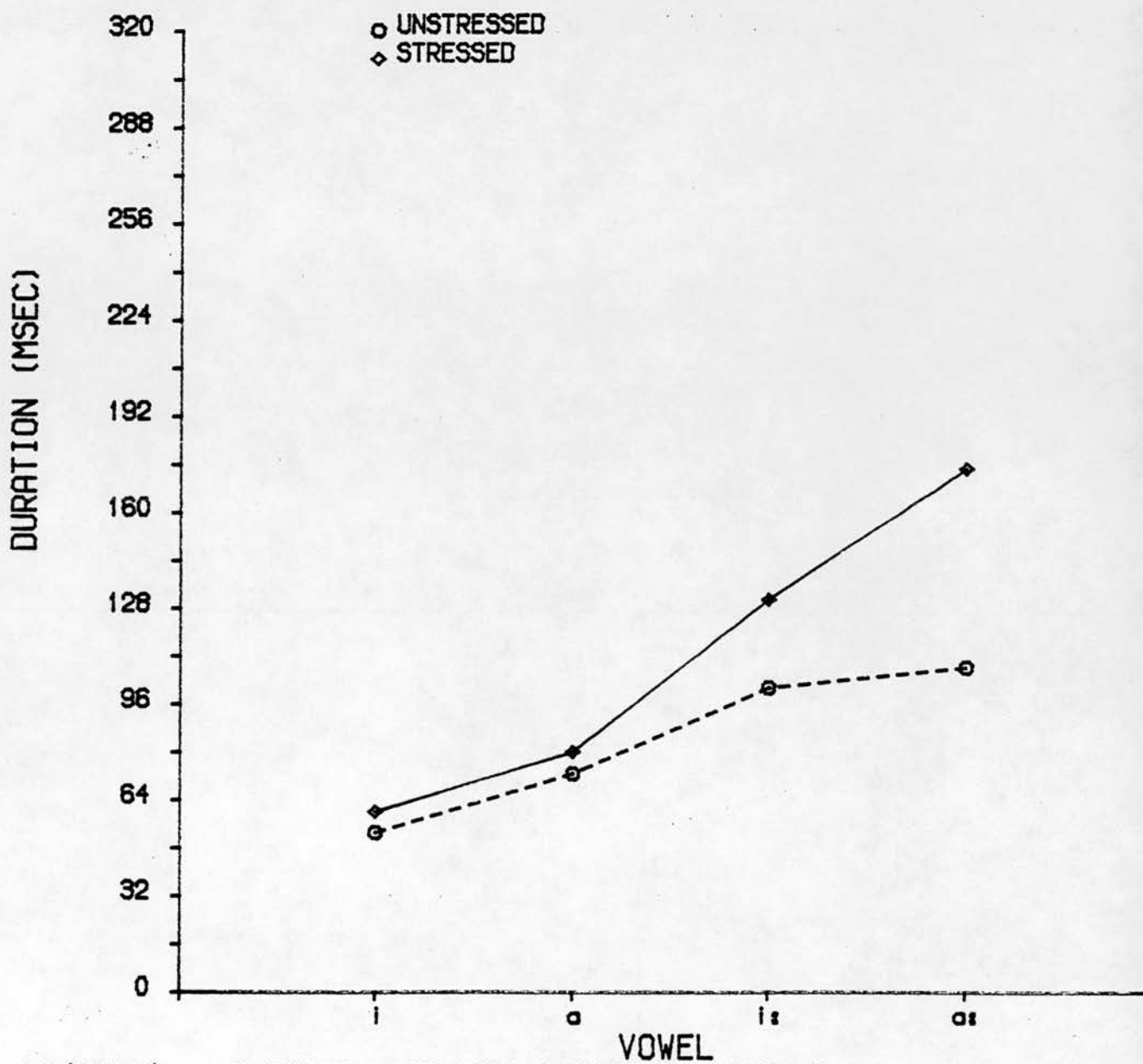
Figure 6.5.2

Graph showing the mean durations of /i/, /a/, /iː/
and /aː/ in stressed and unstressed positions.
In phrase. Speaker HJ.

6.5 ?
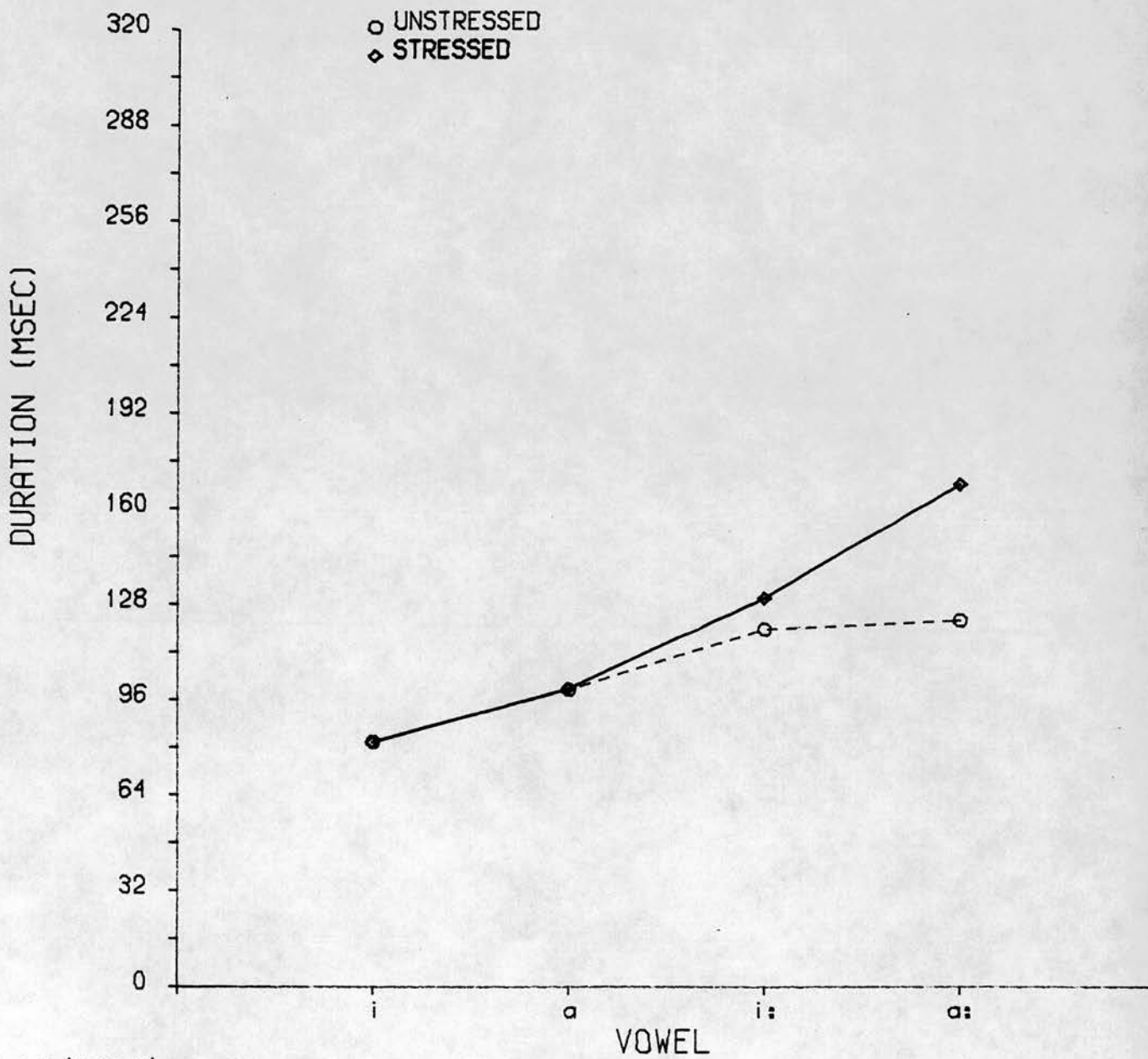
Figure 6.5.3

Graph showing the mean durations of /i/, /a/, /i:/
and /a:/ in stressed and unstressed positions.
In isolation. Speaker HJ.
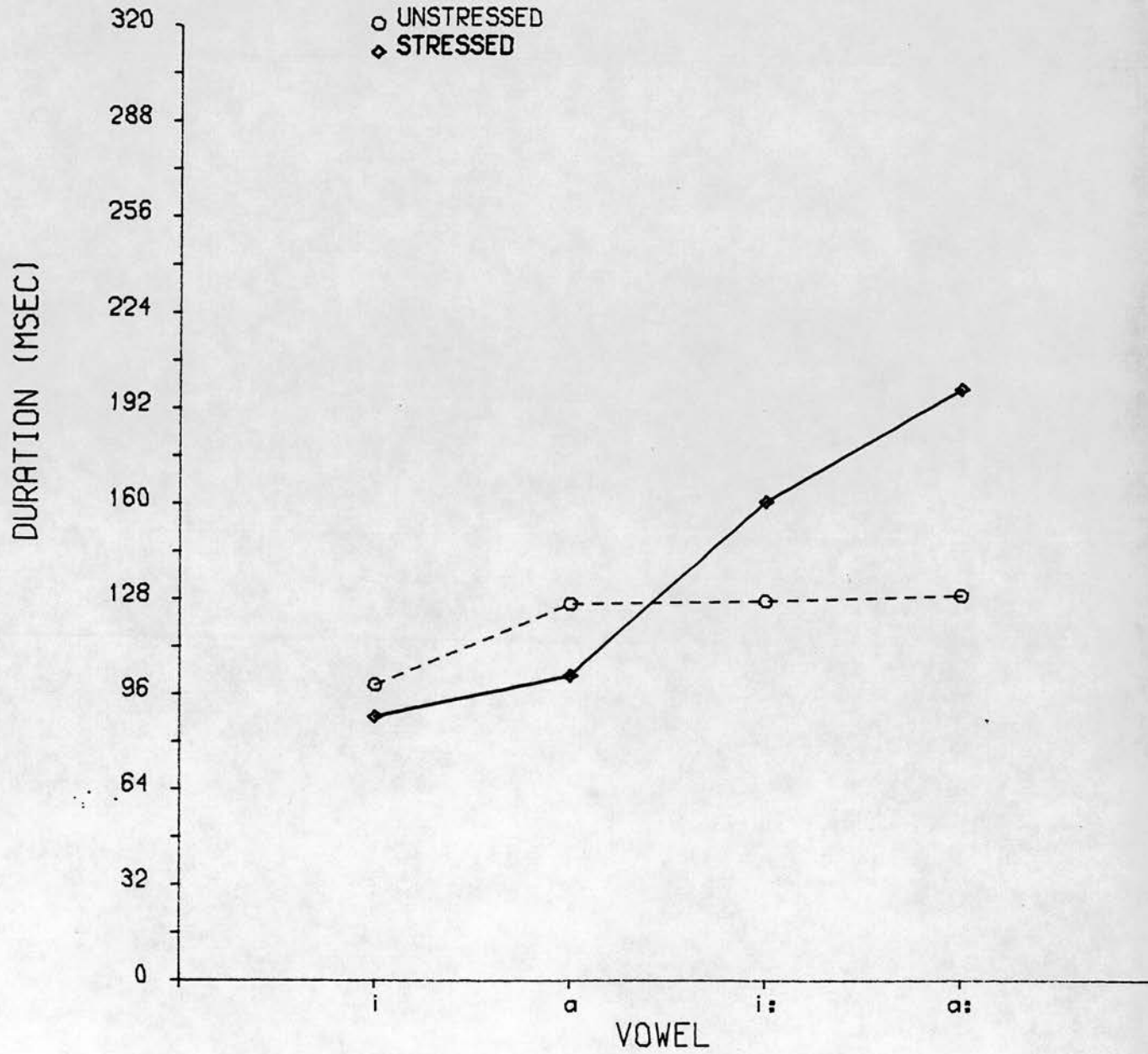
Figure 6.5.4

an average duraion of 101.63 msec in unstressed syllables and 130.89 msec in stressed position. The difference between the two means (29.26 msec) is very significant (t47=2.67, p<0.02) and the ratio is 0.77. /a:/ has an average duration of 118.11 msec in unstressed syllable and 211.16 msec in stressed syllables in isolated words. The difference between the two means (93.05 msec) is statistically very significant (t76=8.35, p<0.001) and the ratio is 0.55. In phrase /a:/ is 108.44 msec in ustressed position and 174.67 msec in stressed position. The durational difference between the two values (66.23 msec) is highly significant (t74=7.20, p<0.001) and the ratio is 0.62.

HJ's data show that /i/ has a mean duration of 99.13 msec in unstressed syllables and 88.24 msec in stressed syllables in isolated words. The ratio between the two means is 1.12 and the difference (10.89 msec) is insignificant (t91=-1.52, p<0.20). In phrase /i/ is 81.90 msec long in unstressed position and 81.67 msec long in stressed position. The durational difference between the two means is almost non-existent and very insignificant (t91=-0.05, p>0.20) and the ratio is 1. In isolated words /a/ is on average 126.18 msec in ustressed syllables ad 102.08 msec in stressed syllables. Thus /a/ is significantly longer in unstressed position than in stressed position (t174=-3.65, p< 0.001) and the ratio is 1.23. While in phrase it has more or less the same

length in stressed (99.53 msec) and in unstressed syllables (99.37 msec). The ratio is 0.99 and the difference is very insignificant. In isolated words /i:/ is 127.40 msec long in unstressed syllables and 160.59 msec in stressed syllables. The ratio between these two means is 0.79 and the difference (33.19 msec) is highly significant ($t69= 2.84$, $p<0.01$). In phrase /i:/ has a mean duration of 119.60 msec in ustressed position and 129.86 msec in stressed position. The ratio between the two values is 0.92 and the difference (10.26 msec) is non-significant ($t69=1.42$, $p<0.20$). /a:/ is significantly longer in duration in the stressed position than the unstressed position. It is 129.22 msec long in unstressed syllables and 198.43 msec in stressed syllables. The ratio is 0.65 and the difference (69.12 msec) is highly significant ($t102=11.36$, $p<0.001$). In phrase /a:/is 122.58 msec in unstressed position and 168.19 msec in stressed positon. The ratio between the two means is 0.72 and the difference is highly significant ($t102=10.07$, $p<0.001$).

The above results reveal that stress has no effect on the duration of the short vowels /i/ and /a/ since they are as long or even longer in unstressed syllables than they are in stressed syllables. The longer duration of /a/ in unstressed position than in the stressed position may be explained by the fact that when it is unstressed it occurs in word-final open syllables in most instances while when it is stressed it occurs in

non-word-final positon as stress usually falls on the penultimate syllables. Hence the lengthening effect of utterance final open syllables is more marked than the effect of stress. In phrase this effect seems to diminish as the word-final short vowel is not utterance final as it is followed by more segments of the carrier phrase.

The results also revealed that stress has a significant effect on the duration of the long vowels /i:/ and /a:/ which suggest that vowel duration is a very important acoustic correlate of stress for the long vowels but not for the short vowels.

6.6. The effect of word length

The shortening of the phones in polysyllabic words has been observed in many languages, e.g. English (Sharf 1962 Harris and Umeda 1974), Hungarian (Meyer & Gombocz 1909), Spanish (Menzerath & Oleza 1928), Swedish (Elert 1964) and Maltese (Azzopardi 1981). Tables 6.6.1-8 and Graphs 6.6.1-4 reveal a similar result for QA. The number of syllables in the word does influence the duration of long and short vowels as vowels in monosyllabic words are much longer than when they are in multisyllabic words.

FB's data show that in isolated words /i/ has a mean duration of 116.50 msec in monosyllabic words, 64.75

Table 6.6.1

Mean durations in msec and ratios of vowels in monosyllabic
words to bisyllabic words. In isolated words. Subject FB.

Vowel	1-syllable	2-syllable	Ratio	Significance
i	116.50	64.75	0.55	$p < 0.001$
a	130.20	99.68	0.76	$p < 0.001$
i:	235.48	168.07	0.71	$p < 0.001$
a:	252.68	212.46	0.84	$p < 0.001$

Table 6.6.2

Mean durations in msec and ratios of vowels in monosyllabic
words to bisyllabic words. In phrase.   Subject FB.

Vowel	1-syllable	2-syllable	Ratio	Significance
i	89.20	57.71	0.64	$p < 0.001$
a	95.42	75.85	0.79	$p < 0.001$
i:	158.78	135.92	0.85	$p < 0.001$
a:	195.5	172.41	0.88	$p < 0.001$

Table 6.6.3

Average durations in msec and ratios of vowels in bisyllabic
words to trisyllabic words. In isolated words. Subject FB.

Vowel	2-syllable	3-syllable	Ratio	Significance
i	64.75	60.93	0.94	$p > 0.20$
a	99.68	82.29	0.82	$p < 0.001$
i:	168.07	128.63	0.76	$p < 0.001$
a:	212.46	144.15	0.67	$p < 0.001$

Table 6.6.4

Average durations in msec and ratios of vowels in bisyllabic
words to trisyllabic words. In phrase. Subject FB.

Vowel	2-syllable	3-syllable	Ratio	Significance
i	57.71	55.60	0.96	$p > 0.20$
a	75.85	71.11	0.93	$p = 0.20$
i:	135.92	110.09	0.80	$p < 0.01$
a:	172.41	131.60	0.76	$p < 0.001$

Table 6.6.5

Mean durations in msec and ratios of vowels in bisyllabic
words to monosyllabic words. In isolated words. Subject HJ.

Vowel	1-syllable	2-syllable	Ratio	Significance
i	177.58	95	0.53	$p < 0.001$
a	163.27	125.40	0.76	$p < 0.001$
i:	231.03	173.30	0.75	$p < 0.001$
a:	248.66	189.20	0.76	$p < 0.001$

Table 6.6.6

Mean durations in msec and ratios of vowels in bisyllabic
words to monosyllabic words. In phrase. Subject HJ.

Vowel	1-syllable	2-syllable	Ratio	Significance
i	143.48	82.05	0.57	$p < 0.001$
a	142.16	102.45	0.72	$p < 0.001$
i:	156.90	136.74	0.87	$p < 0.001$
a:	189.70	162.13	0.85	$p < 0.001$

Table 6.6.7

Average durations in msec and ratios of vowels in trisyllabic words to bisyllabic words. In isolated words. Subject HJ.

Vowel	2-syllable	3-syllable	Ratio	Significance
i	95.13	86.63	0.91	p > 0.20
a	125.40	94.81	0.75	p < 0.001
i:	173.30	129.21	0.74	p < 0.001
a:	189.20	150.96	0.79	p < 0.001

Table 6.6.8

Average durations in msec and ratios of vowels in trisyllabic words to bysyllabic words. In phrase. Subject HJ.

Vowel	2-syllable	3-syllable	Ratio	Significance
i	82.05	80.73	0.98	p > 0.20
a	102.45	84.44	0.82	p < 0.001
i:	136.74	115.64	0.84	p < 0.001
a:	162.13	136.83	0.84	p < 0.001

Graph showing the effect of the number of syllables
in a word on the duration of the vowels /i/, /a/, /i:/
and /a:/. In isolation, speaker FB.
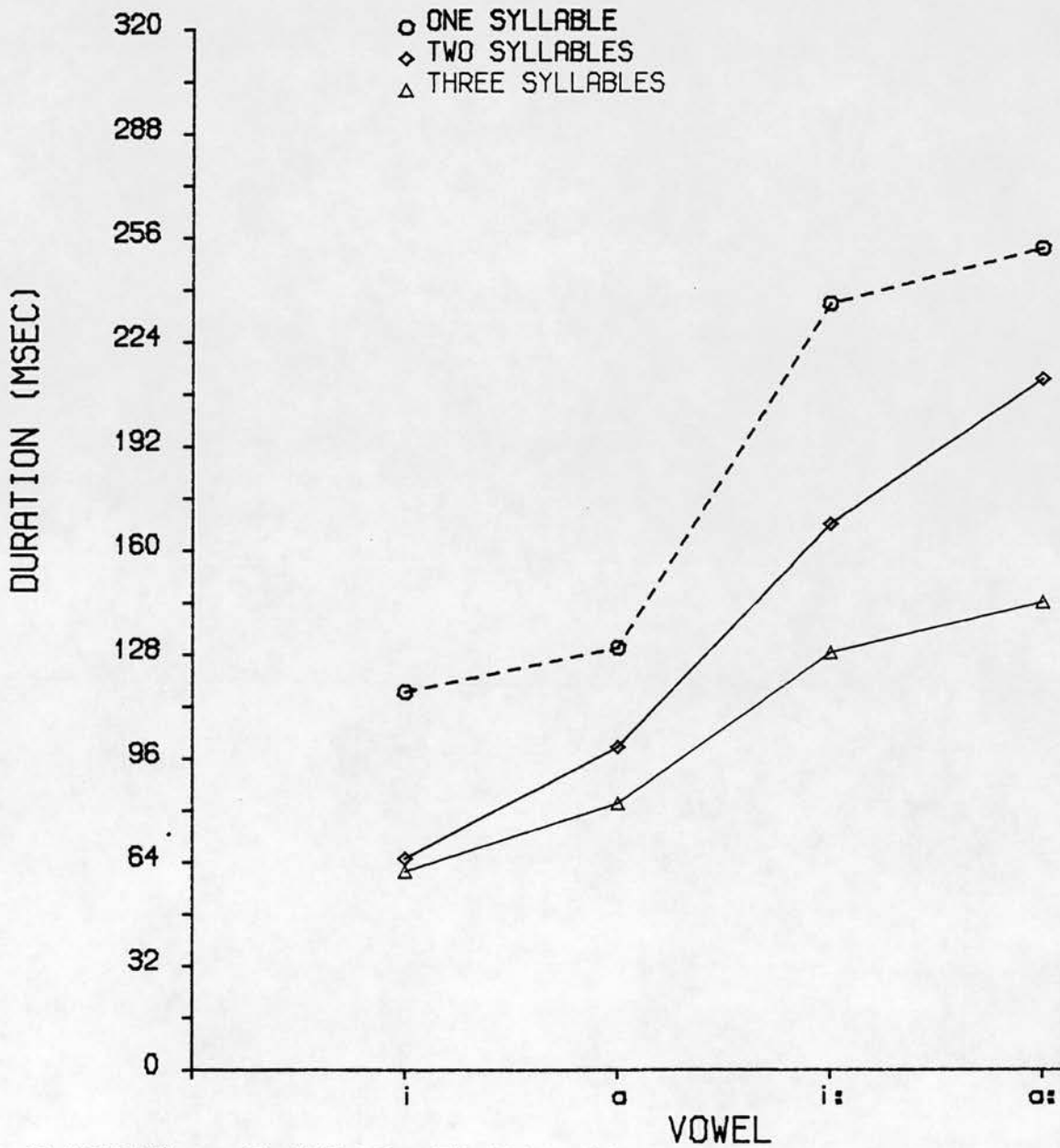
Figure 6.6.1

Graph showing the effect of the number of syllables in a word on the duration of the vowels /i/, /a/, /i:/ and /a:/. In phrase, speaker FB.
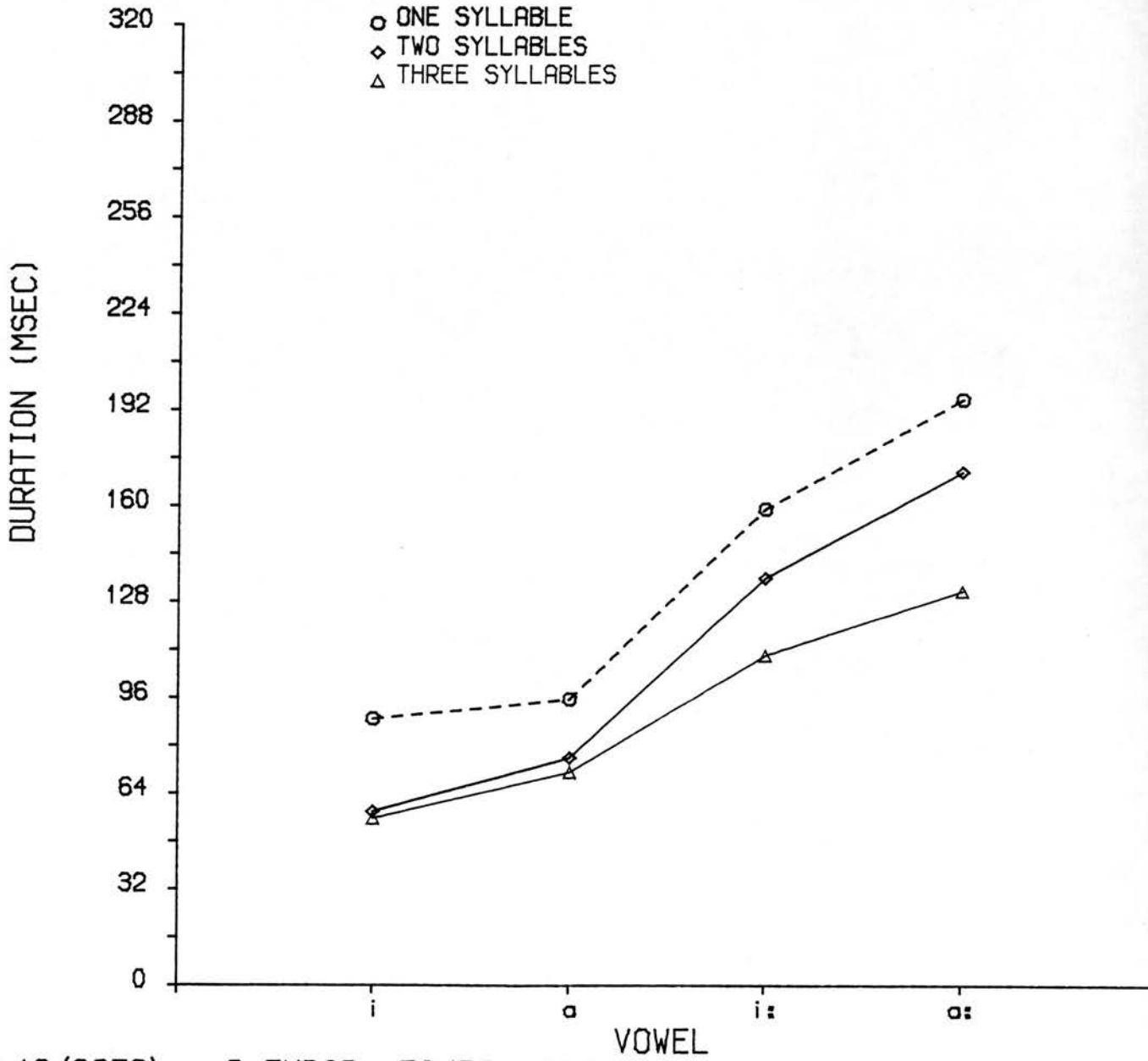
Figure 6.6.2

msec in bisyllabic words and 60.93 msec in trisyllabic words. The durational difference between the vowel in the monosyllabic and disyllabic words (51.75 msec) is highly significant (t109=12.84, p<0.001) and the ratio is 0.55. But the difference between the disyllabic and trisyllabic words is very slight (3.82 msec) and is not significant (t69=0.64, p>0.20) and the ratio between them is 0.94. In phrase /i/ is 89.20 msec long in monosyllabic, 57.71 msec in bisyllabic and 55.60 msec in trisyllabic words. The durational difference between the vowel in monosyllabic and bisyllabic words (31.49 msec) is very significant (t109=10.12, p< 0.001) and the ratio is 0.64. While the difference between bisyllabic and trisyllabic words is very small (2.11 msec) and very insignificant (t69=0.48, p>0.20). /a/ is on average 130.20 msec long in one-syllable words, 99.68 msec in two-syllable words and .82.29 msec in three-syllable words. The durational difference between the vowel in one-syllable and two-syllable words is big (30.52 msec) and proved to be very significant (t183=7.53, p<0.001) and the ratio is 0.76. The difference between the two-syllable words and the three-syllable words is much smaller (17.39 msec) but still significant (t150=3.04, p<0.01) and the ratio is 0.82. In phrase /a/ is 95.42 msec long in monosyllabic words, 75.85 msec in disyllabic words and 71.11 msec in trisyllabic words. The difference between the first and the second values (19. 57 msec) is highly significant

(t182=6.92, p<0.001) and the ratio is 0.79. While the difference between the second and the third values is very small (4.74 msec) and non-significant (t148=1.28, p=0.20) and the ratio is 0.93. /i:/ is 235.48 msec long in 1-syllable words, 168.07 msec in 2-syllable words and 128.63 msec in 3-syllable words in isolation. The difference between the first two means (67.41 msec) is very significant (t60=7.16, p<0.001) and the ratio between them is 0.71. The difference between the last two means is also big (39.44 msec) and highly significant (t47=4.27, p<0.001) and the ratio is 0.76. In phrase /i:/ is 158.78 msec long in monosyllabic, 135.92 msec in bisyllabic and 110.09 msec in trisyllabic words. The durational difference between the first and the second values (22.86 msec) reaches a significant level (t58=3.05, p<0.01) and the ratio is 0.85. And the difference between the second and the third values (25.83 msec) is also very significant (t47=2.87, p<0.01) and the ratio is 0.80. In isolated words /a:/ is 252.68 msec long in monosyllabic words, 212.46 msec in bisyllabic words and 144.15 msec in trisyllabic words. The differece between the first and the second mean (40.22 msec) is highly significant (t114=5.49, p<0.001) and the ratio is 0.84. And the differece between the second and the third mean (68.46 msec) is also highly significant (t47=4.27, p<0.001) and the ratio is 0.76. In phrase /a:/ is 195.50 msec in 1-syllable words, 172.41 msec in 2-syllable words and 131.60 msec in 3-syllable

words. The durational difference between the first and the second measurement (23.09 msec) proved to be highly significant (t114=3.54, p<0.001) and the ratio is 0.88; and the difference between the second and the third measurement (40.81 msec) reached a highly significant level (t74=4.18, p<0.001) and the ratio is 0.76.

HJ's data show a very similar result to those of FB (see Tables 6.6.5-8 and Graphs 6.6.3-4). All the four vowels are very significantly shorter in duration in bisyllabic words than monosyllabic words (p<0.001) in both the isolation and phrase condition. Also all the vowels, except /i/, are very significantly shorter in trisyllabic words than in bisyllabic words (p<o.001).

Thus our results confirm those reported in the literature. Vowels are realized as longer in monosyllabic words than in multisyllabic words, so the longer the word or the more syllables it has the shorter is the duration of the vowels it contains. Vowels in monosyllabic words are significantly longer than those in bisyllabic words; and vowels in bisyllabic words are longer than those in trisyllabic words. But the greatest difference exists between vowels in one-syllable and two-syllable words and their duration decreases progressively as the number of syllables increases. Elert (1964) does not believe that the duration of a syllable is directly dependent on the number of syllables contained in the word as he ascribes the shorter duration of

Graph showing the effect of the number of syllables in a word on the duration of the vowels /i/, /a/, /i:/ and /a:/. In isolation, speaker HJ.
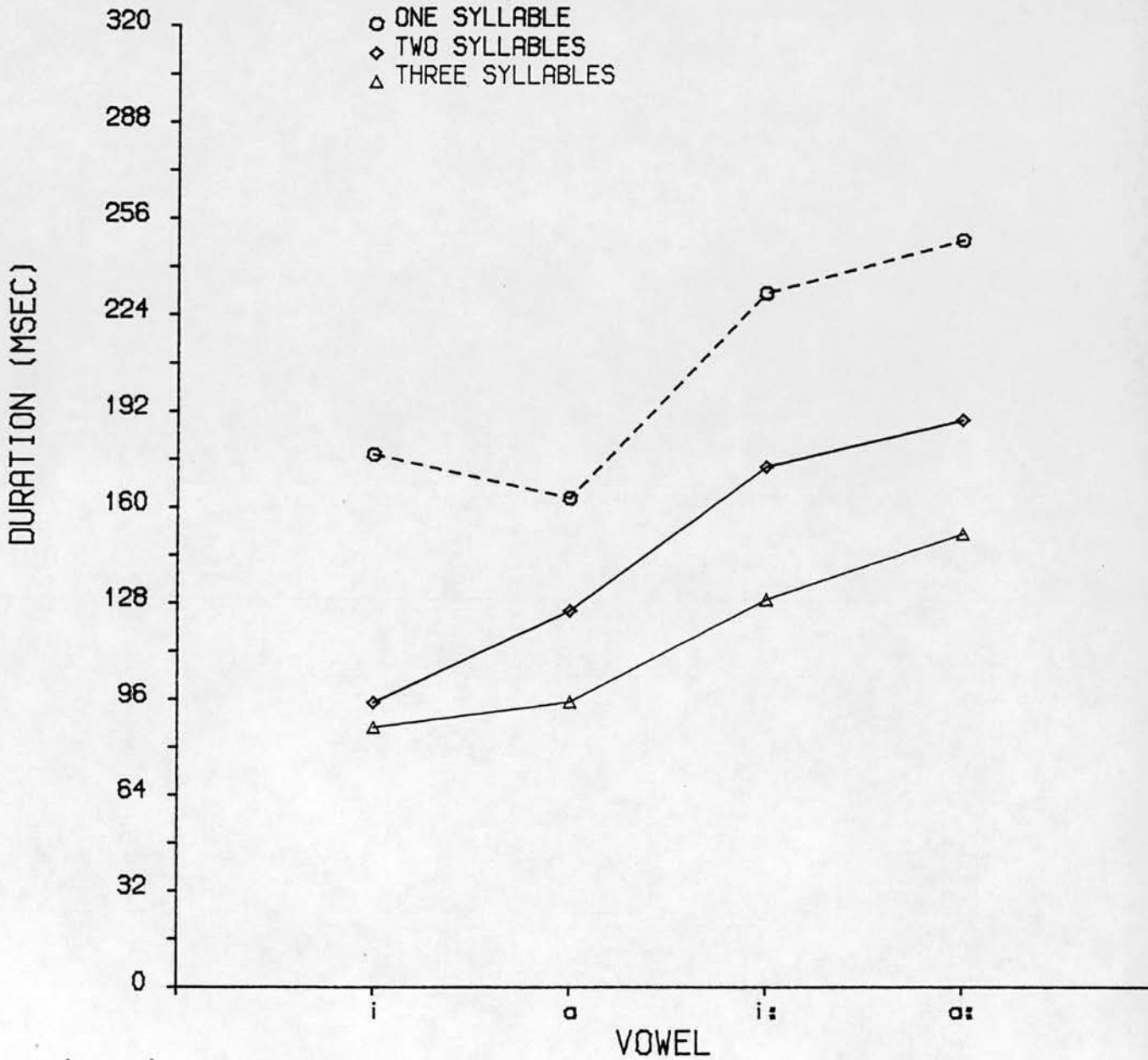
Figure 6.6.3

Graph showing the effect of the number of syllables
in a word on the duration of the vowels /i/, /a/,
/i:/ and /a:/. In phrase, speaker HJ.
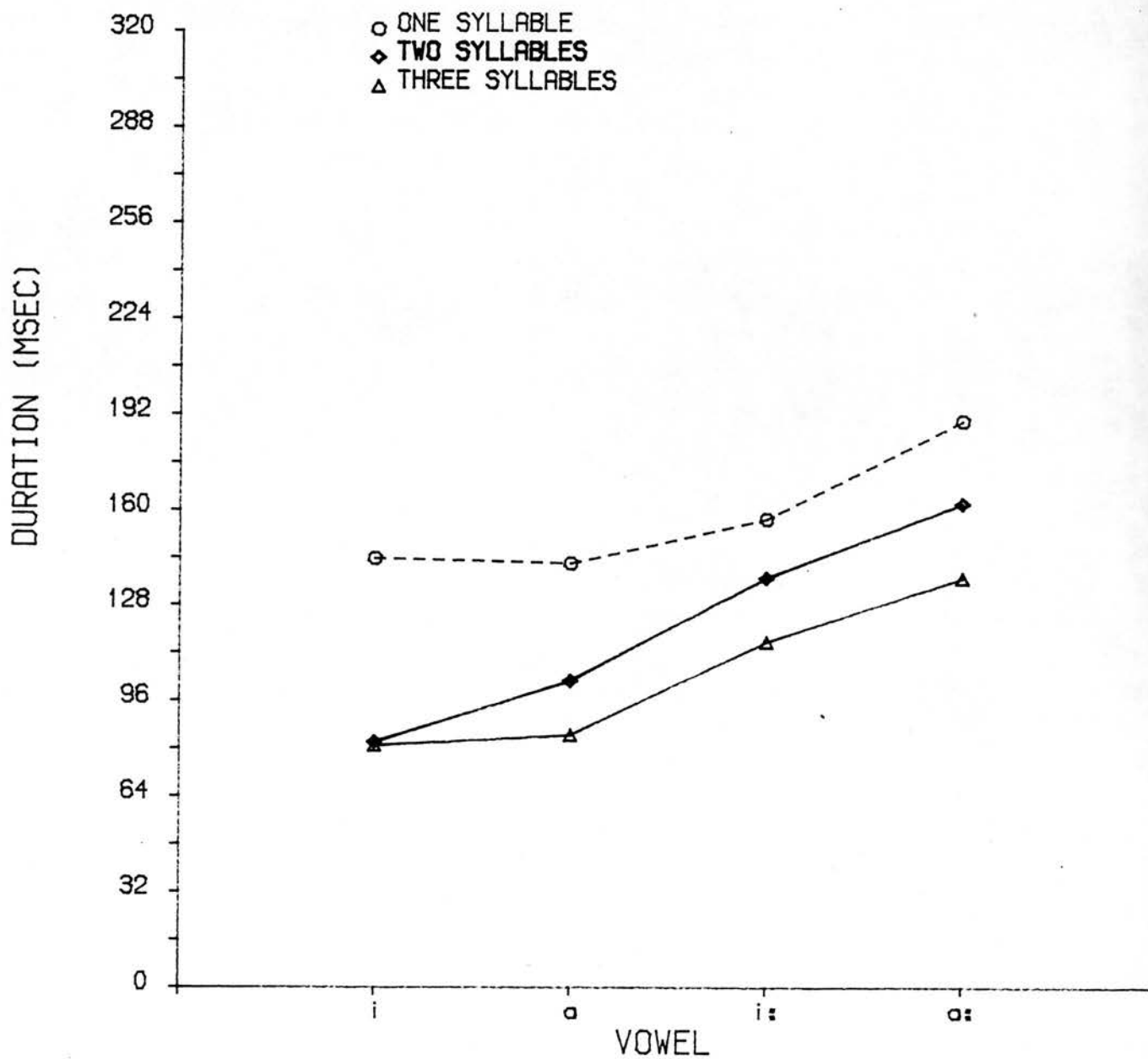
Figure   6.6.4

vowels in polysyllabic words to the stress or rhythm of the language "It is likely that the primary cause of the shortening of the phones in long words is not the length of the word itself but the fact that, when words are long, the intervals between stressed syllables contain more syllables and phones. If now, the duration of such intervals in speech is equalized, the individual phones will have longer duration in those containing few syllables and phones than those containing a larger number." (pp.137-138).

6.7. The effect of vowel place in word structure

Vowels in word-final position are significantly longer in duration than vowels in non-word-final open syllable position. FB's data (see Tables 6.7.1-2 and Graphs 6.7.1-2) reveal that in isolated words /i/ has an average duration of 59.11 msec in non-word-final position and 93.14 msec in word-final position. The difference between the two means (34.03 msec) is very significant ($t23=4.89$, $p<0.001$) and the raio is 0.63 msec. While in phrase /i/ is 57.88 msec in non-word-final position and 53.71 msec in word-final position. The difference between the two means (4.17 msec) is very insignificant ($t23=0.72$, $p>0.20$) and the ratio is 1.07. /a/ is 82.80 msec in non-word-final position and 124 msec in word-final

Table 6.7.1

Average durations in msec and ratios of vowels in non-word-Final (NWF) position to Word-Final (WF) position. In isolated words.　　Subject FB.

Vowel	NWF	WF	Ratio	Significance
i	59.11	93.14	0.63	p< 0.001
a	82.80	124	0.66	p< 0.001
i:	136.57	239	0.57	p< 0.001
a:	161.77	254.66	0.63	p< 0.001

Table 6.7.2

Average durations in msec and ratios of vowels in non-word-Final position to word-Final position.　In phrase. Subject FB.

Vowel	NWF	WF	Ratio	Significance
i	57.88	53.71	1.07	p> 0.20
a	68.27	75.15	0.90	p< 0.20
i:	106.14	165	0.64	p< 0.01
a:	144.55	208.66	0.69	p< 0.001

Graph showing the mean durations of the vowels /i/, /a/,
/i:/ and /a:/ under two positional conditions: open syllable
word-final and open syllable non-word-final. In isolation, speaker
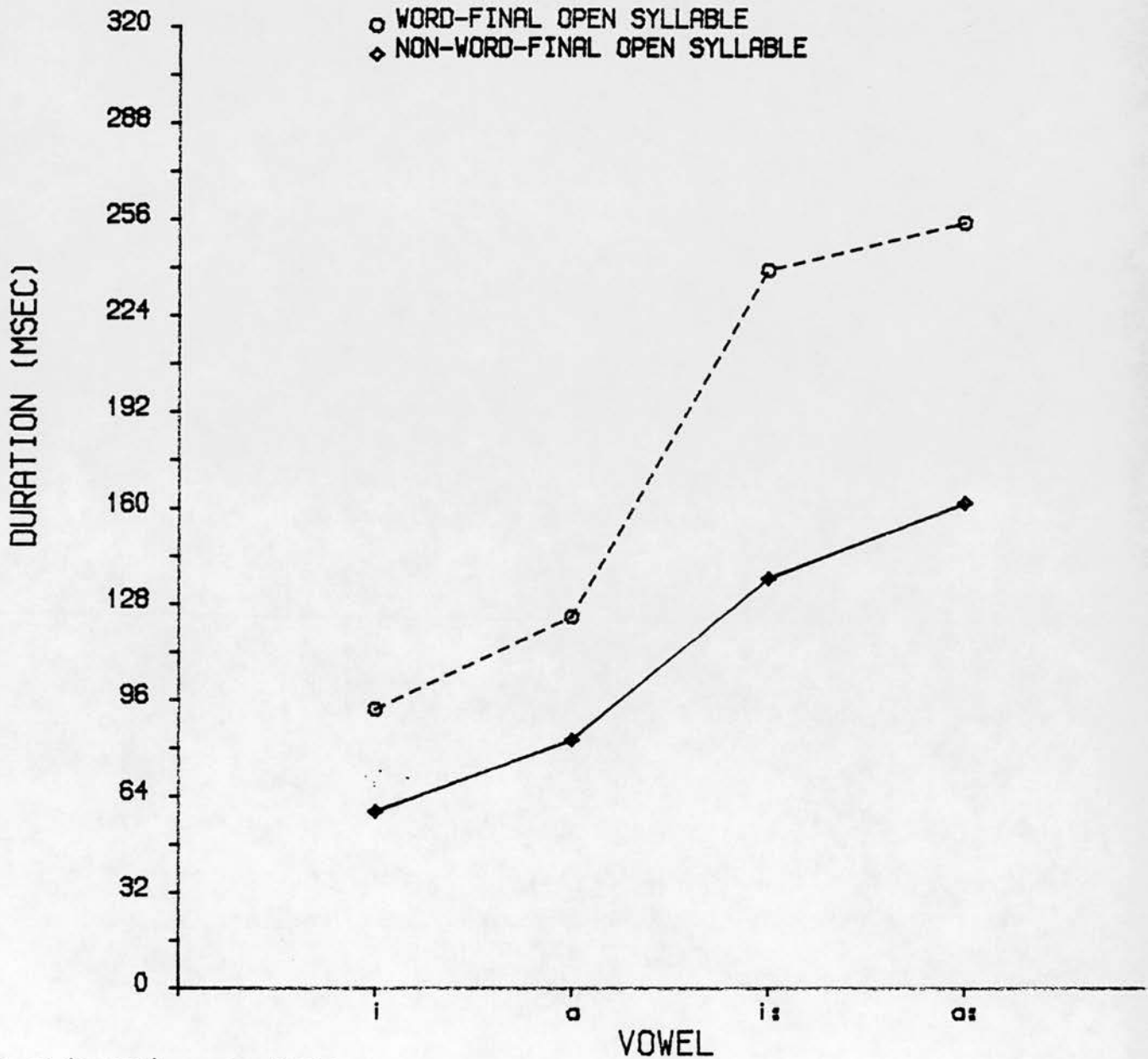
Figure 6.7.1

Graph showing the mean durations for the vowels
/i/, /a/, /i:/ and /a:/ under two positional
conditions: open syllable word-final and open syllable
non-word-final. In phrase, speaker FB.
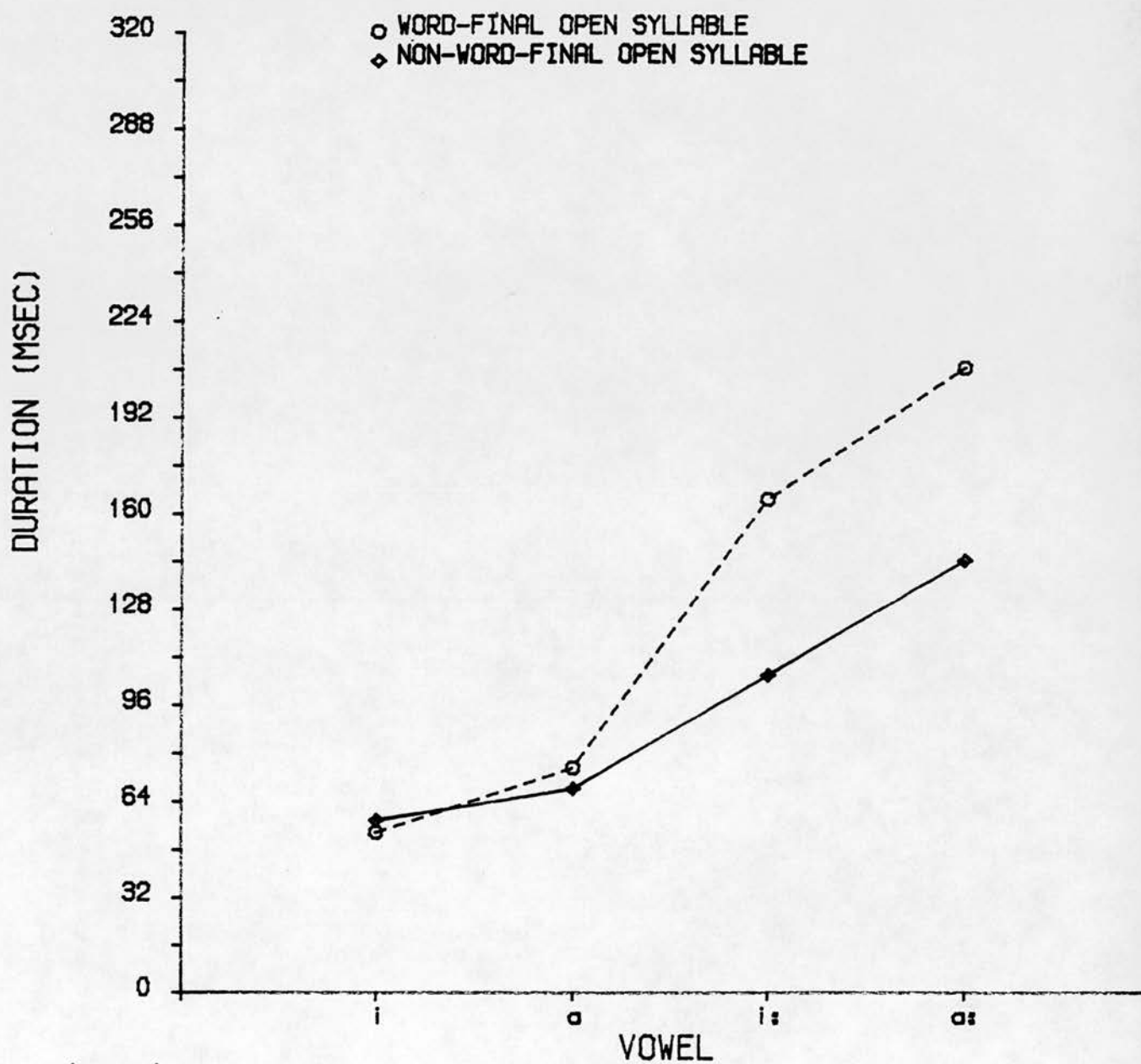
Figure   6.7.2

position in isolation. The durational difference between the two values (41.2 msec) is highly significant ($t66=7.30$, $p<0.001$) and the ratio is 0.66. While in phrase the difference between the two means is very small (6.88 msec) and non-significant ($t65=1.42$, $p<0.20$) and the ratio is 0.90. /i:/ is 136.57 msec long in non-word-final position and 239 msec in word-final position in isolation. The ratio between the two means is 0.57 and the difference is very big (102.43 msec) and highly significant ($t14=4.27$, $p<0.001$). In phrase, the durational difference is smaller (59 msec) but still significant ($t14=3.52$, $p<0.01$). In isolation, /a:/ has an average value of 161.77 msec in non-word-final position and 254.66 msec in word-final position. The ratio between the two means is 0.63 and the difference is large (92.89 msec) and very significant ($t22=6.39$, $p<0.001$). In phrase, the ratio between the two means is 0.69 and the difference (64.11 msec) is highly significant ($t22=4.30$, $p<0.001$).

Thus, all the four vowels are significantly longer in word- final position than in non-word-final position in isolation. While in phrase only the long vowels /i:/ and /a:/ are significantly longer in word-final position than non-word-final position as the short vowels /i/ and /a/ do not exhibit any significant difference in their duration when they are in word-final and non-word-final position. This may be explained by the fact that short vowels are always unstressed when they occur in word-final position,

while the long vowels are always stressed when they occur in word-final position. Also vowels in word-final position are utterance final position in isolation, while they are not so in phrase as they are followed by the consonants of the following words, thus we expect word-final vowels to be much longer in the isolated word condition than in the phrase condition.

HJ's data (see Tables 6.7.3-4, and Graphs 6.7.3-4) show that vowels are significantly shorter in non-word final position than in word-final position no matter whether they are short or long in isolation or in phrase.

6.8.   Summary

To summarize the results of the above investigation of vowel duration, the following factors were shown to affect the duration of vowels in QA:

1. Vowel height: low or open vowels are longer than high or close vowels. And the difference between them hovers around the JND's value. This result is in agreement with those found for other languages and supports the claim for its universality. This lengthening effect of low vowels is physiologically conditioned by the height of the tongue and the position of the lower jaw which delay the constriction of the following consonant thus lengthening the preceding open vowel.

Table 6.7.3

Average durations in msec and ratios of vowels in non-word-Final (NWF) position to word-Final (WF) position. In isolated words.   Subject HJ.

Vowel	NWF	WF	Ratio	Significance
i	79.89	162	0.49	p < 0.001
a	87.45	165.76	0.52	p < 0.001
i:	137.56	252	0.54	p < 0.001
a:	165.92	251.33	0.66	p < 0.001

Table 6.7.4

Average durations in msec and ratios of vowels in non-word-Final position to word-Final position. In phrase. Subject HJ.

Vowel	NWF	WF	Ratio	Significance
i	71.15	123	0.57	p < 0.001
a	81.72	122.92	0.66	p < 0.001
i:	122.34	162	0.75	p < 0.001
a:	152.72	205.11	0.74	p < 0.001

Graph showing the mean durations for the vowels
/i/, /a/, /i:/ and /a:/ under two positional
conditions: open syllable word-final and open syllable
non-word-final. In isolation, speaker HJ.
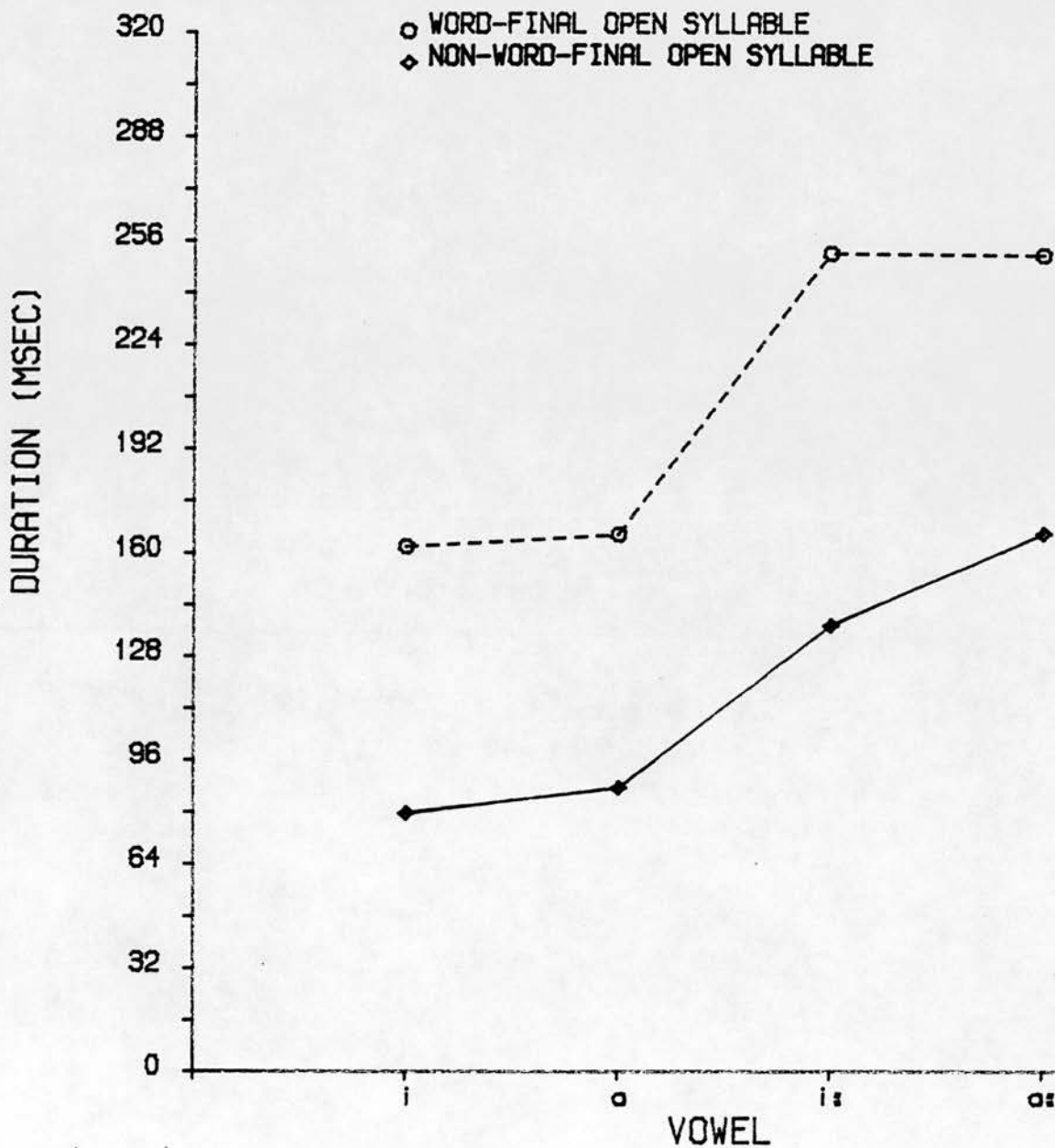
Figure 6.7.3

Graph showing the mean durations for the vowels
/i/, /a/, /iː/ and /aː/ under two positional
conditions: opensyllable word-final and open syllable
non-word-final. In phrase, speaker HJ.
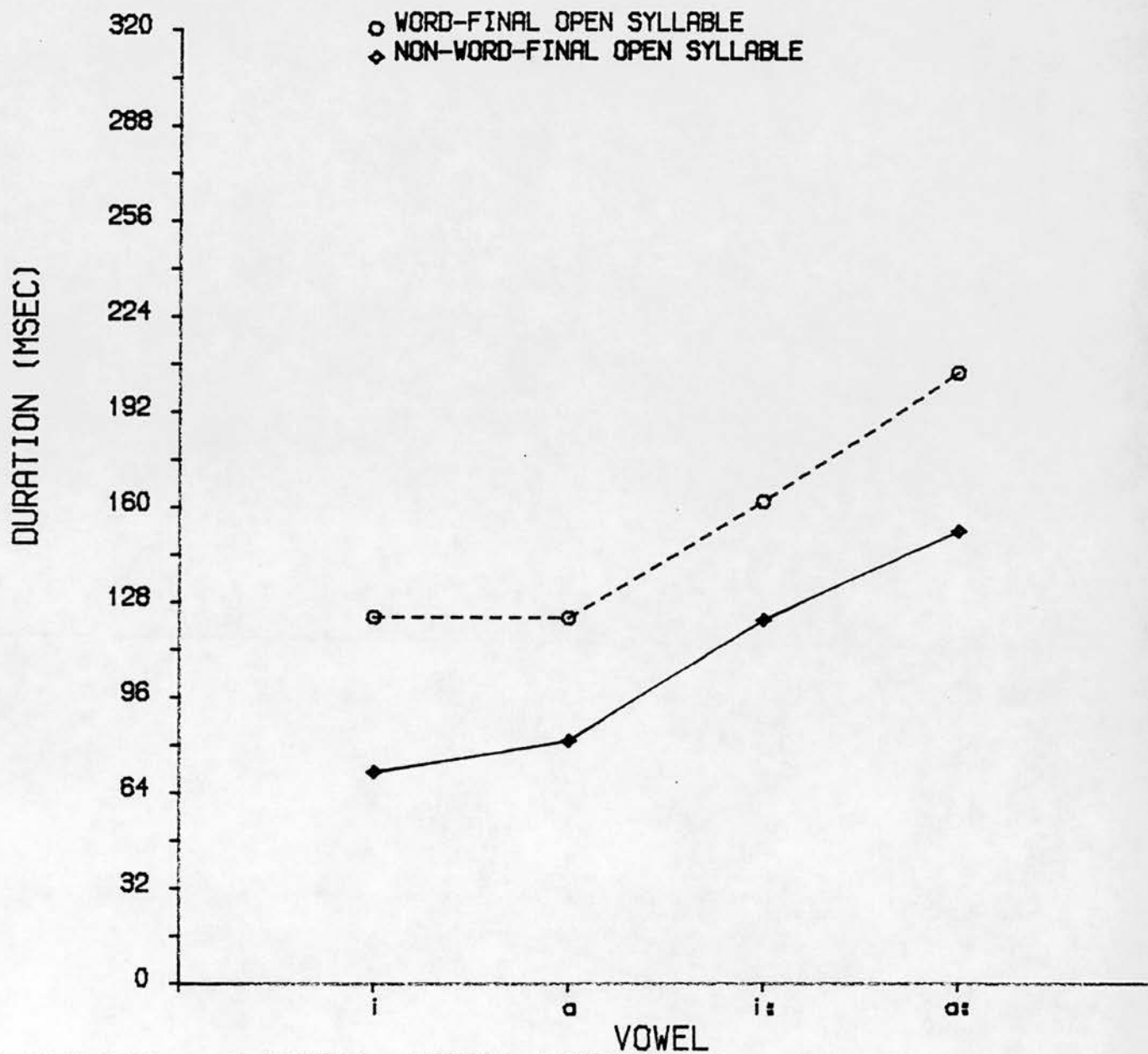
Figure 6.7.4

2. Vowel length: phonologically long vowels are almost twice as long as the phonologically short vowel. The durational difference between them is much higher than the JND´s value and is phonologically significant as long vowels are deliberately lengthened by the speaker to differentiate them form their corresponding short vowels for phonological reasons. Thus, this factor is not a language-universal one, but a language-specific one determined by the phonological system of QA.

3. Manner of articulation: vowels are longer when preceding fricatives than when preceding plosives. But the difference between them reached a significant level for only one of the two speakers. This factor does not seem to be specific to QA as it has been shown to be true for several other languages. House and Fairbanks, (1953), ascribe this factor to the fact that "the gradual, controlled movements of continuants favour longer vowel duration more than the abrupt, ballistic movements of the stop plosives." (p.108).

4. Pharyngealization: vowels proved to be significantly longer before pharyngealized consonants than those before non-pharyngealized counterparts. The durational difference between them hovers around the JND´s value. This lengthening effect of pharyngealization seems to be physiologically conditioned as it seems to be caused by the secondary articulation which delays the constriction for the primary articulation of the emphatic consonants.

This factor seems to be a language-specific one, but it may be a language-universal one operating in languages where pharyngealization exists.

5. Consonant duration: vowels preceding geminates and clusters are significantly shorter than those preceding single consonants. This may be a language-universal factor as it has shown to operate in some other languages, and no counter-observations have been made.

6. Place of articulation: The data showed that vowels (especially front high vowels) have a tendency to be shortest before velars and longest before palato-alveolars and pharyngeals. This is a language-specific phenomenon as other languages revealed different and inconsistent patterns.

7. Stress has a significant effect on the duration of long vowels only as it has been shown that they are much longer in stressed syllables than in unstressed syllables; while it has no effect on the duration of short vowels as they are as long or even in some cases longer in unstressed syllables than stressed syllables. This phenomenon seems to be particular to QA.

8. Word length: Vowel duration is related to the number of syllables in a word as it has been shown that vowels are much longer in monosyllabic words than in multisyllabic words. Thus the more syllables a word has the shorter is the duration of the vowels it contains. This could be a language-universal factor as it is found

to operate in other languages.

9. Vowel place in word structure: Vowels in word-final open syllable position are much longer in duration than vowels occuring elsewhere in the word. This phenomenon is reported to operate in several other languages, thus we might expect it to be a language-universal one.

10. Voicing proved to have little or no effect on the duration of vowels in QA, as vowels before voiceless consonants are as long or even, in some cases, longer the those before voiced consonants. This means that the lengthening effect of voicing is not a language-universal phenomenon but rather a language-specific one.

CHAPTER   SEVEN

CONCLUSION

7.1 Conclusion

Xeroradiographic analysis revealed that the main physiological difference between the pharyngealized consonants and their non-pharyngealized counterparts is that they exhibit a large and a narrow constriction between the back of the tongue and posterior wall of the pharynx at the level of C2 and/or C3 with the highest point of the tongue being under the soft palate.

Electropalatographic investigation of the emphatic consonants showed that they exhibit a slight tongue tip and/or blade retraction in their primary area of constriction as compared to their non-emphatic cognates. They also exhibit a larger number of linguopalatal contacts in the anterior part of the palate, indicating a bigger area of primary constriction, while they exhibit a fewer linguopalatal contacts in both the posterior and the central regions of the palate as a result of tongue lowering and retraction. Furthermore, it was found that the primary constriction for the pharyngealized consonants is held for a longer period of time than that for the non-pharyngealized counterparts in most cases. Airflow analysis showed that the emphatic consonants exhibit a slightly lower oral airflow and the emphatic voiceless plosive has almost a zero VOT. Acoustically, the

emphatic consonants exhibit a much lower second formant value than their non-emphatic counterparts.

Xeroradiographic investigation of the pharyngeal consonants /ħ/ and /ʕ/ revealed that physiologically they are characterized by a considerable retraction of tongue back and root towards the posterior wall of the pharynx causing a very narrow constriction between the epiglottis and the pharyngeal wall at the level of C3 and/or C4. During the production of the geminate /ʕʕ/, this close approximation stricture between the epiglottis and the pharyngeal wall turns into a complete closure accompanied by a glottal closure, thus, resulting in a double articulation. The position of the hyoid bone and the larynx seem to depend on the quality of the adjacent vowel. They are raised when adjacent to front vowels and they are lowered next to back vowels, while their position is only slightly affected by the low central vowels. The velopharyngeal opening observed during the production of the single /ʕ/ did not result in a nasal airflow on the airflow record. This is probably due to the lateral walls contraction of the nasopharynx. This velopharyngeal opening seems to be necessary for the audible nasal quality of /ʕ/. /ħ/ exhibited a very slight velopharyngeal opening which seems to be idiosyncratic as only one of the two speakers showed nasal airflow during its production. Both /ħ/ and /ʕ/ become heavily

nasalized in the neighbourhood of a nasal consonant as they exhibit a wide velopharyngeal opening and a considerable nasal airflow.

Acoustically, the pharyngeal consonants are characterized by a relatively high first formant value and low second formant value. /ħ/ has been shown to be a voiceless fricative, exhibiting a non-periodic noise with a visible formant-like bands. /ʕ/ has been shown to be a voiced approximant exhibiting vertical spikes and vowel-like formant bands with a creaky voice and a stop variant.

Having a place of articulation down in the oropharynx, the pharyngeal consonants leave tongue dorsum free to coarticulate with the adjacent vowels. Thus, while a pharyngeal consonant is articulated, tongue dorsum takes the posture required for the adjacent vowel. Acoustically, this low pharyngeal constriction effect on the vowels results in raising the first formant and lowering the second formant of front high vowels, raising the first and second formants of high back vowels and lowering the third formant of almost all the vowels.

Tongue and lips gestures for the adjacent vowel, in turn, affect the pharyngeal consonants by lowering their first formant next to high front and back vowels, and raising their second formant next to high front vowels and lowering their second formant next to high back

vowels. The low central vowels do not seem to affect or be affected by the pharyngeal consonants as their production involve a similar articulatory gestures. The scope of both anticipatory and perseverative coarticulatory effects of the pharyngeal consonants is found to be small as they only influence the immediately neighbouring vowels.

It has been observed that coarticulatory effects of pharyngealization or tongue back retraction spills over from a phonologically emphatic consonant to influence both its preceding and following segments. In the word /na ʃ i:ɛ/, for example, anticipatory effects of the word-final segment /ɛ/ is observed during the articulation of the word-initial segment /n/, thus, all the preceding four segments (600 msec) coarticulate with /ɛ/ despite the intervening high front vowel /i:/ and the palatoalveolar consonant /ʃ/ which were found to block or weaken the spread of emphasis by previous researchers. Similarly, perseverative coarticulatory effects of emphasis were found to extend over about 600 msec or as many as six segments as in the word /sa:matla/, where the backing effect of the word-initial /s/ spreads to cover all the following segments in the word.

It was found that both anticipatory and carryover

effects of pharyngealization may cross word boundaries. That is to say, if a word ends with a phonologically emphatic consonant, the initial segment of the following word is affected; and, similarly, if a word begins with an emphatic consonant, the last segment of the preceding word is affected. In the phrase /be:t ṭa:jir/ (CV:C#ʕV:CVC), for example, it was observed that the word-initial emphatic consonant /ṭ/ of the second word is anticipated during the production of the first word and carried over to the segments of the second word. In the phrase /bas iṣi:r/ (CVC#VʕVC) the word-medial /ṣ/ anticipatory effects influence all the segments of the first word regardless of the front high vowel /i/ and the word boundary. Similarly, in /ḥaṭ ismi/ (CVʕ#VCCV) the perseverative effects of the word-final /ṭ/ is carried over to all the segments of the second word even though it starts with a high front vowel.

Thus, the result of our investigation of linguopharyngeal coarticulation associated with the production of the emphatic consonants in QA seems to be in agreement with those results found for labial coarticulation associated with rounded vowels (Lubker 1981, Sussman & Westbury 1981) and velopharyngeal coarticulation associated with nasal consonants (Moll & Daniloff 1971, Dixit & MacNeilage 1972, Benguerel 1974, Benguerel et al. 1977a,b) where it was found that

coarticulatory effects spread across both syllable and word boundaries and that their influence is detected by about 600 msec or as many as 6 segments ahead of the concerned segment.

Most of the studies on coarticulation have claimed that anticipatory coarticulatory effects are more extensive than perseverative coarticulatory effects and that anticipatory coarticulation is deliberately programmed and controlled by a high level articulatory mechanism, while perseverative coarticulation is a result of a low level mechano-inertial constraints and that it is caused by the "sluggish" response of the articulators. The majority also explain anticipatory effects within the frame of Henke's (1966) binary-feature look-ahead model of speech production or a modefied version of it (Bladon & Al-Bamerni 1976, Bladon 1977, Sussman & Westbury 1981) in which "coarticulation effects attributable to following or future phonemes result from a "look ahead" procedure that may invoke goals of future phonemes when such goals do not conflict with the goals of the current or more immediate phonemes" (Henke 1966, p.2).

But in the present study, it was shown that both anticipatory and perseverative linguopharyngeal coarticulation are of the same nature and magnitude; their propagation is not restrained by syllable and word boundaries nor by antagonistic segments like /i:/ and /ʃ/

which require tongue body raising and fronting; also they expand to a maximum distance of about 600 msec prior to the production of the emphatic consonant and continue to a maximum distance of 600 msec after its articulation. This leads us to agree with Bladon's & Al-Bamerni's (1976) claim that both anticipatory and carryover coarticulation are caused by the same mechanism of articulatory control.

Furthermore, this indicates that both perseverative and anticipatory linguopharyngeal coarticulation associated with the emphatic consonants to be a result of a low level articulatory control mechanism. Pharyngealized or emphatic consonants require a rather complicated manoeuvre from the vocal organs to achieve their optimal configuration. The secondary stricture has to be attained first by lowering and retracting the back of the tongue towards the posterior wall of the pharynx, then the primary stricture has to be attained by tongue tip and/or blade. To be achieved, this complicated configuration requires a certain amount of time, depending on the status of the organs and the nature of the neighbouring segments. Thus, pharyngealization can not be achieved suddenly, but only gradually, as it starts at a certain distance away from the emphatic consonant and gets stronger and stronger as we proceed towards it . Once the optimal configuration needed for the emphatic consonant is achieved, it is not terminated suddenly either. The primary stricture is first to be dissolved as

tongue tip and/or blade moves quickly towards the posture required for the following segment, the secondary stricture last for a longer period of time as the massive back of the tongue, being not as briskly mobile as tongue tip and blade, slowly disengages itself, resulting in the following segments being coloured by pharyngealization which gradually fades away as we move away from the emphatic consonant. Thus the phonologically emphatic consonant represents the maximum realization of emphasis which spreads increasingly towards or diminishingly away from the pharyngealized consonant regardless of syllable or word boundaries.

Investigation of variation in vowel duration as a function of the intrinsic quality of the vowel itself and the nature of the following consonant has revealed that some factors are physiologically conditioned by the intrinsic property of the vocal apparatus and are in agreement with results found for other languages, proving likely to be language-universal factors; while other factors seemed to be conditioned by the phonology of QA and did not agree with findings for other languages, thus proving to be language-particular factors.

Voicing characteristics of the following consonant is not anticipated by the duration of the preceding vowel in QA, as it is the case in some other languages such as English. Other factors being equal, vowel duration before

a voiced consonant is the same or even, in some cases, slightly shorter than when preceding a voiceless consonant. This insignificant effect of consonant voicing on vowel duration could be constrained by the sound system of the dialect. Vowel length is phonemically contrastive in Arabic and lengthening vowels before voiced consonants may disturb their phonemic opposition (Anderson 1981).

The phonological opposition between short and long vowels is realized phonetically by the long vowel having a duration almost double the length of its short vowel counterpart. This significant durational difference between short and long vowels is requisite of the phonemic structure of Arabic.

Stress was found to affect the duration of long vowels only as they proved to be significantly longer in stressed syllables than in unstressed syllables, while it did not affect short vowels' duration as they exhibited more or less similar values in both stressed and unstressed syllables. This may be ascribed to the fact that, in most cases, when they are unstressed the short vowels have a word final position or occur in open syllables.

Pharyngealized consonants were found to lengthen the duration of their preceding vowels. This lengthening effect of pharyngealization seems to be due to the relatively slow movements of the back of the tongue

which results in a slight delay in attaining the primary stricture for the emphatic consonant and thus lengthens the duration of its preceding vowel. As this factor seems to be physiologically conditioned, we may claim its universality, that is to say that we expect languages with pharyngealization to exhibit a similar behaviour.

Word length and consonant length were found to have a shortening effect on the duration of vowels, in other words, the more segments or syllables a word contains the shorter is the duration of the vowels it contains. Also postvocalic long consonants (geminates and clusters) shorten the duration of their preceding vowels. Such results have been reported for other languages, so we may consider them likely to be a language-universal phenomenon.

Another factor which gave evidence to support its universality is vowel height. In agreement with reports on other languages, low or open vowels were found to be significantly longer than high or close vowels.

Both manner and place of articulation of the postvocalic consonants did not reveal a very consistent pattern of effect on their preceding vowels. But there was a tendency for vowels to be longer when preceding fricatives than when preceding plosives, and a tendency for them to be longest before palatoalveolar and pharyngeal consonants and shortest before velar consonants.

7.2   Suggestions for future research

1.   The articulatory investigation of the coarticulatory effects of the pharyngealized consonants on neighbouring segments need to be supplemented by a perceptual investigation in which a perceptual test is designed to find out the significance of linguopharyngeal coarticulatory effects for the speech perception process, its inteligibility and naturalness, and to find out whether the listener can predict the presence of an emphatic consonant from its coarticulatory effects even though the emphatic consonant itself is spliced away.

2.   A more thorough acoustic investigation of the coarticulatory effects of emphasis is needed by extending it to more speakers and dialects in order to be able to precisely quantify its gradient nature, so rules can be constructed for the amount of influence an emphatic consonant exerts on segments which are zero-msec away, 50-msec away, 100-msec away, etc.

3.   A further study is needed in order to be able to construct rules, similar to those developed by Klatt (1979) for English, for vowel duration under combined

influence of the various contextual factor found in the
present study.

4.   A detailed perceptual test is needed to find out the
perceptual   importance   of   the   variations   in   vowel
durations as a function of the factors investigated in
this study, to establish whether the factors observed to
have a significant effect on the duration of the vowels
during their production are also significant for their
perception, i.e. whether they are used by the listener as
cues for the nature of the following consonant.

APPENDICES

APPENDIX A

The following examples illustrate the different syllable-initial two-consonant clusters, CC-, in QA:

/bgara/	´cow´
/btufag/	´with a gun´
/bkilmi/	´with a word´
/bdiwij/	´bedouin´
/bqarʃi/	´with a bottle´
/bnu:g/	´banks´
/bma:j/	´with water´
/bla:d/	´country´
/brika/	´blessing´
/bsiri/	´unripe date´
/bfard/	´with a gun´
/bθu:r/	´pimples´
/bðu:r/	´seeds´
/bza:r/	´a mixture of spices´
/bʃu:t/	´cloaks´
/bXala/	´misers´
/bħu:r/	´seas´
/bha:ra:t	´spices´
/bčalb/	´with a dog´
/bdʒidir/	´with a pot´
/bwe:k/	´a small purse´
/bju:t/	´houses´
/bʕi:d/	´far away´
/bʈu:n/	´stomachs´
/bˣ̌ab/	´with a lizard´
/bsala/	´onion´
/tbu:g/	´she steals´
/tta:biʕ/	´she follows´
/tdaris/	´she teaches´
/tkalam/	´he spoke´
/tgu:l/	´she says´
/t2ajjid/	´she supports´
/tma:niʕ/	´she refuses´
/tna:dij/	´she calls´
/tla:l/	´hills´
/tra:b/	´earth´
/tfa:ga/	´guns´
/tθu:r/	´she rebels´
/tðil/	´she humiliates´
/tsu:m/	´she asks about the price´
/tzu:r/	´she visits´
/tʃa:wir/	´she consults´
/tXu:n/	´she betrays´
/tħib/	´she loves´
/thu:n/	´she becomes easy´
/tčallib/	´she hooks´

/tdʒasim/	´she distributes´
/twaddij/	´she takes away´
/tju:s/	´billy goats´
/tʕu:d/	´she returns´
/tɫa:liʕ/	´she looks´
/tˣir/	´she harms´
/tǝadig/	´she believes´
/dba:b/	´fat´ (pl.)
/dga:g/	´thin´ (pl.)
/dqa:m/	´assimilation´
/dma:n/	´addiction´
/dla:l/	´coffee pots´
/dɹa:m/	´cylindrical container´
/dfa:f/	´lady´s cloaks´
/dˣa:n/	´name of a town in Qatar´
/dha:n/	´paint or oil´
/dju:n/	´debts´
/kba:r/	´big or old´ (pl.)
/kta:b/	´book´
/kna:r/	´a kind of cherry´
/kla:b/	´dogs´
/kru:ʃ/	´paunches´
/kfu:f/	´slaps´
/kθa:r/	´too many´
/ksu:r/	´fractions´
/kwe:t/	´Kuwait´
/kja:s/	´bags´
/gba:l/	´in front of´
/gdu:m/	´the coming´
/gma:r/	´gambling´
/gna:d/	´cardamom´
/gle:t/	´false jewels´
/gra:ħ/	´wounds´
/gfu:ɫ/	´locks´
/gza:z/	´glass´
/gʃu:r/	´peels or husks´
/gʰa:b/	´whores´
/ghawa/	´coffee´
/gwe:tij/	´small box´
/gja:s/	´measurements´
/gʕu:d/	´sitting down´ (pl.)
/gɫirij/	´Qatari´ (mas. sing.)
/gɫu:b/	´hearts´
/gˣu:ˣ/	´holes´
/gǝu:r/	´palaces or shortage´
/qta:l/	´fighting´
/qza:r/	´deep´
/qra:ʃ/	´bottles´
/qla:mij/	´a type of earrings´
/qwe:rij/	´a small tea pot´

/qju:m/	´clouds´
/mbajjin/	´appearing´
/mtabal/	´pickles aubergine´
/mdawwar/	´round´
/mkajjif/	´happy´
/mgaᵴir/	´not doing his best´
/mqasil/	´he has washed´
/mʔajjid/	´he is supporting´
/mmallaħ/	´salted´
/mna:zi/	´cots´
/mla:l/	´bowls´
/mriga/	´curried sauce´
/mfa:rig/	´leaver´
/mθalaθ/	´triangle´
/mȢawwib/	´melter´
/msa:fir/	´traveller´
/mzawwir/	´forger´
/mʃawwiʃ/	´not clear´
/mXajjim/	´camper´
/mħa:sib/	´accountant´
/mħarrib/	´smuggler´
/mčallib/	´hooker´
/mdʒa:bil/	´facing´
/mwaddij/	´taker´
/mjarrib/	´experiencer´
/mʕallim/	´teacher´
/mⱡabbul/	´drumer´
/mȢa:rib/	´fighter´
/mᵴawwir/	´photographer´
/nbu:g/	´we steal´
/ntu:b/	´we repent´
/ndu:s/	´we tead on´
/nku:n/	´we become´
/nga:l/	´it was said´
/nqa:r/	´we get jealous´
/nʔammin/	´we trust´
/nmu:t/	´we die´
/nna:m/	´we sleep´
/nlu:m/	´we blame´
/nru:h/	´we go´
/nfa:X/	´swell´
/nθu:r/	´we rebel´
/nȢu:r/	´vows´
/nsu:m/	´we ask about the pice´
/nzu:r/	´we visit´
/nʃu:f/	´we see´
/nXaⱡa/	´palm tree´
/nha:n/	´he was insulted´
/nħa:s/	´copper´
/nčab/	´he prostrated´
/ndʒihat/	´she succeeded´
/nwaddij/	´we take´

/nju:m/	´stars´
/nʕaji/	´ewe´
/nɫa:liʕ/	´we see´
/nˇʂirat/	´she looked´
/nʂifat/	´she halved´
/lba:s/	´cloths´
/ltam/	´he got together´
/lka:b/	´the dish´
/lga:n/	´large round metal plates with raised brim´
/lma:l/	´the money´
/lla:m/	´the "l"´
/lfa:r/	´the mouse´
/lθa:m/	´veil´
/lsa:n/	´tongue´
/lXa:ɫ/	´the uncle´
/lℏa:m/	´solder´
/lha:m/	´inspiration´
/lwe:n/	´to where´
/lja:j/	´the comer´
/lʕa:m/	´last year´
/rba:ɫ/	´tier´
/rta:ℏ/	´to rest´
/rga:g/	´thin flat loaf of bread´
/rma:l/	´sand´
/rfu:f/	´shelves´
/rsu:m/	´drawings´
/rʃu:ʃ/	´spray´
/rXi:ʂ/	´cheap´
/rwe:d/	´radish´
/rju:l/	´feet´
/rʕadi/	´shiver´
/rʂa:ʂ/	´bullets´
/fta:g/	´hernia´
/fˇda:k/	´he dies for you´
/fne:ji:l/	´a small coffee cup´
/fga:r/	´vertebrae´
/flu:s/	´money´
/fra:ʃ/	´bed´
/fsa:g/	´viciousness´
/fʃa:r/	´boasting´
/fXu:ʐ/	´legs´
/fℏami/	´a piece of coal´
/fˇcu:ˇc/	´gaps´
/fwe:riɫ/	´name of a town in Qatar´
/fju:z/	´fuze´
/fʂu:ʂ/	´gems´
/θga:l/	´heavy´
/θne:n/	´two´
/θdʒa:l/	´heavy´
/θwe:r/	´small ox´

/θˈja:b/	´clothes´
/ˠbiñaw/	´they slaughtered´
/ˠku:r/	´males´
/ˠlifaw/	´they went away´
/ˠra:ʕ/	´cubit´
/ˠja:b/	´wolves´
/sbe:ta:r/	´hospital´
/sta:ˠ/	´teacher´
/skitaw/	´they stopped talking´
/sgu:f/	´ceilings´
/smiʕaw/	´they heard´
/snu:n/	´soot´
/sla:ħ/	´weapon´
/sru:r/	´happiness´
/sse:r/	´the belt´
/sha:mik/	´your arrows´
/swa:ga/	´driving´
/sju:f/	´swords´
/sʕa:l/	´coughing´
/sɬu:r/	´lines´
/zba:li/	´rubbish´
/zta:t/	´quickly´
/zda:n/	´it became nicer´
/zka:m/	´flu´
/zra:r/	´button´
/zze:n/	´the goodness´
/zhu:r/	´flowers´
/zwa:ʕ/	´vomit´
/zja:ra/	´visit´
/zʕa:g/	´screaming´
/ʃba:g/	´what did he steal?´
/ʃta:g/	´he longed´
/ʃka:l/	´what did he weigh?´
/ʃga:l/	´what did he say?´
/ʃqa:b/	´earrings´
/ʃna:n/	´a kind of herb´
/ʃlo:n/	´how?´
/ʃra:ʕ/	´sail´
/ʃʃe:b/	´the grey hair´
/ʃñami/	´a piece of fat´
/ʃhu:r/	´months´
/ʃwa:r/	´food for animals made of husk´
/ʃjara/	´tree´
/ʃʕa:d/	´never mind´
/ʃtu:l/	´how long?´
/ʃsˁa:r/	´what happened?´
/Xba:ni/	´hemming´
/Xta:n/	´circumcision´
/Xdu:d/	´cheeks´

/Xla:l/	´spit´
/Xre:ʃ/	´fool´
/Xfa:f/	´light´ (pl.)
/Xsa:ra/	´loss´
/Xˠa/	´take it!´
/Xʃu:m/	´noses´
/Xwa:n/	´brothers´
/Xju:l/	´horses´
/ħbu:b/	´pills´
/ħta:r/	´he got puzzled´
/ħgu:g/	´rights´
/ħta:dʒ/	´he needed´
/ħma:r/	´donkey´
/ħnu:č/	´chins´
/ħlu:dʒ/	´mouths´
/ħra:m/	´garments of the Mecca pilgrim´
/ħˠa:k/	´near you´
/ħsa:b/	´arithmetic´
/ħza:m/	´belt´
/ħwajjir/	´small nymph´
/ħju:l/	´bracelets´
/ħᵵuba/	´a piece of wood´
/ħˠu:ˠ/	´lucks´
/ħɵa:n/	´horse´
/hba:l/	´craziness´
/hta:f/	´cheerings´
/hma:l/	´negligence´
/hna:k/	´there´
/hla:l/	´crescent´
/hwa:ʃ/	´quarrel´
/čtu:f/	´shoulders´
/čma:m/	´sleeves´
/čla:b/	´dogs´
/čfu:f/	´backs of the hands´
/dʒdu:r/	´pots´
/dʒna:zi/	´funeral´
/dʒlu:d/	´skins´
/dʒdʒaw/	´the weather´
/dʒwe:tij/	´a small pair of shoes´
/dʒju:b/	´pockets´
/wka:d/	´certain´
/wle:d/	´small boy´
/wriga/	´a piece of paper´
/wju:h/	´faces´
/ʕta:d /	´old´ (pl.)
/ʕda:l/	´wholesome´ (pl.)
/ʕga:l/	´men´s head band´
/ʕma:n/	´Oman´

/ʕne:zi/	´small goat´
/ʔlu:č/	´chewing gum´
/ʕru:dʒ/	´veins´
/ʕθiraw/	´they found´
/çɣiraw/	´they excused´
/ʕsa:wa/	´brooms´
/ʕče:fi/	´small plait´
/ʕwe:n/	´small eye´
/ʕju:n/	´eyes´
/ʕʈu:r/	´perfumes´
/ʕɣa:ma/	´bones´
/ʈbu:l/	´drums´
/ʈga:ʕ/	´wind´
/ʈma:m/	´ceiling´
/ʈna:zi/	´object of ridicule´
/ʈra:ra/	´begging´
/ʈlu:ʕ/	´sprouts of hair´
/ʈwe:r/	´small bird´
/ʈju:r/	´birds´
/ʈʈe:r/	´the bird´
/ɣlu:ʕ/	´ribs´
/ɣru:s/	´teeth´
/ɣwa:g/	´tight´ (pl.)
/ɣju:f/	´guests´
/ɣʕa:f/	´week´ (pl.)
/sba:r/	´Indian fig´
/sda:ʕ/	´headache´
/sgu:r/	´hawks´
/sqa:r/	´small´ (pl.)
/sma:m/	´valve´
/sno:bar/	´pine nuts´
/sra:X/	´screaming´
/slu:m/	´nuts without their shells´
/sfu:f/	´classrooms´
/sXala/	´lamb´
/sħe:n/	´small plate´
/swe:nijji/	´small tray´
/sja:m/	´fasting´
/sʕawa/	´swallow´
/ssi:n/	´the china´

APPENDIX B

The following examples illustrate all possible
word-medial two-consonant sequences, -CC-, in phonemic
transcription with English gloss.

/-bC-/
/ħabbe:t/	´I loved´
/nabti/	´a plant´
/čabdi/	´liver´
/ŧibkum/	´your medicine´
/jubga/	´he remains´
/nabqij/	´we want´
/libni/	´concentrated yogurt´
/habli/	´a fool´ (fem.)
/Xabra/	´inform him!´
/mabθu:r/	´pustulated´
/mabǯu:r/	´seeded´
/ħibsa/	´imprison him!´
/Xubzij/	´my bread´
/mabʃu:r/	´grated´
/mubXar/	´fumigator´
/sabħa/	´bathe him!´
/ñabhi/	´her seeds´
/jabčij/	´he cries´
/labdʒi/	´suitable´
/labwa/	´lioness´
/sibja:n/	´servants´
/sabʕi/	´seven´
/sabŧa/	´smooth it!´
/Xabła/	´crazy´ (fem.)
/nab%a/	´his pulse´
/Xabsa/	´mess´

/-tC-/
/bitbu:l/	´you will urinate´
/ħitta/	´scrape it off!´
/mitdalil/	´spoiled´
/jitkallam/	´he speaks´
/bitgu:l/	´you will say´
/bitqa:r/	´you will get jealous´
/jit2ammar/	´he orders´
/bitmil/	´you will get bored´
/matna:n/	´he got fat´
/bitlu:m/	´you will blame´
/matru:s/	´full´
/nitfi/	´small piece´
/bitθu:r/	´you will rebel´
/bitǯi:ʕ/	´you will broadcast´
/bitsim/	´you will poison´
/bitzu:r/	´you will visit´
/bitʃi:r/	´you will consult´
/bitXif/	´you will be light´

/matħaf/	´museum´
/bithu:n/	´you will become easy´
/bitču:f/	´you will see´
/bitdʒa:bil/	´you will face´
/fatwa/	´formal legal opinion´
/bitjij/	´you will come´
/mutˤa/	´pleasure´
/bit#i:r/	´you will fly´
/bit%ir/	´you will harm´
/bitɛi:r/	´you will become´

/-dC-/

/madbu:l/	´hemmed´
/ħadda:d/	´ironsmith´
/ħadkum/	´your limit´
/madgu:g/	´ground or hit´
/jadqim/	´he assimilates´
/mudmin/	´addict´
/hudni/	´cease-fire´
/badli/	´suit´
/madru:s/	´studied´
/madfu:n/	´buried´
/madθu:r/	´ancient´
/madsu:s/	´inserted´
/madzu:z/	´pushed´
/madʃu:ʃ/	´entered´
/madXal/	´entrance´
/ma:dħi:n/	´they have praised´
/jadhi/	´her hand´
/jadwij/	´to echo´
/jadji/	´my hand´
/jadˤim/	´he hits (by car)´

/-kC-/

/makbu:t/	´suppressed´
/maktu:t/	´scattered´
/makdu:s/	´pickled aubergine´
/makka/	´Mecca´
/makman/	´hiding place´
/maknu:n/	´hidden´
/ʃakli/	´his shape´
/fikra/	´idea´
/jakfij/	´it suffices´
/jakθir/	´it increases´
/jak%ib/	´he lies´
/jaksir/	´he breaks´
/makʃu:f/	´uncovered´
/makħili/	´kohl container´
/akčal/	´bald´
/ʃakwa/	´complaint´
/ʔakja:s/	´bags´
/jak#um/	´he suppresses´

/-gC-/
/magbu:l/   'accepted'
/ʃigga/   'tear it!'
/lugma/   'a bite'
/jagnis/   'he hunts'
/jigra/   'he reads'
/magfu:ł/   'locked'
/magsu:m/   'divided'
/nagzi/   'a jump'
/magʃu:ʃ/   'swept'
/migwad/   'steering wheel'
/magju:l/   'said'
/magʕad/   'seat'
/nigʈa/   'a dot'
/mugła/   'a frying pan'
/magӽu:ӽ/   'pierced'
/magsab/   'slaughter house'

/-qC-/
/jaqbil/   'he accepts'
/miqta:ӽ/   'angry'
/naqdi/   'embroidery'
/ħaqqaq/   'to investigate'
/jaqmiz/   'he winks'
/jaqlij/   'it boils'
/saqra/   'reduce it!'
/jiqfa/   'he dozes'
/jaqθij/   'he bothers'
/jaqsil/   'he washes'
/jaqzil/   'he spins'
/maqʃu:ʃ/   'cheated'
/maqha/   'cafe'
/jaqwij/   'he seduces'
/muqʈa/   'lid'
/maqłu:ɣ/   'thrown away'
/jaqӽa/   'awakening'
/niqsa/   'spoiling (someone's pleasure)'

/-2C-/
/saʔʔal/   'he asked a lot'
/juʔmin/   'he believes'
/maʔlu:f/   'familiar'
/maʔӡu:n/   'official who performs marriages'

/-mC-/
/sambu:si/   'samosa'
/simti:/   'you asked about its price' (fem.)
/ħamdi/   'the praiser' (fem.)
/jamkum/   'near you'
/jamgir/   'he bites'
/samqik/   'your glue'
/simma/   'poison him!'
/simni/   'clarified butter'
/ħamli/   'campaign'

/ħamra/	´red´ (fem.)
/jamsik/	´he holds´
/qamzi/	´wink´
/qamʃi/	´opaque´ (fem.)
/θamXa/	´deaf´ (fem.)
/jimħij/	´he wipes off´
/ʔumha/	´her mother´
/hamči/	´a lot´
/samdʒi/	´digusting´ (fem.)
/ʃimju:l/	´lower part of a dress´
/jimʕi/	´Friday´
/tamɬir/	´it is raining´
/ħa:mˠa/	´sour´ (fem.)
/ħamθa/	´roast it!´

/-nC-/
/jinba:g/	´it can be stolen´
/jintif/	´he plucks out´
/jindas/	´it can be inserted´
/minkum/	´from you´ (pl.)
/minga:ʃ/	´a pair of tongs´
/jinqiz/	´he pricks´
/jinmaʃ/	´it can be wiped´
/wanni/	´groan´
/jinla:m/	´he can be blamed´
/jinraʃ/	´it can be sprayed´
/manfi/	´exile´
/jinθir/	´he scatters´
/janˠir/	´he warns´
/minsaf/	´winnow´
/Xinzi:r/	´pig´
/jinʃif/	´it dries´
/janXir/	´it eats away´
/janħir/	´he slaughters´
/minha:r/	´collapsed´
/qanči/	´platter´
/mundʒid/	´helper´
/janwij/	´he intends´
/binjij/	´we will come´
/munʕim/	´benefactor´
/binɬil/	´we will peep´
/minˠa:r/	´telescope´
/manθu:f/	´halved´

/-lC-/
/ʕulbi/	´box´
/maltu:t/	´pounded´
/maldu:q/	´stung´
/mulka/	´his property´
/jalguf/	´he grabs´
/malqu:m/	´mined´
/malmu:m/	´gathered´
/ma:lni/	´ours´
/malli/	´bowl´

/milfaʕ/	'women's head shawl'
/malθu:m/	'veiled'
/jilɣaʕ/	'it cauterizes'
/malsu:n/	'talkative'
/malzu:m/	'obliged'
/bilʃi/	'difficult situation'
/ѕalXa/	'skin it!'
/milħij/	'my salt'
/jilhim/	'he coheres'
/malči/	'writing the marriage contract'
/ħaldʒi/	'his mouth'
/jalwij/	'he twists'
/ħalji/	'rusty' (fem.)
/malʕab/	'playground'
/Xilҍa/	'mix it!'
/jalɣum/	'to insert thread in a needle'
/jalѕig/	'it sticks'

/-rC-/

/marbu:ҍ/	'fastened'
/murtij/	'my wife'
/mardu:d/	'returned'
/markab/	'ship'
/sirga/	'stealing'
/marqu:b/	'desired'
/hurma/	'woman'
/hirni/	'we got puzzled'
/marra/	'once'
/jarfuҳ/	'he rejects'
/jarθij/	'he pities'
/jarsim/	'he draws'
/mirza:m/	'pipe for draining rain water on the roof'
/qarʃi/	'bottle'
/farXa/	'chick'
/farħa/	'happiness'
/marham/	'salve'
/birči/	'pond'
/mardʒiʕ/	'reference'
/jarwij/	'he waters'
/qarji/	'village'
/marʕa/	'grassland'
/ʃirҍa/	'police'
/jirɣa/	'he agrees'
/marѕu:ѕ/	'compressed'

/-fC-/

/mifta:ħ/	'key'
/jaҍdij/	'he sacrifices'
/ʔafka:r/	'thoughts'
/mafgu:d/	'missing'
/dafni/	'his burial'
/jiflis/	'he gets bankrupt'
/ħufra/	'pit'
/ѕaffa/	'his class'

/jifsid/	´he spoils´
/qafzi/	´jump´
/maf∫u:∫/	´subsided´
/jifXar/	´he boasts´
/jifħam/	´he silences with arguments´
/jifham/	´he understands´
/mafču:č/	´open´
/mafdʒu:ʕ/	´voracious´
/ʕafji/	´well done´
/jifʕa/	´he crams´
/jaftin/	´he realizes´
/jifʐaħ/	´he discloses´
/jifʐaX/	´he takes off (his clothes)´

/-θC-/

/jiθbit/	´he proves´
/jiθgal/	´he gets heavy´
/jaθnij/	´he folds´
/miθla/	´like him´
/naθra/	´scatter it!´
/ħiθθa/	´urge him!´
/ʔaθwab/	´more rewarding´

/-ʁC-/

/čiʁbi/	´lie´
/ʔaʁka/	´more clever´
/maʁmu:m/	´blameworthy´
/ʔiʁnij/	´my ear´
/maʁlu:l/	´humiliated´
/ħaʁra/	´warn him!´
/ħiʁfa/	´throw it!´
/laʁʁi/	´pleasure´
/maʁhu:l/	´stunned´
/jaʁwij/	´it withers´
/miʁja:ʕ/	´radio´
/maʁʕu:r/	´frightened´

/-sC-/

/misba:h/	´rosary´
/mastu:r/	´covered´
/masdu:d/	´blocked´
/miski:n/	´poor´
/masgu:f/	´roofed´
/mas?u:l/	´responsible´
/masmu:ħ/	´allowed´
/masnu:n/	´sharpened´
/muslim/	´muslim´
/masraħ/	´theatre´
/missa/	´touch it!´
/jisXar/	´he laughs at´
/masħu:r/	´bewitched´
/ʔashum/	´shares´
/misči:n/	´poor´
/masdʒu:n/	´imprisoned´

/jiswa/   'it is worth'
/masjad/   'mosque'
/jisɕal/   'he coughs'
/mastara/   'ruler'

/-zC-/
/mazbili/   'dunghill'
/jizda:n/   'it becomes prettier'
/mazku:m/   'he got a cold'
/lazga/   'sticker'
/jazqid/   'he catches by the throat'
/mazmu:m/   'gathered'
/jaznij/   'he commits adultery'
/jazlig/   'he slips'
/jizraɕ/   'he plants'
/ħazzi/   'time'
/mazXu:X/   'caught'
/jizħar/   'he eats'
/nizha/   'picnicking'
/nazwa/   'whim'
/mazju:n/   'beautiful'
/jizɕal/   'he gets angry'

/- ʃC-/
/jiʃbaɕ/   'he gets satisfied'
/jaʃtim/   'he curses'
/maʃdu:d/   'tight'
/jaʃkij/   'he complains'
/maʃgu:g/   'torn'
/maʃqu:l/   'busy'
/maʃʔu:m/   'ominous'
/maʃmu:m/   'sweet basil'
/maʃnaqa/   'gallows'
/maʃlu:l/   'paralysed'
/maʃru:b/   'drink'
/jaʃfij/   'he heals'
/miʃʃa/   'wipe it!'
/maʃXu:l/   'drained'
/maʃħu:n/   'loaded'
/maʃhad/   'scene'
/jaʃdʒij/   'he distresses'
/maʃwij/   'grilled'
/maʃji/   'manner of walking'
/jaʃɕil/   'he lights'
/maʃtu:b/   'crossed out'

/-XC-/
/muXba/   'pocket'
/jiXta:r/   'he chooses'
/jiXdim/   'he serves'
/maXmal/   'velvet'
/jaXnij/   'meat sauce'
/jiXlij/   'he empties'
/saXra/   'rock'

/maXfu:s/	´destroyed´
/ja:Xˠa/	´he takes it´
/jiXsir/	´he loses´
/maXzan/	´store´
/jaXʃij/	´he fears´
/muXXa/	´his brain´
/jaXdʒil/	´he gets shy´
/ʔiXwa/	´brothers´
/jaXɬir/	´it occurs to the mind´
/naXɬa/	´palm tree´
/jiXˠar/	´it becomes green´
/maXɕu:ɕ/	´special´

/-ħC-/

/jaħbij/	´he crawls´
/jiħtar/	´he gets angry´
/maħdu:d/	´limited´
/maħku:k/	´scrabbed´
/jiħgid/	´he became embiltered´
/jaħqid/	´he became embiltered´
/laħmi/	´piece of meat´
/miħni/	´misfortune´
/naħli/	´bee´
/maħru:m/	´deprived´
/maħfu:f/	´surrounded´
/taħˠir/	´she bewares´
/taħsib/	´she counts´
/miħzam/	´belt´
/maħʃij/	´stuffed´
/maħħad/	´nobody´
/jaħčil/	´he deprives´
/jaħdʒib/	´he veils´
/miħwa:s/	´searcher´
/maħju:b/	´prevented´
/maħɬu:ɬ/	´put down´
/maħˠu:ˠ/	´lucky´
/maħsu:b/	´he got measles´

/-hC-/

/mahbu:l/	´fool´
/mahtu:t/	´free´
/mahdu:d/	´left in his own´
/ʃahga/	´a gasping inhaling´
/jahmil/	´he neglects´
/mihni/	´profession´
/muhli/	´respite´
/nahra/	´his river´
/mahfu:f/	´whiffled´
/jahðij/	´he raves´
/jahzim/	´he defeats´
/dahʃi/	´surprise´
/mahhad/	´he facilitated´
/bahdʒi/	´joy´
/gahwa/	´coffee´

/mahja:wa/	´small pickled fish´
/jahtil/	´it pours down´
/nahǧa/	´boom´

/-čC-/
/mačbu:s/	´curried rise´
/mačqu:q/	´pierced´
/mačnu:z/	´full´
/kačli/	´bald´ (fem.)
/kačra/	´rubbish´
/mačfu:f/	´hemmed´
/jačθij/	´it becomes opaque´
/jačǧib/	´he lies´
/jačsij/	´he clothes´
/ħačči/	´itching´
/ʕičwi/	´tail´
/mačju:l/	´weighed´
/mačʕa/	´pluck it!´

/-dʒC-/
/hadʒba/	´veil him!´
/nadʒdi/	´help´
/madʒmaʕ/	´gathering place´
/ħadʒni/	´our pilgrimage´
/jadʒlid/	´he flogs´
/ħidʒra/	´room´
/tadʒfij/	´she deserts´
/jadʒθim/	´he weighs heavily on´
/jadʒǧib/	´he attracts´
/madʒzu:m/	´vowelless´
/jidʒħid/	´he denies´
/madʒhu:d/	´effort´
/ħadʒdʒi/	´pilgrimage´
/ʔadʒwa:ʔ/	´air´
/ʔadʒja:l/	´generations´

/-wC-/
/ta:wli/	´table´
/jiwra/	´it lights´
/jawfij/	´he fulfils´
/mawsim/	´season´
/mawzu:n/	´weighed´
/ʕawʃo:/	´girl´s proper name´ (diminutive)
/jawħij/	´he inspires´
/mawhu:b/	´talented´
/mawdʒu:d/	´available´
/ʔawwal/	´first´
/tawji/	´fold´
/mawʕid/	´date´
/mawtin/	´homecountry´
/mawǧu:ʕ/	´topic´
/mawsu:f/	´described´

/-jC-/

/ma:jbil/	´he does not wet´
/ma:jtil/	´he does not pull´
/ma:jdil/	´he does not know the way´
/ma:jkil/	´he does not get tired´
/ma:jgil/	´it does not decrease´
/ma:qiʃ/	´he does not cheat´
/ma:j2ammin/	´he does not trust´
/majmu:n/	´blessed´
/majnu:n/	´mad´
/ma:jlu:m/	´he does not blame´
/hajra:n/	´puzzeled´
/ma:jfu:h/	´it does not boil´
/ma:jθu:r/	´he does not rebel´
/ma:jɣir/	´he does not scatter´
/majsu:r/	´wealthy´
/ma:jzu:r/	´he does not visit´
/ma:jʃi:l/	´he does not lift´
/ma:jXa:lif/	´it does not matter´
/ma:jñib/	´he does not love´
/majhu:d/	´ill´
/ma:jču:f/	´he does not see´
/ma:jwid/	´he does not like´
/ñajji/	´snake´
/ma:jʕid/	´he does not count´
/ma:jⱨir/	´he does not beg´
/ma:jⱬir/	´he does not harm´
/majɤu:ɤ/	´plastered´

/-ʕC-/

/liʕbi/	´toy´
/maʕtu:h/	´idiot´
/jaʕdim/	´he excutes´
/jaʕkif/	´he devotes´
/maʕgu:d/	´knotted´
/maʕmu:l/	´sweet pastry filled with nuts or dates´
/maʕni/	´meaning´
/maʕlu:m/	´known´
/ʃaʕra/	´one hair´
/jaʕfij/	´he forgives´
/jaʕθir/	´he finds´
/jaʕɣir/	´he excuses´
/maʕsu:l/	´honeyed´
/jaʕzim/	´he invites´
/maʕʃu:g/	´lover´
/maʕču:f/	´plaited´
/jaʕdʒib/	´it pleases´
/maʕwij/	´twisted´
/maʕju:f/	´deserted´
/naʕʕam/	´to grind´
/jaʕⱨij/	´he gives´
/maʕⱬu:ⱬ/	´bitten´
/raʕɤa/	´compression´

/-ⱨC-/

/tiṭbaX/ 'she cooks'
/maṭgu:g/ 'hit'
/jaṭqij/ 'he tyrannizes'
/maṭmu:m/ 'roofed'
/maṭnizi/ 'object of ridicule'
/maṭlu:b/ 'in demand'
/muṭrib/ 'singer'
/jiṭfij/ 'he switches off'
/maṭzu:z/ 'harmed in the eye'
/maṭḥu:n/ 'ground'
/ḥiṭha/ 'put her down!'
/maṭwij/ 'folded'
/maṭju:r/ 'out of his mind'
/maṭṣu:n/ 'stabbed'
/baṭṭa/ 'duck'

/-ḷC-/
/Xiḷḷa/ 'wedding room'

/-ɣC-/
/maɣku:k/ 'compressed'
/muɣqa/ 'chew it!'
/maɣmu:m/ 'gathered'
/ḥaɣni/ 'our luck'
/maɣlu:m/ 'unjustly treated'
/jaɣrub/ 'he hits'
/jaɣfij/ 'he adds'
/maXɣu:ɣ/ 'pumped'
/jiɣhak/ 'he laughs'
/jiɣhar/ 'he appears'
/jiɣwij/ 'it gleams'
/Xiɣɣa/ 'shake it'

/-sC-/
/jasbur/ 'he gets patient'
/jasdir/ 'he issues'
/masku:k/ 'closed'
/jisqar/ 'it diminishes'
/masmu:m/ 'closed with a valve'
/Xasni/ 'it concerned us'
/Xisla/ 'lock of hair'
/masru:f/ 'expenditure'
/jisXa/ 'he permits'
/mushaf/ 'Koran'
/jishar/ 'he melts'
/ḥaswa/ 'small stone'
/masjad/ 'trap'
/jisʕab/ 'it gets difficult'
/gissa/ 'cut it!'

APPENDIX C

The following examples illustrate all possible syllable final two-consonant clusters, in phonemic transcription with English gloss:

/sabb/	´he cursed´
/sabt/	´Saturday´
/ʕabd/	´slave´
/kabʃ/	´ram´
/ẍabħ/	´slaughtering´
/gabˣ/	´holding´
/ħatt/	´to scrape off´
/fatg/	´opening´
/fatħ/	´opening´
/ħakk/	´to scratch´
/rigadt/	´I slept´
/ħadd/	´limit´
/ħagg/	´right´
/wagt/	´time´
/wagf/	´stopping´
/baqq/	´to burst´
/raqs̱/	´dancing´
/waʔd/	´to bury alive´
/simt/	´I asked about the price´
/ħamd/	´praising´
/ṣamq/	´gum´
/samm/	´to poison´
/ʔamn/	´peace´
/ʔams/	´yesterday´
/ʔimʃ/	´walk!´
/ʃamX/	´scratch´
/ʃamʕ/	´wax´
/ẍanb/	´sin´
/bint/	´girl´
/ʕind/	´with´
/bang/	´bank´
/wann/	´to moan´
/ʕanz/	´goat´
/ħinč/	´chin´
/landʒ/	´boat´
/čalb/	´dog´
/gilt/	´I said´
/dʒild/	´skin´
/mulk/	´property´
/ħilm/	´dream´
/tall/	´to pull´
/milħ/	´salt´

/wilf/	´valve´
/ɦaldʒ/	´mouth´
/darb/	´path´
/dirt/	´I searched´
/bard/	´cold´
/farg/	´difference´
/barq/	´lightning´
/marr/	´to pass by´
/ʕirs/	´wdding´
/jarʕ/	´daring´
/ʕirdʒ/	´vein´
/ʔarɣ/	´earth´
/girθ/	´loaf´
/ʃarʈ/	´condition´
/raff/	´shelf´
/ɦaθθ/	´to urge´
/ʃaɣɣ/	´to divert´
/libast/	´I put on´
/Xass/	´lettuce´
/wiʈ/	´middle´
/fizt/	´I won´
/Xazz/	´to pierce´
/biʃt/	´cloak´
/baʈʈ/	´ducks´
/ʈubaXt/	´I cooked´
/faXX/	´trap´
/riñt/	´I went´
/mañ̃/	´to erase´
/ɦadʒdʒ/	´pilgrimage´
/faʈʈ/	´to open´
/ʕahd/	´promise´
/saww/	´to do´
/wajh/	´face´
/ɦajj/	´alive´
/simaʕt/	´I heard´
/waʕd/	´promise´
/ʃaʕʕ/	´to shine´
/gaʈb/	´heart´
/gaʈʈ/	´to decrease´
/gaʈʕ/	´cutting´
/gaʈʈ/	´to throw away´
/gaʈd/	´purpose´
/qaθf/	´hitting´
/gaθθ/	´cutting´

APPENDIX D

The following examples illustrate the possible vowels that may precede each of the consonant phonemes:

/ӕib/	´medicine´
/sab/	´cursing´
/dub/	´bear´
/χi:b/	´wolf´
/ʕe:b/	´shame´
/ba:b/	´door´
/θo:b/	´robe´
/tu:b/	´repent!´
/sit/	´six´
/dӡat/	´grass´
/či:t/	´cotton´
/be:t/	´house´
/ma:t/	´to die´
/mo:t/	´death´
/mu:t/	´die!´
/ʕid/	´count!´
/sad/	´dam´
/ʕi:d/	´feast´
/ge:d/	´bond´
/ga:d/	´to lead´
/ʕo:d/	´big´
/ʕu:d/	´stick´
/sik/	´close!´
/sak/	´to close´
/čuk/	´no´
/fi:k/	´in you´
/ke:k/	´cake´
/ha:k/	´take it!´
/ʃo:k/	´thornes´
/bu:k/	´purse´
/ʃig/	´tear!´
/ʃag/	´to tear´
/lugma/	´mouthful´
/ǰi:g/	´tightness´
/ba:g/	´to steal´
/bo:g/	´stealing´
/bu:g/	´steal!´
/laqliq/	´make a mess!´
/luqa/	´language´
/bali:q/	´eloquent´
/sa:q/	´to mould gold´
/so:q/	´jewels´
/su:q/	´mould gold!´

/la:ʔ/	´no´
/sim/	´poison´
/sam/	´to poison´
/ʔum/	´mother´
/si:m/	´string´
/qe:m/	´clouds´
/la:m/	´to blame´
/lo:m/	´blaming´
/lu:m/	´blame!´
/min/	´who´
/fan/	´art´
/bun/	´coffee´
/li:n/	´softness´
/le:n/	´until´
/la:n/	´to soften´
/lo:n/	´colour´
/Xu:n/	´betray!´
/sil/	´tuberculosis´
/fal/	´to unfold´
/ful/	´Arabic jasmine´
/fi:l/	´elephant´
/ʒe:l/	´tail´
/ga:l/	´to say´
/go:l/	´saying´
/gu:l/	´say!´
/sir/	´secret´
/mar/	´to pass´
/mur/	´bitter´
/si:r/	´go!´
/se:r/	´belt´
/sa:r/	´to go´
/θo:r/	´ox´
/θu:r/	´rebel!´
/lif/	´turn!´
/laf/	´to turn´
/tuf/	´phew´
/si:f/	´shore´
/se:f/	´sword´
/ča:f/	´to see´
/Xo:f/	´fear´
/ču:f/	´see!´
/ħiθ/	´urge!´
/ħaθ/	´to urge´
/qi:θ/	´help!´
/la:θ/	´to remain behind´
/lo:θ/	´remaining behind´
/lu:θ/	´remain behind!´

/ħe:θ/	'as'
/Xiɣ/	'take!'
/Xaɣ/	'to take'
/laɣi:ɣ/	'delicious'
/ʃa:ɣ/	'abnormal'
/lo:ɣ/	'seeking refuge'
/lu:ɣ/	'seek refuge!'
/dis/	'insert'
/das/	'to insert'
/Xi:s/	'get rotten!'
/te:s/	'billy goat'
/ka:s/	'cup'
/mu:s/	'razor'
/ho:s/	'stirring'
/ʕiz/	'luxury'
/ʕaz/	'to endear'
/ƚi:z/	'arse'
/me:z/	'drawer'
/fa:z/	'to win'
/mo:z/	'bananas'
/bu:z/	'mouth'
/miʃ/	'wipe!'
/maʃ/	'to wipe'
/ri:ʃ/	'feather'
/ʕe:ʃ/	'rice'
/ʕa:ʃ/	'to live'
/ħo:ʃ/	'courtyard'
/ħu:ʃ/	'touch!'
/ƚiX/	'hit!'
/faX/	'trap'
/muX/	'brain'
/si:X/	'skewer'
/ʃe:X/	'sheik'
/ʃa:X/	'silver'
/jo:X/	'broadcloth'
/ku:X/	'cottage'
/kiħ/	'cough!'
/kaħ/	'to cough'
/ri:ħ/	'wind'
/ƚe:ħ/	'falling'
/ƚa:ħ/	'to fall'
/lo:ħ/	'a piece of wood'
/ru:ħ/	'soul'
/sa:miʕ/	'hearer'
/maʕdan/	'metal'
/rubuʕ/	'quarter'
/bi:ʕ/	'sell!'

/be:ʕ/	'selling'
/ba:ʕ/	'to sell'
/ro:ʕ/	'fright'
/ku:ʕ/	'elbow'

/mihni/	'job'
/ẓahra/	'his back'
/muhli/	'time limit'
/Xalli:h/	'leave it!'
/X̌e:h/	'take it!' (fem.)
/Xalla:h/	'he left it'
/Xallo:h/	'they left it'
/Xallu:h/	'leave it!' (pl.)

/gałbič/	'your heart' (fem.)
/lač/	'for you' (fem.)
/di:č/	'cock'
/ʕle:č/	'chewing gum' (diminutive)
/ha:č/	'take it!' (fem.)
/ʃo:č/	'thorns'
/ʔubu:č/	'your father' (fem.)

/ṣidʒ/	'true'
/ħadʒ/	'pilgrimage'
/zi:dʒ/	'lace'
/ħle:dʒ/	'mouth' (diminutive)
/ṣa:dʒ/	'he is right'
/go:dʒ/	'plums'
/ʕru:dʒ/	'veins'

/ħiliw/	'sweet'
/saw/	'do!'
/ħle:w/	'kind'
/ja:w/	'they came'

/ʔiXtij/	'my sister'
/naj/	'raw'
/ma:j/	'water'
/bo:j/	'servant'
/ʔubu:j/	'my father'

/niɫ/	'jump!'
/baɫ/	'duck'
/muɫ/	'pull!'
/naʃi:ɫ/	'active'
/Xe:ɫ/	'thread'
/ma:ɫ/	'he has pulled'
/ʃo:ɫ/	'electrical shock'
/su:ɫ/	'make a mess!'

| /Xaɫ/ | 'vinegar' |
| /Xaɫa:ɫ/ | 'unripe dates' |

| /giẓ/ | 'pierce!' |

/gaɬ/	'hole'
/muɬ/	'rinse!'
/bi:ɬ/	'white' (fem. pl.)
/be:ɬ/	'eggs'
/ba:ɬ/	'to lay egg'
/ħo:ɬ/	'pool'
/Χu:ɬ/	'go through!'
/niɕ/	'half'
/maɕ/	'to suck'
/muɕ/	'suck!'
/qami:ɕ/	'shirt'
/Χa:ɕ/	'special'
/mo:ɕ/	'rinsing'
/Χu:ɕ/	'strait hair'

APPENDIX E

The following examples illustrate all possible vowels that may follow each of the consonant phonemes, CV, in phonemic transcription with English gloss:

/bir/	´piety´
/bar/	´desert´
/gabur/	´grave´
/bi:r/	´well´
/be:t/	´house´
/ba:n/	´to appear´
/bo:l/	´urine´
/bu:g/	´steal!´
/til/	´pull!´
/tal/	´to pull´
/ta:m/	´complete´
/ti:n/	´figs´
/te:s/	´billy goat´
/ta:b/	´to repent´
/to:li/	´a type of weight´
/tu:r/	´tulle´
/diz/	´push!´
/daz/	´to push´
/dub/	´bear´
/di:n/	´religion´
/de:d/	´breast´
/da:s/	´to tread´
/do:r/	´turn´
/du:r/	´go round!´
/kiʃ/	´send away!´
/kal/	´to eat´
/be:tkum/	´your house´
/ki:ra:n/	´coils´
/ke:f/	´how´
/ka:n/	´there was´
/ko:r/	´coil´
/ku:b/	´cup´
/gir/	´settle down!´
/gar/	´to settle down´
/gum/	´get up!´
/gi:s/	´measure!´
/ge:s/	´hopscotch´
/ga:m/	´to get up´
/go:l/	´saying´
/gu:l/	´say!´
/qiʃ/	´cheat!´
/qaʃ/	´to cheat´

/qi:r/	'get jealous!'
/qe:m/	'clouds'
/qa:r/	'to be jealous'
/qo:s/	'arch'
/qu:rij/	'tea pot'
/ʔihni:/	'here'
/ʔamal/	'hope'
/ʔum/	'mother'
/ʔi:/	'yes'
/ʔa:ni/	'myself'
/ʔo:ʒa/	'bedroom set'
/ʔu:tij/	'iron'
/min/	'who'
/mad/	'to stretch'
/mur/	'bitter'
/mi:l/	'bend!'
/me:z/	'drawer'
/ma:t/	'to die'
/mo:t/	'death'
/mu:t/	'die!'
/nis/	'half'
/namli/	'ant'
/kani:si/	'church'
/ne:ri/	'a gold coin'
/na:r/	'fire'
/no:m/	'sleep'
/nu:r/	'light'
/lim/	'hug'
/lam/	'to hug'
/lub/	'essence'
/li:n/	'softness'
/le:n/	'until'
/la:m/	'to blame'
/lo:m/	'blaming'
/lu:m/	'blame'
/ri ʃ/	'spray!'
/ra ʃ/	'to spray'
/rumma:n/	'pomegranates'
/ri:ʃ/	'feathers'
/re:l/	'train'
/ra:s/	'head'
/ro:b/	'yoghurt'
/ru:s/	'heads'
/fil/	'unfold'
/fal/	'to unfold'
/ful/	'Arabic jasmine'
/fi:l/	'elephant'
/se:fe:n/	'two swords'

/fa:l/	´omen´
/fo:g/	´up´
/fu:l/	´broad beans´
/θilθ/	´one third´
/θaman/	´price´
/θumun/	´one eightth´
/ħiθθi:/	´urge him´
/θa:r/	´to rebel´
/θo:r/	´ox´
/θu:r/	´rebel!´
/ӡir/	´scatter!´
/ӡabħ/	´slaughtering´
/ӡuba:n/	´flies´
/ӡi:b/	´wolf´
/ӡe:l/	´tail´
/ӡa:k/	´that´
/ӡo:q/	´taste´
/ӡu:g/	´taste!´
/sim/	´poison!´
/sam/	´to poison´
/si:m/	´string´
/se:f/	´sword´
/sa:m/	´poisonous´
/so:m/	´asking about the value´
/su:m/	´ask about the value!´
/zim/	´gather´
/zam/	´gathering´
/zi:d /	´lace´
/ze:n/	´nice´
/za:r/	´to visit´
/zo:ʕ/	´vomiting´
/zu:r/	´visit!´
/ʃim/	´smell!´
/ʃam/	´to smell´
/ʃumaX/	´he scratched´
/ʃi:l/	´lift!´
/ʃe:l/	´lifting´
/ʃa:l/	´to lift´
/ʃo:č/	´thorns´
/ʃu:t/	´kick!´
/Xir/	´leak!´
/Xar/	´to leak´
/Xum/	´sweep!´
/Xi:s/	´get rotten!´
/Xe:l/	´horse´
/Xa:f/	´to be frightened´
/Xo:f/	´fear´
/Xu:n/	´betray!´

/ħib/	´love!´
/ħab/	´to love´
/ħub/	´love´
/ħi:li/	´trick´
/ħe:si/	´circle´
/ħa:l/	´condition´
/ħo:ɬa/	´closure´
/ħu:s/	´stir!´
/himad/	´he calmed down´
/hamzi/	´glottal stop´
/be:thum/	´their house´
/hi:n/	´insult!´
/he:l/	´cardimom´
/ha:n/	´to become easy´
/ho:ʃi/	´quarrel´
/hu:n/	´become easier!´
/čib/	´turn up-side-down´
/čab/	´turn up-side-down´
/či:l/	´weigh!´
/če:li/	´a dry measure´
/ča:f/	´to see´
/čo:f/	´seeing´
/ču:f/	´see!´
/dʒili:b/	´well´
/dʒat/	´grass´
/dʒumdʒuma/	´skull´
/dʒi:l/	´generation´
/dʒe:b/	´pocket´
/dʒa:m/	´jam´
/dʒo:z/	´couple´
/dʒu:tij/	´a pair of shoes´
/win/	´groan!´
/wan/	´to groan´
/wi:/	´oh´
/we:n/	´where´
/wa:r/	´yard´
/sawwo:/	´they made it´
/sawwu:/	´do it!´ (pl.)
/jih/	´watermelon´
/jad/	´hand´
/jumma/	´mother!´
/ji:b/	´bring!´
/je:b/	´pocket´
/ja:b/	´to bring´
/jo:m/	´day´
/ju:ʕ/	´hunger´
/ʕind/	´with´

/ʕabd/	´slave´
/ʕumur/	´age´
/ʕiːd/	´feast´
/ʕeːb/	´shame´
/ʕaːd/	´to return´
/ʕoːd/	´big´
/ʕuːd/	´stick´
/ṭir/	´beg!´
/ṭar/	´to beg´
/ṭum/	´cover!´
/ṭiːr/	´fly!´
/ṭeːr/	´bird´
/ṭaːr/	´to fly´
/ṭoːr/	´limit´
/ṭuːl/	´height´
/Xaːɫij/	´my uncle´
/gaɫɫab/	´he turned over´
/gaɫɫaː/	´he fried it´
/gaɫɫiː/	´fry it!´ (fem.)
/gaɫɫoː/	´they fried it´
/gaɫɫuː/	´fry it!´ (pl.)
/gaɫɫub/	´turn over!´
/gɫeːb/	´small heart´
/ɣir/	´harm!´
/ɣar/	´to harm´
/ɣum/	´hug!´
/ɣiːg/	´narrowness´
/ɣeːf/	´guest´
/ɣaːʕ/	´to get lost´
/gaɣɣoː/	´they pierced it´
/giɣɣuː/	´pierce it!´ (pl.)
/ṣik/	´close!´
/ṣal/	´pray!´
/ṣub/	´pour!´
/ṣiːn/	´china´
/ṣeːf/	´summer´
/ṣaːħ/	´to cry´
/ṣoːm/	´fasting´
/ṣuːm/	´fast!´

APPENDIX   F

Figure 3.3.1.a

/ʃoːt/

Figure 3.3.1.b

/ʃoːɬ/

Figure 3.3.2.a

/ris/

511

Figure   3.3.2.b

/ris/

Figure 3.3.3.a

/naʃiːd/

Figure 3.3.3.b

/naʃiː₺/

Figure 3.3.4.a

/ti:n/

Figure 3.3.4.b

/ti:n/

516

Figure 3.3.5.a

/si:n/

517

Figure 3.3.5.b

/ɕiːn/

Figure 3.3.6.a

/sa:d/

Figure 3.3.6.b

/sa:d/

Figure 3.3.7.a

/sid/

Figure 3.3.7.b

/sid/

Figure 3.3.8.a

/tal/

Figure 3.3.8.b

/tal/

Figure 3.3.9.a

/sa:matla/

Figure 3.3.9.b

/sa:matla/

Figure 3.3.10.a

/nisi:b/

Figure 3.3.10.b

/niɛi:b/

Figure 3.3.11.a

/Xalle:na:/

Figure 3.3.11.b

/Xatte:na:/

530

Figure 3.3.12.a

/be:t ta:jir/

Figure 3.3.12.b

/beːt ʈaːjir/

Figure 3.3.13.a

/bas isi:r/

Figure 3.3.13.b

/bas isi:r/

Figure 3.3.14.a

/ħat ismi/

Figure 3.3.14.b

/hat ismi/

APPENDIX H

The following is the word list investigated in the aerometric experiment:

/za:d/	´increased´
/Xa:z/	´he has pierced´
/za:X/	´he has caught´
/Xa:s/	´to get rotten´
/Xa:ɞ/	´private´
/Xa:ɫ/	´uncle´
/Xa:r/	´it has leaked´
/da:s/	´to tread´
/sa:d/	´to prevail´
/ba:b/	´door´
/ba:t/	´to sleep´
/ta:b/	´to repent´
/ba:g/	´to steal´
/ba:d/	´he has distributed´
/ba:q/	´on fire´
/da:m/	´to last´
/ta:m/	´complete´
/ma:d/	´he has stretched´
/ma:t/	´to die´
/za:m/	´turn´
/ma:z/	´absorbing´
/sa:m/	´poisonous´
/ma:s/	´touching´
/ma:n/	´showing his favour´
/dma:n/	´addiction´
/gfa:ʃ/	´spoons´
/fa:ʃ/	´subsiding´
/bza:r/	´spices´
/za:r/	´to visit´
/nña:s/	´copper´
/ña:s/	´to stir´
/ba:ga/	´he stole it´
/ba:ga:/	´he stole him´
/ba:gakum/	´he stole you´
/ba:ga:kum/	´he has stolen you´
/Xa:zba:z/	´a kind of disease´
/suffa:ɫ/	´scales (of fish)´
/misba:ħ/	´rosary´
/jinba:ʕ/	´it can be sold´
/baraka:t/	´blessing´
/ka:t/	´he has thrown´
/tinda:s/	´it can be trodden on´
/da:zi:nkum/	´they are pushing you´
/ba:ddi:n/	´they are distributing´
/ba:ɫɫi:n/	´they are piercing´
/Xa:ɞɞi:n/	´they give special concern´
/da:ʕmi:n/	´they collide with´
/sa:mʕi:n/	´they hear´

/msa:mñi:n/	´they forgive´
/sa:ħri:nhum/	´they bewitch them´
/fa:ʃʃi:n/	´they subside´
/da:ssi:nhum/	´they insert them´
/fa:tti:na/	´they break it up´
/fa:t/	´he has crumbled´
/ča:fa:/	´he has seen it´
/samma:/	´he has called him´
/dazza:/	´he has pushed it´
/la/	´for him´
/kaħ/	´to cough´
/ñak/	´to scratch´
/Xal/	´to leave´
/Xaɫ/	´vinegar´
/giɞ/	´cut!´
/giⱬ/	´pierce!´
/sik/	´close!´
/Ⱬik/	´cramp!´
/ɞig/	´hit!´
/giɞ/	´throw!´
/kiħ/	´cough!´
/ħik/	´scratch!´
/ʕid/	´count!´
/diz/	´push!´
/dis/	´insert!´
/dist/	´I trod on´
/sid/	´block up!´
/tsid/	´you block up´
/zif/	´wed!´
/Xiz/	´pierce!´
/bid/	´distribute!´
/kid/	´work hard!´
/kit/	´throw!´
/miʃ/	´wipe!´
/mid/	´stretch!´
/mitt/	´I died´
/ʃim/	´smell!´
/dim/	´swallow!´
/tim/	´complete!´
/min/	´who´
/dil/	´find the way!´
/dir/	´flow copiously!´
/bin/	´son of´
/bint/	´girl´
/sim/	´poison!´
/simt/	´I inquired about the value´
/tsim/	´she poisons´
/čif/	´hem!´
/tʃif/	´she traces´
/ʃif/	´trace!´
/čift/	´I saw´
/simač/	´fish´
/simačkum/	´your fish´
/disam/	´grease´

/maktibi/	´library´
/giɬɬa/	´cut it!´
/giɬhum/	´throw them!´
/kiḥli/	´kohl in the eyes´
/kiḥil/	´kohl´
/kiḥlathum/	´their kohl´
/siʕra/	´its price´
/tisiʕ/	´nine´
/ḥab/	´to love´
/ʕag/	´to throw´
/gaʕ/	´something bad´
/baṭ/	´ducks´
/ṭab/	´to jump´
/θab/	´to pour´
/baɬ/	´bus´
/sab/	´to curse´
/bas/	´enough´
/bad/	´to distribute´
/baq/	´to go on fire´
/dak/	´to make flat´
/kad/	´to work hard´
/dag/	´to hit´
/das/	´to insert´
/daz/	´to push´
/Xas/	´lettuce´
/Xaz/	´to pierce´
/Xas/	´to distinguish´
/Xar/	´to leak´
/dam/	´blood´
/sam/	´to poison´
/mad/	´to stretch´
/mas/	´to touch´
/man/	´a weight of 2 "rotl"s´
/gad/	´the size of´
/sabt/	´Saturday´
/Xaḷṭ/	´mixing´
/ʃam/	´to smell´
/ʃams/	´sun´
/nmad/	´it stretched´
/ʃtad/	´it became strong´
/sabbab/	´he caused´
/sababkum/	´your cause´
/sabab/	´cause´
/mar/	´to pass by´
/mara/	´woman´
/marag/	´curry´
/qaʃmara/	´joking´
/qaʃmaratkum/	´your joking´
/sabba/	´he cursed him´
/kaḥḥal/	´to paint with kohl´
/daʕʕam/	´to support´
/baṭṭaṭ/	´he made holes´
/gaɣɣaɣ/	´he made small holes´
/baddad/	´he distributed´

/dazzak/	´he pushed you´
/sikat/	´he became silent´
/tinassam/	´he breathed´
/qimaz/	´he winked´
/ma:naʕ/	´he has objected´
/sa:maħ/	´he has forgiven´
/naʃʃaf/	´he dried´
/ʃammaX/	´to scratch´
/gaʈʈa/	´he threw it away´
/gaʈ/	´to throw away´
/kahha/	´coughing´
/ħatta/	´even though´
/hazza/	´he incised it´
/la:/	´no´
/Xalla:/	´he left it´
/ba:ʕ/	´to sell´
/ʕa:b/	´to blame´
/ʃuʕa:ʕ/	´beams´
/ħa:b/	´he is loving´
/ha:b/	´it is blowing´
/ba:ħ/	´to reveal´
/muħa:ħ/	´yoke´
/ba:t/	´he has made a hole´
/ta:b/	´to recover´
/maʈʈa:ʈ/	´rubber´
/ba:s/	´bus´
/sa:b/	´he has poured´
/risa:s/	´bullets´
/da:z/	´he has pushed´
/simsim/	´sesame´
/dizhum/	´push them!´
/sidda/	´block it!´
/dissa/	´insert it!´
/ʃikka/	´impale it!´
/ʃik/	´impale!´
/rizna:mi/	´calender´
/riz/	´prepare´
/dʒida:mkum/	´in front of you´
/mitha:wʃi:n/	´they have quarelled´
/mis/	´touch!´
/misma:rkum/	´your nail´
/daffi/	´cloak´
/maddi/	´mat´
/madrisi/	´school´
/ziba:ra/	´name of a town in Qatar´
/ʃa:k/	´he has doubted´
/ħa:k/	´he has scratched´
/sa:k/	´he has closed´
/ʃa:l/	´he has lifted´
/ħa:l/	´condition´
/ba:l/	´to urinate´
/ča:/	´tea´
/ma:/	(negation particle)
/ʃa:/	´sheep´

/ʃarika:t/	´companies´
/ʃubba:k/	´window´
/ka:tta/	´he has thrown it´
/ṡa:kka/	´he has closed it´
/ʃa:ggi:n/	´they have torn´
/sa:bbi:n/	´they have cursed´
/ʃa:kki:n/	´they have doubted´
/ʃaẛ̌i:n/	´they are abnormal´
/ma:X i:n/	´they are taking´
/ha:tti:na/	´they have scrape it off´
/la:ññi:n/	´they have insisted´
/ħa:rmi:na/	´they are depriving him´
/ħa:li:na/	´they have solved it´
/qaṡa:ṡ/	´punishment´
/qara:r/	´decision´
/dala:l/	´pampering´
/ᵹal:l/	´straying´
/lak/	´for you´
/ñitta/	´scrape it off!´
/litta/	´pound it!´
/sirrik/	´your secret´
/sirra/	´bundle´
/tilla/	´pull it!´
/dilla/	´find it!´
/fi:/	´in´
/fi:kum/	´in you´
/ñibbi:/	´love him!´
/ʕi:d/	´festival´
/bʕi:d/	´far away´
/bi:ʕ/	´sell!´
/ri:ħ/	´wind´
/ᵹi:f/	´add!´
/fi:ᵹ/	´overflow!´
/ti:n/	´figs´
/ᵴi:n/	´clay´
/di:n/	´religion´
/ri:ʃ/	´feathers´
/ʃi:r/	´get caught!´
/ʃi:l/	´lift!´
/bi:b/	´drum´
/ᵹi:b/	´wolf´
/ʕazi:z/	´dear´
/ʕazi:zkum/	´your dear´
/Xasi:s/	´despicable´
/di:k/	´cock´
/na:di:k/	´your club´
/na:di:kum/	´your club´ (pl.)
/ti:k/	´teak´
/ʔaħa:ti:k/	´I worry about you´
/fi:ra:nkum/	´your mice´
/di:da:nkum/	´your worms´
/mi:da:skum/	´your slippers´
/bi:ba:nkum/	´your doors´
/dʒi:ra:n/	´neighbours´

/ki:ra:n/	´coils´
/miza:n/	´scale´
/si:ba:n/	´nits´
/ʕazi:za:n/	´a nick name´
/si:t/	´seat´
/fi:k/	´in you´
/di:m/	´last´
/si:m/	´string´
/mi:m/	´name of the letter "m"´
/ni:l/	´indigo´
/li:n/	´soften!´
/tli:n/	´she softens´
/Xi:s/	´be rotten!´
/tXi:s/	´she gets rotten´
/ri:ħkum/	´your wind´
/bi:ʕhum/	´sell them!´
/ʃiri:ṭhum/	´their tape´
/naʃi:ṭ/	´active´
/di:nkum/	´your religion´
/ħabi:bhum/	´their lover´
/ni:ra:n/	´fires´
/ẓab/	´lizard´
/ẓa:g/	´to tighten´
/ṭib/	´medicine´
/ẓil/	´shade´
/ẓil/	´humiliation´
/ṣik/	´close!´
/ẓi:g/	´tightness´
/ṣi:n/	´china´
/si:n/	´name of the letter "s"´
/ẓabji/	´female gazelle´
/ṣafra/	´yellow´ (fem.)
/ṭaffa/	´switch it off!´
/laṣṣa:g/	´adherence´
/muṭa:r/	´airport´
/muṭa:rkum/	´your airport´
/minẓa:r/	´binoculars´
/ṭa:laʕ/	´to look´
/ẓa:ga/	´he tasted it´
/ṣa:raX/	´he screamed´
/ṭibkum/	´your medicine´
/ṣikka/	´close it!´
/ẓiffa/	´river bank´
/raẓẓi:na/	´they bruised him´
/Xaẓ/	´to shake´
/maẓ/	´to rinse´
/ba:ẓ/	´to lay eggs´
/ma:ṭ/	´he has pulled´
/Xa:ẓ/	´he has gone through´
/Xa:ṭ/	´he has inscribed´
/Xiẓ/	´shake!´
/Xiṭ/	´inscribe!´
/Xiṣ/	´give special attention!
/bi:ẓ/	´white´ (pl.)

/Xaɫɫat/	'he mixed'
/Xassas/	'he gave special concern'
/haẓẓar/	'he prepared'
/Xaẓẓa:ẓ/	'shaker'
/Xiṭṭa/	'plan'
/giẓẓa/	'pierce it!'
/Xissa/	'give him special regard!'
/ʃiri:ṭ/	'tape'
/qami:ṣ/	'shirt'
/mari:ẓ/	'patient'
/qami:ṣkum/	'your shirt'
/mari:ẓkum/	'your patient'
/laħ/	'to insist'
/maħ/	'to erase'
/ṭa:ħ/	'to fall'
/fa:ħ/	'to boil'
/ẓa:ʕ/	'to get lost'
/ṭa:ʕ/	'to obey'
/ʃa:ʕ/	'to be widespread'
/niħ/	'nudge!'
/liħ/	'insist!'
/ti:ʕ/	'obey!'
/ṭi:ħ/	'fall!'
/riħli/	'trip'
/tiʕmi/	'you become blind'
/niʕmi/	'wealth'
/muri:ħ/	'comfortable'
/masi:ħ/	'Christ'
/zim/	'gather!'
/damkum/	'your blood'
/wazinkum/	'your weight'
/mankum/	'your 2 "rotl"s'
/ħama:m/	'pigeons'
/ħamma:m/	'bathroom'
/ʃimma/	'smell it!'
/minkum/	'from you'
/zimma/	'gather it!'
/simma/	'poison him!'
/ʕari:ʃ/	'arbour'
/ni i:f/	'clean'
/Xari:f/	'autumn'
/marri:X/	'Mercury'
/maz/	'to absorb'
/faz/	'to jump up'
/Xaẓ/	'to take'
/faẓ/	'strong'
/ʃaẓ/	'to deviate'
/fa:z/	'to win'
/ga:z/	'gas'
/ʃa:ẓ/	'deviant'
/Xiz/	'pierce!'
/ʃiẓ/	'deviate!'
/Xazzak/	'he pierced you'
/dazza:kum/	'he pushed you'

/mumta:z/	´excellent´
/Xabba:z/	´baker´
/baXXa:X/	´spray´
/minga:ʃ/	´a pair of tongs´
/jinča:f/	´it can be seen´
/raʃʃa:ʃ/	´machine gun´
/ziffa/	´get him married´
/miʃʃa/	´wipe it!´
/niXXij/	´chickpeas´
/iXizkum/	´he pierces you´
/faX/	´trap´
/zaX/	´to hold´
/Xa ʃ/	´to hide´
/ba θ/	´to broadcast´
/ħaθ/	´to urge´
/Xaf/	´to be light´
/raf/	´shelf´
/zaf/	´to be married off to´
/fa:X/	´he is deeply asleep´
/Xa:f/	´to be frightened´
/la:θ/	´to remain´
/la:f/	´he has gone round´
/fa:ħ/	´to boil´
/diʃ/	´enter!´
/kiʃ/	´recoil!´
/fiʃ/	´subside!´
/Xiʃ/	´hide!´
/li:f/	´fiber´
/sib/	´curse!´
/ʃib/	´grow!´
/ťigga/	´hit him´
/ʁaba:b/	´fog´
/sima:d/	´fertilizer´
/jinťa:g/	´tolerable´
/ʕaʁa:b/	´suffering´
/ħisa:b/	´accountancy´
/ʕadda:d/	´meter´
/misa:d/	´message´
/sibba/	´curse him!´
/kidda/	´exploit him!´
/tigga/	´hit him!´
/midda/	´stretch it!´
/ħibba/	´love him!´
/bi:bhum/	´their drum´
/Xi:bhum/	´their wolf´
/ħadi:dhum/	´their iron´
/ sidi:g/	´freind´
/kat/	´to throw´
/fat/	´to crumble´
/baq/	´to be on fire´
/makka/	´Mecca´
/maktab/	´office´
/fattan/	´to denounce´
/bitru:ħ/	´you will go´

/ma:Xiɤ/	'he has taken'
/gisʲei:hum/	'cut them!'
/giʈʈi:hum/	'throw them!'
/giɤɤi:hum/	'pierce them!'
/čilla:b/	'hook'
/sʲa:bir/	'he is patient'
/msa:fir/	'traveller'
/či:t/	'Indian dress material'
/laɤi:ɤ/	'delicious'
/niXi:l/	'palm trees'
/Xali:l/	'bosom friend'
/misa:mi:r/	'nails'
/ʕasʲa:fi:r/	'birds'
/di:ma/	'let it last!'
/ʃi:la/	'lift it!'
/XiʃʃI:/	'hide it!' (fem.)
/ɲitti:/	'put it!' (fem.)
/ba:s/	'to kiss'
/ba:ʃ/	'smiling'
/ba:X/	'spraying'
/ba:ħ/	'to reveal'
/ħasan/	'nice'
/ħassan/	'to shave'
/naʕam/	'yes'
/naʕʕam/	'to grind'
/sa:ma:/	'he inquired about its value'
/samma:/	'he poisoned him'
/ʃiga/	'misery'
/ʃigga/	'tear it!'
/basʲar/	'eye sight'
/basʲsʲar/	'to predict'
/bada:li/	'instead of him'
/badda:li/	'telephone exchange'
/siħar/	'to bewitch'
/siħħar/	'witches'

APPENDIX G

The following is a list of the words investigated in the spectrographic experiment:

/ħib/	´love!´
/ƚib/	´medicine´
/dig/	´hit!´
/ƚig/	´hit!´
/ṣid/	´block!´
/ṣid/	´turn away!´
/ħit/	´scrape off!´
/ħiƚ/	´put down´
/ris/	´origin´
/riṣ/	´compress!´
/ẓil/	´humiliation´
/ℵil/	´shade´
/bi:b/	´drum´
/bi:ʕ/	´sell!´
/ti:n/	´figs´
/ƚi:n/	´clay´
/si:n/	´name of the letter "s"´
/ṣi:n/	´china´
/ℵi:ʕ/	´broadcast!´
/ẓi:ʕ/	´get lost!´
/bi:ℵ/	´lay eggs!´
/ṣi:b/	´hit!´
/ƚi:b/	´recover!´
/be:b/	´pipe´
/be:ʕ/	´selling´
/ʕe:b/	´shame´
/be:ℵ/	´eggs´
/ℵe:f/	´guest´
/te:s/	´billy goat´
/ƚe:ʃ/	´recklessness´
/se:f/	´sword´
/ṣe:f/	´summer´
/ħab/	´to love´
/ƚab/	´to jump´
/baƚ/	´to make a hole´
/tal/	´to pull´
/ƚal/	´to look through´
/ħat/	´to scrape off´
/ħaƚ/	´to put´
/sab/	´to curse´
/ṣab/	´to pour´
/bas/	´enough´
/baṣ/	´bus´
/salb/	´to rob´
/ṣalb/	´hard´
/ẓal/	´to humiliate´
/ℵal/	´to go astray´
/Xaℵ/	´to take´
/Xaℵ/	´to shake´

/ҳam/	'to criticise'
/ᶍam/	'to hug'
/kalb/	'dog'
/gaɫb/	'heart'
/ba:b/	'door'
/ħa:b/	'he has loved'
/ʕa:b/	'to blame'
/ba:ħ/	'to disclose'
/ba:ʕ/	'to sell'
/ta:b/	'to repent'
/ƫa:b/	'to recover'
/ba:t/	'to sleep'
/ba:ƫ/	'he has made a hole'
/ᵴa:b/	'he has poured'
/ba:ᵴ/	'bus'
/sa:d/	'prevailed'
/ᵴa:d/	'name of the letter "s"'
/Xa:s/	'it became rotten'
/Xa:ᵴ/	'especial'
/ҳa:r/	'he has scattered'
/ᶍa:r/	'harmful'
/ba:ҳ/	'to lay eggs'
/ħub/	'love'
/dub/	'fat'
/ƫub/	'jump!'
/buƫ/	'make a hole!'
/ᵴub/	'pour!'
/ʕo:m/	'asking about the price'
/ᵴo:m/	'fasting'
/ʃo:t/	'kicking'
/ʃo:ƫ/	'electric shock'
/ᵴo:b/	'direction'
/bu:ħ/	'reveal!'
/tu:b/	'repent!'
/ƫu:b/	'bricks (Egyptian)'
/su:m/	'ask about the price!'
/ᵴu:m/	'fast!'
/mu:s/	'razor'
/mu:ᵴ/	'rinse!'
/ҳu:g/	'taste!'
/ᶍu:g/	'taste!'
/bi:fi:d/	'he will be useful'
/bi:fi:ҳ/	'it will overflow'
/ma:jfi:d/	'he will not be useful'
/ma:jfi:ҳ/	'it will not overflow'
/ma:fa:d/	'it did not help'
/ma:fa:ҳ/	'it did not overflow'
/niʃi:d/	'anthem'
/niʃi:ƫ/	'energetic'
/Xami:s/	'Thursday'
/qami:ᵴ/	'shirt'
/maħdu:d/	'limited'
/maħᶎu:ҳ/	'lucky'
/maʕᶎu:ҳ/	'bitten'

/safra/	´journey´
/ѕafra/	´yellow´
/sa:ma/	´he asked about its price´
/ѕa:ma/	´he fasted it´ (for the period of Ramadan)
/su:mla/	´ask about the price for him!´
/ѕu:mla/	´fast for him!´
/sa:matla/	´she asked about the price for him´
/ѕa:matla/	´she fasted for him´
/samma:m/	´poison´
/ѕamma:m/	´valve´
/tiba:ʃi:r/	´foretokens´
/ҭiba:ʃi:r/	´chalk´
/bi:ði:ʕ/	´he will broadcast´
/bi:ẓi:ʕ/	´he will get lost´
/bi:su:m/	´he will ask about the price´
/bi:ѕu:m/	´he will fast´
/ma:ssi:n/	´they are touching´
/ma:ѕѕi:n/	´they are sucking´
/nisi:b/	´a relative by marriage´
/niѕi:b/	´share´
/Xalle:ta/	´I left it´
/Xaɫɫe:ta/	´I emptied it´
/Xalle:na:/	´we left it´
/Xaɫɫe:na:/	´we emptied it´
/Xa:lij/	´empty´
/Xa:ɫij/	´my uncle´
/bitsu:mla/	´she will ask about the price for him´
/bitѕu:mla/	´she will fast for him´
/be:t ta:jir/	´a rich man´s house´
/be:t ҭa:jir/	´a flying house´
/da:s ise:f/	´he trod on the sowrd´
/da:s iѕe:f/	´he trod on the summer´
/bas isi:r/	´if he just goes´
/bas iѕi:r/	´if it just happens´
/bi:fi:d ilma:j/	´it will benefit the water´
/bi:fi:ẓ ilma:j/	´the water will overflow´
/su:s wa:hid/	´one decay´
/ѕu:ѕ wa:hid/	´one chick´
/Xas ami:ni/	´Amina´s lettuce´
/Xaѕ ami:ni/	´it concerned Amina´
/ħat ismi/	´he scraped off his name on´
/ħaҭ ismi/	´he put his name´

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