Prosodic constituent structure and anticipatory pharyngealisation in Libyan Arabic

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A thesis submitted in partial fulfilment of the requirement for
the degree of Doctor of Philosophy

to
Linguistics and English Language
School of Philosophy, Psychology and Language Sciences
University of Edinburgh

2013

Declaration

I hereby declare that this thesis is of my own composition, and that it contains no material previously submitted for the award of any other degree. The work reported in this thesis has been executed by myself, except where due acknowledgement is made in the text.

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Abstract

This study examines anticipatory pharyngealisation (i.e., emphasis) in Libyan Arabic, across a hierarchy of prosodic boundary levels (syllable vs. word vs. phonological phrase vs. intonation phrase ‘IP’) in order to quantify the magnitude, and identify the planned domain of anticipatory pharyngealisation. The acoustic manifestation of pharyngealisation is lowering in the second formant (F2) in pharyngealised contexts compared to their plain cognates. To investigate speech production models of how pharyngealisation is anticipated in advance, F2 measurements were taken at onset, mid and offset points of both vowels (V) in a word-final VCV sequence, in the context [VbV # Emphatic trigger]. The strength of [#], a prosodic boundary, was varied syntactically to manipulate the presumed hierarchical strength of that boundary from zero (where the VbV and the trigger are in the same word) up to an intonational phrase boundary. We expect that the stronger the boundary, the greater the resistance to the spread of pharyngealisation. The duration of the final vowel (i.e., the pre-trigger vowel) was also measured to assess if pharyngealisation magnitude on it and on the first vowel is influenced by the temporal proximity to the emphatic trigger.

Results show (1) that within word boundaries pharyngealisation effects are present on both vowels, and (2) there are effects of pharyngealisation on the final vowel, i.e. the pre-trigger across word and phrase boundaries, and (3) there is no evidence of pharyngealisation across an IP boundary. An examination of the pre-trigger vowel + pause duration suggests that the lack of coarticulatory effects on the final vowel, i.e., pre-trigger vowel, across an IP boundary may be due to the temporal distance from the trigger: all tokens in this condition had a pre-trigger pause. For word and phrase boundary conditions, F2 was higher the greater the temporal distance from the pharyngealised trigger. These results suggest that anticipatory pharyngealisation is qualitatively different within the word as compared to across word boundaries. More clearly, the magnitude of pharyngealisation is categorical within word boundaries, and gradient across prosodic boundaries higher than the word. These findings suggest that pharyngealisation within the word is phonological, whereas across word boundaries it is primarily a phonetic process, conditioned by the temporal proximity to the pharyngealised trigger.

Results also show that the planned domain of [pharyngealisation] is the word. However, additional phonetic pharyngealisation effects can extend across word boundaries as a result of coarticulation.

Acknowledgements

First and foremost, I must thank God. May your name be exalted, honored, and glorified.

This dissertation would not have been possible without the support of many people. I wish to express my deepest gratitude to my supervisor, Alice Turk, who was generously helpful and offered invaluable assistance, support and guidance throughout my PhD years. I have been amazingly fortunate to have a supervisor, who carefully read and commented on countless revisions of the manuscript of this thesis. Alice taught me how to question thoughts and always gave me the guidance to recover when my steps delayed. Her patience and support helped me overcome many crisis situations and complete this dissertation.

My co-supervisor, James Scobbie, gave insightful comments and feedback. I am deeply grateful to him for his discussions.

I would like to thank the members of my viva committee for their feedback - Barry Heselwood and James Kirby.

Thanks to the LEL community at Edinburgh University. I would particularly thank Bob Ladd, Bert Remijsen, and Satsuki Nakai for their discussions that helped me improve my knowledge in the area.

Thanks are also due to all members of the P-workshop for their comments and questions on a number of presentations. Thanks to Eddie Dubourg for helping with computing and software, to Michael Bennett for helping with Praat scripting, and to Barry Campbell for helping with the studio and the recordings.

Needless to say, the years I have spent in Edinburgh working on this dissertation would have been intolerable without the love and support from my beautiful wife, Najla Ben Ramadan. I would like to thank Najla for her understanding, constant support and patience throughout the time of my PhD. Since the beginning of the first year in Edinburgh, Najla has given birth to our first child, Fatima, and second, Mann. Thanks are also due to my parents, Bashir Maiteq and Fatima Maiteq for instilling in me a love of learning from an early age.

Last, but definitely not least, thanks to my two sisters, Asma and Abeer, for their care and support.

Contents

List of tables

Table of Figures

Chapter 1. Introduction

1.1 General preview

In all human languages, when a speech sound is spoken in a connected stream of speech sounds it is influenced by its preceding and following context. This contextual variability is well documented and is commonly referred to as "coarticulation". *Anticipatory coarticulation* occurs when a speech sound influences the preceding sound(s). *Carryover coarticulation* occurs when a speech sound influences the following sound(s). An example of anticipatory coarticulation is that the lip rounding movement in anticipation of an upcoming rounded vowel, i.e., /u/ may start during the preceding sound(s). For example, in the English word "screw" [skru:] the lip rounding that underlyingly belongs to [u:] may start as early as the first [s] in the consonant cluster preceding the trigger. An interesting case of anticipatory coarticulation, which will be addressed in the present dissertation, is anticipatory pharyngealisation in the Arabic dialect spoken in Libya.

Arabic has a set of underlyingly pharyngealised sounds [T, D, S, TH] for which the tongue is retracted. This backing gesture is not limited just to these pharyngealised sounds, but extends to preceding and following sounds. More specifically, these pharyngealised sounds exert an influence on the neighbouring sounds commonly referred to as "*pharyngealisation*" (Al-Ani 1970, Ghazeli 1977, Card 1983, Bukshaisha 1985, Zawaydeh 1999). Since there are corresponding non-pharyngealised sounds, pharyngealisation is contrastive. For example, the word /baaT/ "underarm" contrasts with /baat/ "he slept". These two words differ only in terms of the word-final sound, i.e., a final pharyngealised /T/ vs. a final plain /t/ in the underlying form, respectively. However, in the surface representation, i.e., the phonetic realisation of sounds, pharyngealisation extends from the word final pharyngealised trigger /T/ throughout the entire word thus: [baaT] "underarm" vs. [baat] "he slept".

The actual extent of this anticipatory pharyngealisation has been a topic of phonetic and phonological interest for some years because of the theoretical insights it can bring into the relationships between phonetics and phonology, segmental and non-segmental phenomena. It has been reported that in Qatari Arabic, anticipatory pharyngealisation can extend as early as five segments, 600 ms, prior to the pharyngealised trigger (Bukshaisha 1985). Previous research sought to describe pharyngealisation in terms of its domain. The domain of pharyngealisation refers to the linguistic unit to which pharyngealisation is confined.

Pharyngealisation has mainly been detected and analysed via a) impressionistic transcription, and b) acoustic and articulatory analyses, see Chapter 3 on the underlying articulation. A consistent acoustic measure of pharyngealisation is a lowering of the second formant (F2), where F2 is substantially lower in pharyngealised contexts as compared to their plain counterparts (Ghazeli 1977, Card 1983, Bukshaisha 1985, Zawaydeh 1999, Bin-Muqbil 2006, Al-Masri 2010).

It will be undertaken in the present dissertation to explore the magnitude of anticipatory pharyngealisation in light of current models of speech production, and to determine how to best define the domain of pharyngealisation. The outline of this chapter is as follows. Section 1.2 presents two possible explanations for the extent of pharyngealisation, i.e., phonological feature spreading vs. phonetic coarticulation. Section 1.3 summarises conflicting reports regarding the pharyngealisation domain in previous research, where different domain types have been claimed. These domain types are the syllable, the word and the syntactic phrase. Section 1.4 introduces the aims of the present dissertation. Section 1.5 explains the methodology to answer the research questions. Section 1.6 outlines the structure of the remainder of the thesis.

1.2 Pharyngealisation magnitude

There are two main lines of explanation for the magnitude of anticipatory pharyngealisation effects. These two possibilities are: a categorical feature spreading (phonological) vs. a gradient process of coarticulation (often discussed as phonetic). A primary goal underlying this dissertation is to distinguish these two possibilities using controlled acoustic data.

1.2.1 Categorical feature spreading (phonological)

In phonological theory it is assumed that the phoneme is the basic unit in the grammar in terms of which phonological contrasts are made, i.e., plain /t/ vs pharyngealised /T/ in Arabic. In the phonological “underlying representation”, phonemes are characterised in terms of distinctive features, e.g. binary feature values [± feature]. This means that features are either specified with a negative feature value [– feature] or with a positive feature value [+ feature] prior to any phonological rule application. In a feature-spreading model of coarticulation, the input to the model is a sequence of discrete, timeless, invariant phonemes, which are characterised in terms of feature bundles. An implementation process then translates binary feature values to continuous values corresponding to the controllable physical dimensions in the phonetic representation. A feature is assumed to spread categorically as a result of a phonological rule. Let us consider an example from pharyngealisation in Libyan Arabic in a word such as /b<u>iba</u>.Tal/ “he will quit”. The underlined [iba] sequence precedes a post-boundary pharyngealised trigger, where the boundary [.] here refers to the syllable boundary. The syllable-initial pharyngealised segment /T/ is specified with a [+ pharyngealisation] feature value. A [– pharyngealisation] feature value is specified for the /i/ vowel segment because it involves tongue fronting. It is, therefore, articulatorily incompatible with the tongue backing gesture required for pharyngealisation. Phonologically, /b/ and /a/ do not have a contrast for pharyngealisation, therefore they are not specified phonologically. Thus, pharyngealisation is assumed to spread categorically from /T/ throughout the [ba] sequence by the application of a phonological feature spreading rule, resulting in [+pharyngealisation] feature being assigned to both /b/ and /a/. Categorical feature spreading implies that phonetically there would be an equally large magnitude of pharyngealisation throughout the affected sound(s), matching a positive feature value. More clearly, the categorical magnitude of pharyngealisation is equally distributed regardless of the duration of the affected sound(s).

As noted above, a [– pharyngealisation] feature value is specified for the vowel /i/. The high vowel /i/ is, therefore, assumed to terminate the spreading of pharyngealisation. When pharyngealisation spreading is not allowed, as in the case of the high front vowel /i/, pharyngealisation will be totally blocked from spreading, matching a zero feature value. If a vowel falls within the scope of the spreading of an upcoming pharyngealisation feature, then it is assumed that phonetically, the vowel will show an equally distributed magnitude of pharyngealisation no matter, for example, whether the duration of that vowel is 80 ms or 150 ms. As will be discussed in Chapter 3, in the phonetic surface form, once the spreading of a feature is allowed, it will result in an equally spread pharyngealisation magnitude regardless of the duration of the preceding sound(s) during which the spreading occurs, see Chapter 3 for further details. In Chapter 3, I review available evidence relating to categorical pharyngealisation in the different dialects of Arabic. For example, some, but not all previous data, suggest that pharyngealisation is phonological and spreads categorically over a number of preceding segments (Younes 1982). In addition, it has been claimed that pharyngealisation might be totally blocked by speech sounds such as /i/ that are specified for a [+high] feature value (Card 1983).

1.2.2 Gradient coarticulation (phonetic)

The second possibility is a gradient process of coarticulation as proposed in the look-ahead model (Henke 1966, Keating 1990). The process of coarticulation is often discussed as phonetic, but see Browman & Goldstein (1986, 1995) for an alternative view. Input to the model is a sequence of timeless, discrete, invariant phonemes. A 'look-ahead' planning device scans the next specified target in the sequence. Then an implementation process follows in order to achieve the upcoming articulatory target in time and space. Movement towards the target will start as soon as possible as long as there is no contradictory articulatory requirement in the sequence preceding that target. The look-ahead model predicts that the magnitude of coarticulatory effects will increase with the approach to the trigger. Let us reconsider the same /biba.Tal/ example cited above. The look-ahead planning device scans the upcoming target for the pharyngealised trigger /T/. Movement towards this target is allowed to start once any contradictory articulation such as the high vowel /i/ is achieved. Pharyngealisation may start at the offset of the high vowel /i/. Interpolation rules connect the offset of /i/ to the pharyngealised segment /T/, making a gradual increase as the trigger is approached. A recent version of the look-ahead model is introduced in the window model (Keating 1990). The 'window' refers to the possible range of articulatory target achievement. Segments assumed to totally block the effect might, to a certain extent, accommodate with the theoretically contradictory target. More specifically, the /i/ vowel may acquire some rounding effect in anticipation of a following rounded vowel as long as its acoustic percept is maintained. This allows the window model to adequately account for some observed coarticulatory effects (e.g. Ghazeli 1977, Bukshaisha 1985) that start during or even before rather than after the theoretically incompatible high vowel /i/.

An alternative view of gradient effects that increase as the trigger is approached is expressed in contexts of gestural overlap (Browman & Goldstein 1986). This comes in Articulatory Phonology, where input to the model is articulatory gestures, described as dynamic objects that overlap with neighbouring gestures (Browman & Goldstein 1986, 1989, 1991, 1992, 1995, Fowler & Saltzman 1993). On this view, gesture onsets and offsets extend in time and space beyond their resultant acoustic boundaries as defined in terms of constriction onset and release. Articulatory phonology predicts that in our example /biba.Tal/ the tongue backing gesture will start at a fixed time point before the oral constriction responsible for the primary articulation and will increase in magnitude as the trigger is approached.

Both views, the look-ahead and articulatory phonology, are similar in that they predict gradient effects that increase with the approach to the trigger. Both views differ in terms of the input units or at least in how they describe these input units, i.e., articulatory targets vs. gestures, respectively. Crucially, they also differ in terms of the extent of the coarticulatory effects. More specifically, the look-ahead model assumes unlimited effects as long as there is no contradictory articulatory requirement intervening. However, articulatory phonology assumes a limited extent because duration is an inherent property of underlying gestures and is, thus, limited in extent.

As will be discussed in Chapter 3, evidence in support of gradient pharyngealisation magnitude in previous research will be reviewed. It has been reported that the decrease in pharyngealisation magnitude may result from the temporal distance from the emphatic trigger (Ghazeli 1977, Card 1983, Bukshaisha 1985). For example, a low vowel like /a/ is compatible with a pharyngealised vocal tract configuration.

Unlike /i/, /a/ requires no contradictory gesture to pharyngealisation. This, generally, makes /a/ a prime candidate for pharyngealisation effect. There is evidence that /a/ may share varying degrees of pharyngealisation with a pharyngealised trigger depending on the temporal distance from that trigger (Ghazeli 1977, Bukshaisha 1985). In other words, the magnitude of pharyngealisation in /a/ next to a pharyngealised trigger might be larger than when /a/ is temporally distant from that trigger; see Chapter 3 for further details.

To summarize, when studying any spreading/coarticulatory phenomenon, an important question is the *magnitude* of the effects. A primary issue underlying the present dissertation is to examine the magnitude of pharyngealisation in light of existing models of speech production, and closely considering the duration of the affected segment(s) preceding the pharyngealised trigger in order to find out whether pharyngealisation is a categorical spread of phonological feature or if it is the result of phonetic coarticulation.

1.3 Pharyngealisation domain

The second purpose underlying the present study is to examine pharyngealisation across a hierarchy of prosodic boundary types in search for the potential domain of pharyngealisation. The domain of spreading phenomena, like pharyngealisation, refers to the linguistic unit to which the spreading effects are *primarily* confined. A single domain unit may be a single phoneme, syllable, word, phrase etc. Smaller effects between such linguistic units may still be present due to the fact that speech organs may not move instantaneously from one articulatory position to another. The linguistic structure such as prosodic structure can have an influence of the phonetic shape of the spreading within the domain unit. For example, pharyngealisation magnitude may appear gradual across a hierarchy of prosodic boundary levels. More clearly, it is possible that pharyngealisation is maximal within words and decreases across boundary levels, i.e., the word and the phrase, for instance. Thus, across higher prosodic boundary types such as the intonation phrase and the utterance it is likely that pharyngealisation is blocked.

More details are still lacking regarding the domain of pharyngealisation. Various domain types have been proposed in previous research on the different Arabic dialects (Lehn 1963, Ali & Daniloff 1972, Broselow 1976, Ghazeli 1977, Card 1983, Bukshaisha 1985, Zawaydeh 1999, Hassan 2005). Some studies have defined the syllable as the domain of pharyngealisation (Lehn 1963, Ali & Daniloff 197 72). Other investigators observed that the word serves as the domain of pharyngealisation (Ghazeli 1977, Card 1983, Hassan 2005). Data from Qatari Arabic provide support that the spread of pharyngealisation might extend across word boundaries making the entire syntactic phrase as the domain of pharyngealisation (Bukshaisha 1985). In addition, discrepancies regarding the domain of pharyngealisation exist even in studies carried out on the *same* dialect. For example, it has been claimed that the domain of pharyngealisation in Egyptian and Iraqi Arabic is the syllable (Broselow 1976, Ali & Daniloff 1972, respectively). However, in these two dialects other studies have proposed that it is the entire word (Ghazeli 1977, Hassan 2005, respectively). As will be reviewed in Chapter 3, the disagreement regarding pharyngealisation domain in the literature might be due to dialect variations, different materials and experimental methods. Crucially, it might be that pharyngealisaton is realised differently across different prosodic boundary levels, i.e., the syllable, the word, the phrase the intonation phrase etc. It may well be due to different domain definitions, an issue that is still lacking in discussions of coarticulatory phenomena in the broader sense. This issue of coarticulation domain definition will be argued for and exemplified in section 2.3 below. For example, there is ample evidence from data on different articulatory subsystems that the domain unit of coarticulation might be realised differently on the surface representation from what is actually intended by the speaker (e.g. Kozhevnikov & Chistovich 1965, Younes 1982, Magen 1997). Younes (1982) defines the domain as the unit, where the magnitude of pharyngealisation is equally distributed. In addition, although commonly cited in favour of the syllable domain, Ali & Daniloff (1972) define the domain of pharyngealisation as not necessarily the syllable, but rather the effects are syllable-tied. These investigators do not rule out marginal effects of pharyngealisation between syllables.

Thus, it will be undertaken in the present study to see how to best define and identify the potential domain of pharyngealisation in Libyan Arabic. This will be carried out manipulating controlled segmental and boundary type factors.

1.3.1 Possible reasons for domain discrepancies

These domain discrepancies in previous research might be due to the fact that research on pharyngealisation have been carried out on different data from different Arabic dialects. Another possibility might be due to different experimental techniques and methodologies.

a) Dialectal differences:

The conflicting domain reports might be due to dialectal variation. It is possible that dialects take different domain types. Arabic dialects have been classified as two major geographical areas. The eastern area includes the Arabian Peninsula, Mesopotamia, the Levant, Egypt and the Maghreb. Libyan Arabic, as well as Tunisian, Algerian, Moroccan and Mauritanian Arabic, belongs to the Western, i.e., Maghreb dialect group (Versteegh 1997). Recent evidence for Eastern/Western group distinction comes in Embarki et al (2012), where the researchers examined pharyngealisation variation as a function of regional location. Their acoustic data were recorded from sixteen speakers from Yemen, Kuwait, Jordan and Morocco. Their EMA data were recorded from a Tunisian speaker. They found that the patterns of CV pharyngealisation effects vary according to speech variety and geographical clustering. The different Arabic dialects also vary in their phonemic inventory. Some sound phonemes, i.e., /q, θ, ð, TH/ are present in one dialect and absent in another (Embarki et al 2011: 195). In addition, (Embarki et al 2012: 195) state that, "...this concerns not only the way in which the phonemes are produced, but also the gestural and temporal adjustments during larger units such as syllables, phonological words, and other prosodic domains". Thus, one may assume that different dialects take different domain units for pharyngealisation.

b) Control of segmental composition:

It is possible that some of the domain discrepancies in previous research exist because of the lack of controlling the segmental composition in order to draw reliable conclusions regarding the spreading and consequently the domain of pharyngealisation. There is evidence that pharyngealisation may be blocked or largely attenuated by vowels or consonants specified for the [+high] feature such as /i/ and /ʃ/ (Al-Ani 1970, Ghazeli 1977, Card 1983). Ali & Daniloff (1971: 103-4) conclude, in their X-ray examination, that pharyngealisation extends from the trigger to adjacent vowels and syllables. They examine data items like, for example, /Tabaʃir/ "chalk", where carryover pharyngealisation extends over three phonemes [aba] following the word-initial pharyngealised trigger /T/. This example shows that pharyngealisation extends in the trisyllabic word throughout the first two syllables but not to the third. This suggests, to these investigators, a disyllabic domain of pharyngealisation. Ali & Daniloff conclude that a syllable is either entirely plain or entirely pharyngealised. As shown in the word [Tabaʃir] above, the spreading of pharyngealisation extends over the first two syllables. However, the blocking of pharyngealisation from spreading to the third syllable is likely to be induced by segment identity, i.e., /i/ and /ʃ/. More clearly the onset and nucleus of the third syllable [ʃi] are both characterised by the feature [+ high], which is not compatible with the feature pharyngealisation. Thus, a carefully controlled data design to accurately define the domain of pharyngealisation is still lacking.

c) Boundary manipulation:

The word /Tabaʃir/ from Ali & Daniloff (1972) discussed above shows that pharyngealisation does not spread across the boundary of the third syllable. This is possibly because a [+ high] feature coincides with the syllable boundary. It is, therefore, unclear as to whether the blocking is due to the syllable boundary or to segment type. In his X-ray study of Tunisia Arabic, Ghazeli (1977) reported that anticipatory pharyngealisation does not spread across word boundaries in the word, for example, [beet # iTTahir] "Al-Tahir's home". The pharyngealised trigger is preceded by /i/, which is contradictory to pharyngealisation. It is likely that the blocking of pharyngealisation is due to /i/ in such an example and not to the word boundary. In addition the first word [beet] ends with /t/, a sound segment during which the tongue is actively involved. Crucially, this was the only test item in Ghazeli's data to assess for anticipatory pharyngealisation across word boundaries. It seems from such data that previous claims regarding the domain of pharyngealisation are questionable. More clearly, the tongue in such test words is not allowed to freely anticipate the upcoming pharyngealised vocal tract configuration. Thus, a careful segmental composition along with tightly controlled prosodic boundary manipulation, such as the syllable, the word, the phrase and the intonation phrase, is required before one can draw adequate conclusions regarding the potential pharyngealisation domain.

d) Domain definition:

As will be discussed in Chapter 2 below, a major problem in the phonetic literature is that a definition of the domain of coarticulatory phenomena is still lacking. It will be clarified that the term 'coarticulation domain' is not even used consistently in the literature. By the end of Chapter 2, an appropriate way to identify the potential domain of coarticulation in general will be proposed.

Younes (1982) defines the pharyngealisation domain as the linguist unit in which the magnitude of pharyngealisation should be equally distributed. Younes concludes that the domain of pharyngealisation is not the syllable, the word nor the phrase. Rather, Younes concludes that pharyngealisation is a segmental feature. Younes' conclusion is based on the findings that pharyngealisation has a gradient effect and it might still appear beyond whatever the planned domain might be. Younes discusses his observation in terms of minimal and maximal domains of the spreading.

The prosodic analysis is an alternative view of minimal and maximal domains of pharyngealisation. In this position, the minimal span of pharyngealisation is the sequence CV Lehn (1963) and Broselow (1976). In contrast, card (1982) acknowledged that a word-initial pharyngealised trigger might induce some amount of pharyngealisation on the preceding word, although Card concluded that the word is the domain of pharyngealisation.

Although commonly cited in favour of the syllable domain, Ali & Daniloff (1972) define the domain of pharyngealisation as not necessarily the syllable, but rather the effects are syllable-tied. In their definition, the first two syllables in the tri-syllabic word /Tabaʃir/ "chalk" might be pharyngealised. Ali & Daniloff (1972) also claim that the spread of pharyngealisation may depend on syllable structure. For example, CV open syllables are more likely to be entirely pharyngealised. In contrast pharyngealisation may extend from the word-initial trigger to cover only the adjacent vowel in a CVC type word. Thus, a consistent way of identifying the potential domain of pharyngealisation, and coarticulation in general, is called for.

The present dissertation seeks to precisely identify the pharyngealisation domain with a carefully controlled segmental make-up and tight manipulation of prosodic boundary level. This will provide more accurate description of a potential pharyngealisation domain.

1.4 Aims of the study

This study has two purposes. First, I undertake to determine whether pharyngealisation is a categorical feature spreading or a gradient coarticulation process. Second, I attempt to search for the potential domain of pharyngealisation.

1.5 Methodology

The first question in this study is whether anticipatory pharyngealisation in Libyan Arabic is a categorical feature spreading or a gradient coarticulatory process. The core assumption in this aspect of measurement is that categorical feature spreading of anticipatory pharyngealisation will result in an equally large magnitude of pharyngealisation, regardless of the duration of the affected sounds that precede the pharyngealised trigger. This means that an increase in the duration of the component sound segments will not contribute to decreasing pharyngealisation magnitude as we look further and further away from the trigger, earlier in the test sequence. However, a phonetic, i.e., gradient coarticulatory process of pharyngealisation will result in a decrease in anticipatory pharyngealisation magnitude as a function of increasing the duration of the vowel(s) that precede the trigger. In other words, pharyngealisation magnitude will increase with the approach to the pharyngealised trigger.

To assess pharyngealisation magnitude, F2 measurements are presented. F2 is known to be a correlate of pharyngealisation effects (Ghazeli 1976, Younes 1982, Bukshaisha 1985, Zawaydeh 1990, Al-Masri 2010). F2 measurements in [VbV + pharyngealised trigger] sequences will be examined. The vowels /a/ and /i/ will be embedded in the following combinations ([aba], [abi], [iba], [ibi]), which will enable this study to examine more representative data. The duration of the final vowel and of the entire test sequence will be measured. F2 values, i.e., pharyngealisation will be assessed in terms of how pharyngealisation magnitude may vary as a function of duration (the temporal distance to the emphatic trigger). This will provide a clear distinction between categorical and gradient characterisations of pharyngealisation magnitude.

The second question in the present study is to search for the potential domain of pharyngealisation. This will be assessed in the test sequences above [VbV # pharyngealised trigger], where (#) refers to a hierarchy of boundary types (e.g., syllable, word, phrase and intonation phrase followed by a potential pause). Thus, it is assumed that the boundary of whatever domain pharyngealisation takes will terminate the effects of pharyngealisation.

1.6 Structure of the remainder of the thesis

Chapter two is a review of major models of speech production that undertake to account for coarticulatory effects in spoken language.

Chapter three is a review of previous research data on pharyngealisation in different Arabic dialects.

Chapter four describes the methodology, including data design, segmentation, acoustic measurements and statistical tools.

Chapter five reports the experimental results.

Chapter six is a discussion of the results.

Chapter seven presents the conclusion of the study, and recommendation for future research.

Chapter 2. Review of models of speech production

2.1 Background

This chapter reviews relevant theoretical issues in models of speech production. These models have been proposed to account for the magnitude, extent and domain of anticipatory coarticulation in spoken language. The outline of this chapter is as follows. In section 2.2, I review some theoretical concepts that are relevant to the magnitude of coarticulation extent. Specifically, I discuss the categorical spread of phonological features. I then deal with two views that account for *gradient* effects of anticipatory coarticulation, namely, the phonetic look-ahead model and articulatory phonology. In section 2.3, I discuss the domain of coarticulation and seek to tell a part the planned domain, as intended by the speaker, from the surface domain, as it appears in the surface phonetic signal.

In this chapter, relevant theoretical concepts to the extent and domain of coarticulation are discussed along with data cited from different languages. A review of previous data on Arabic pharyngealisation accompanied with an evaluation of relevant models of speech production will be discussed in Chapter 3 below.

2. 2 Coarticulation magnitude

The present dissertation seeks to quantify the magnitude of pharyngealisation in Libyan Arabic. Previous data regarding the magnitude of pharyngealisation seems to be compatible with two fundamentally distinct models of speech production. The first model posits a categorical pattern that can be accounted for in terms of the phonological feature-spreading model (Daniloff & Hammarberg 1973). There are some data on pharyngealisation in earlier studies suggesting that pharyngealisation may result in an equally distributed, i.e., categorical magnitude of the effects regardless of the duration of the affected sound(s) that precede the pharyngealised trigger (Younes 1982). These findings are consistent with feature spreading assumptions.

The second model assumes a gradient effect and can be accounted for in terms of the look-ahead model of phonetic coarticulation (Henke 1966, Keating 1990). Another view that predicts a gradient pattern of coarticulation is a gestural overlap as posited in coproduction and articulatory phonology models (Fowler 1980, Browman & Goldstein 1989). Some previous data on pharyngealisation provide support that pharyngealisation may be gradient in magnitude as it increases as the trigger is approached (Ghazeli 1977, Card 1983, Bukshaisha 1985). This means that, unlike the feature spreading mechanism, the magnitude of pharyngealisation decreases with the temporal distance from the pharyngealised trigger.

2.2.1 Phonological feature spreading

The feature spreading theory is relevant in the present study, as it appears to readily account for some but not all findings in previous pharyngealisation research. Such data provide support that pharyngealisation is categorical, i.e., equally distributed in magnitude throughout the affected sound(s).

The feature spreading theory (Daniloff & Hammarberg 1973) was an attempt to bridge the gap between the mental and physical representations of spoken utterance. Proponents of these models believe that coarticulation in speech production should be accounted for within the domain of the grammar via the application of phonological feature spreading rules. In some phonological theory, phonemes are characterized in terms of binary features [±feature]. A specified phoneme is either assigned a positive feature value [+ feature] or a negative feature value [–feature]. In contrast, a phoneme may be unspecified for a given feature because it does not use that feature. In other words, an unspecified phoneme for a given feature is neither assigned a positive [+feature] nor a negative [–feature] value of that particular feature. For example, an alveolar fricative /s/ is unspecified for the lip rounding feature. Thus, the articulatory configuration of the lips is phonologically irrelevant for that alveolar fricative phoneme. More specifically, it is neither assigned [–round] nor [+round] feature value. Similarly, the velar stop /k/ has no specification for the feature [±round]. In a phonetic sequence like [li: # sku:t] “Lee scoot” the entire consonant cluster preceding /u:/ is unspecified for either value of the feature [round] (Perkell & Matthies 1992). The feature-spreading theory assumes that phonological rules assign a phonological feature to all the preceding unspecified phoneme(s). Thus, in the above example [li: # sku:t], the [+round] feature value will spread *categorically* to the entire consonant cluster [sk] preceding the source of the rounding feature, which is /u:/, if the language has such a rule. However, when a negatively specified segment, i.e., [–round] intervenes, such as the vowel /i/, the feature spreading will be totally blocked. But if the spreading does occur, it is an all-or-nothing category change. As shown in (Figure 1), the categorical spread of a feature results in an equally distributed magnitude of the spreading throughout a preceding phoneme regardless of whether that phoneme is, for example, 100 ms or 200 ms. In addition, the spreading will terminate once a negatively specified phoneme intervenes. Phonology has no reference to time. In the mapping from phonology to phonetics, therefore, segments have no duration encoded, and feature spreading is either present (+) or absent (–). Thus, the presence or absence of a phonological feature value is time-independent and categorical.

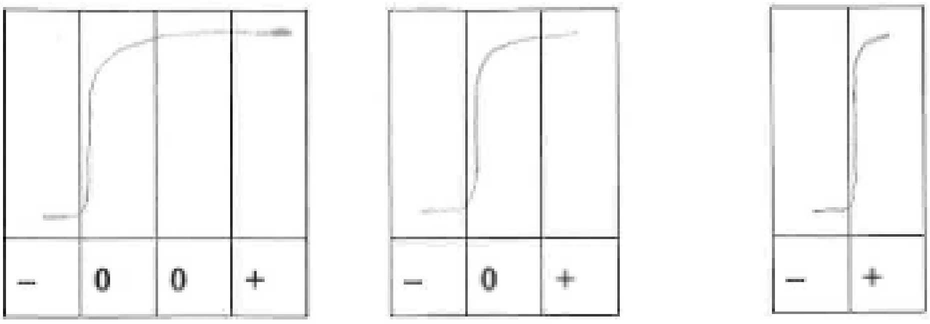

Figure 1: Anticipatory coarticulation magnitude as predicted by the feature-spreading model, Keating (1990)

Unfortunately, there are few data that have been cited to support the original postulations of phonological feature spreading. The often-cited data on lip rounding in Benguerel & Cowan (1974) is only in part compatible with the feature spreading speculations. Benguerel & Cowan (1974) investigated the temporal organisation of upper lip protrusion in French. Their results demonstrate that anticipatory lip protrusion starts as early as six segments prior to the rounded vowel (i.e., the rounding trigger) in sequences (e.g., [rstry], [trstry] and [strstry]). They explained their data using a feature-spreading model where features are categorically assigned to all unspecified segments preceding the rounded trigger. (Table 1) exemplifies the procedure of a feature-spreading model applied by Benguerel & Cowan to account for lip rounding from /y/ throughout the preceding phonemes. Row 2 represents the phoneme level and row 3 represents the feature specification at the articulatory level.

1	i	s	t	r	s	t	r	y
2	–	0	0	0	0	0	0	+
3	–	+	+	+	+	+	+	+

Table 1: Feature spreading assumptions that are used in Benguerel & Cowan (1974) to account for lip rounding in French

Although Benguerel & Cowan (1974) argued for the feature-spreading model, some of their findings were incompatible with feature spreading predictions regarding the contradictory features. For example, some of Benguerel & Cowan's data show that the rounding gesture began during or even before the vowel /i/, which is phonologically specified as [–round]. Within feature spreading speculations, however, the front vowel /i/ is expected to terminate the spread of the feature [–round] and the effects are, thus, allowed to start after not before the offset of /i/. Benguerel & Cowan's data show that the rounding feature extended as early as six segments in advance of the rounding trigger /u/. Crucially, it seems that Benguerel & Cowan interpreted this early initiation of the rounding feature as indicative of a feature spreading mechanism. An early initiation of an upcoming feature cannot be taken for its own sake as an indication of a categorical feature spreading. In order to diagnose a categorical spread of a feature it is crucial to assess the spatial magnitude along the time axis of the temporal extent of the effect. In this case, a categorical effect will appear in an equally distributed magnitude regardless of the duration of the affected sound(s).

Moll & Daniloff (1971) studied anticipatory nasalisation in English on cinefluorographic data. Their test sequences were CN, CVN and CVVN with syllable and word boundaries embedded in the sequences in a number of different ways. Their results showed that the onset of velar movement in anticipation of the nasal consonant trigger began as early as the onset of the initial vowel in the sequence regardless of syllable and word boundaries. These results in Moll & Daniloff (1971) demonstrated that anticipatory effects might extend to as early as the first vowel in the sequence. Similar to Benguerel & Cowan's interpretation, it seems that Moll & Daniloff interpreted the finding that nasalisation started two segments before the trigger as a categorical feature spreading. More specifically, the magnitude of nasalization in such data needs to be quantified by how it may vary along the duration of the affected vowels, a procedure that is lacking in Moll & Daniloff (1971). In addition, Moll & Daniloff's data do not consider the amount of velar lowering that might be inherent in the preceding vowels examined. This requires more tightly controlled data make-up, which is based on minimal pair contrasts. This would tell apart velum lowering activity that is due to an upcoming nasal sound from that, which is inherent in vowels (Bell-Berti & Krakow 1991).

Clearly, a major problem in the feature-spreading theory is that these investigators relied on the early initiation of an upcoming feature as a diagnostic of a categorical feature spreading mechanism. As was discussed above, Benguerel & Cowan's data show that the lip rounding started as early as six sounds before the trigger. To Benguerel & Cowan, this was a categorical feature spreading primarily because of the early initiation of the rounding feature. This has been explicitly stated by Kuhnert & Nolan (1999: 20), "Support for the feature spreading account came primarily from studies showing that anticipatory labial coarticulation started as early as the first consonant preceding a rounded vowel". A very early feature initiation does not, however, guarantee categorical spreading of the effect.

A key diagnostic for deciding a feature spreading mechanism is to assess how the magnitude of the effect may vary as a function of the temporal distance from the trigger. Feature spreading effects will result in equally distributed magnitude that does not decrease with the duration of the affected sequence of segments.

As will be discussed in the next chapter, some but not all of the previous studies on pharyngealisation provide evidence that pharyngealisation is a categorical spreading of phonological features (Younes 1982). Specifically, such data show that pharyngealisation magnitude is equal at the vowel onset, mid and offset points without closely examining how the magnitude of the effect may vary over time. Thus, assessment to see if the magnitude of pharyngealisation increases with the approach to the pharyngealised trigger will be carried out in the present dissertation in order to diagnose a regressive feature spreading mechanism.

2. 2. 2 The look-ahead model of phonetic coarticulation

A fundamentally distinct view from feature spreading is the look-ahead model of phonetic coarticulation (Henke 1966, Keating 1990). This view is relevant in the present study, as it appears to readily account for some data, which are counterevidence against the feature-spreading view. Such data show that pharyngealisation decreases in magnitude with the temporal distance from the trigger (Ghazeli 1977, Bukshaisha 1985).

The look-ahead model of phonetic coarticulation was first developed in Henke (1966) as a computer model for the articulation of [stop + vowel] sequences. Input to the model is a sequence of discrete invariant phonemes. In this aspect, i.e., the input units, the look-ahead model is similar to the feature-spreading model discussed above.

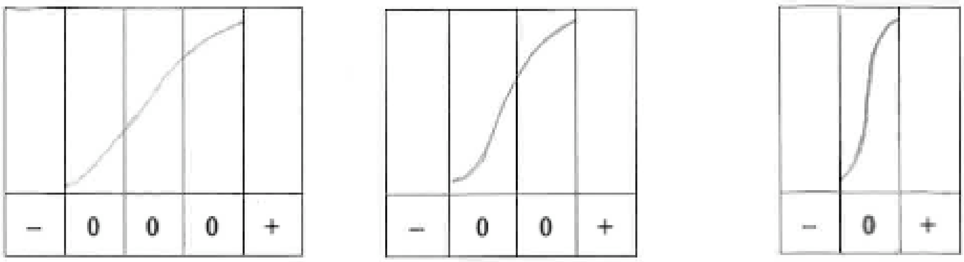

Figure 2: Variation of anticipatory coarticulation magnitude with the duration of preceding segments. The pattern is achieved via phonetic implementation as predicted by the look-ahead model, Keating (1990)

The look-ahead model assumes a (planning) look-ahead device, which scans and assigns an upcoming articulatory target characteristic of the trigger to all preceding segments that do not conflict with that articulatory target. This would allow movement towards that trigger to start as soon as possible, after the upcoming articulatory target is realised, as shown in (Figure 2).

Another similarity between Henke’s look-ahead model and the feature spreading view is that the effects can only initiate once there is no intervention of incompatible articulatory requirement. Like the feature spreading model, the look-ahead model assumes that lip rounding initiates as early as possible. This implies that the effect will start at the onset of the neutral consonant cluster [sk] in the sequence [li: # sku:t] to the left of the rounding trigger. In other words, movement towards the rounded trigger starts once the offset of the contradictory vowel /i/ is achieved. This is because none of the cluster consonants is specified for rounding. In other words, the articulatory requirements for each segment in the cluster do not contradict with the rounding feature of the upcoming trigger [u:]. Henke introduced interpolating mechanisms connecting [i] to [u:]. This will result in a gradual increase in rounding magnitude as the trigger is approached (Figure 2). The early version of the look-ahead model assumes a gradual coarticulatory magnitude that gradually attenuates as a function of the temporal distance from the trigger, but not as a function of segment type. In other words, negatively specified segments do not allow for the effects during or through them, and anticipatory effects will, consequently, be terminated.

A recent version of the look-ahead postulation comes in the window model (Keating 1990). The window model allows a specified segment to accommodate with a following target. This accommodation takes place through a range of possible articulatory parameters or ‘window sizes’. This type of effect is not allowed for in the early Henke version of the look-ahead model, where contradictory segments must terminate anticipatory coarticulation. Keating’s model accounts for phonological as well as phonetic characterisation of coarticulation. Phonological effects are categorical and extend in an equally distributed magnitude regardless of the duration of the affected sound(s). Phonetic effects extend and gradually increase with the approach to the trigger. Coarticulatory effects are also allowed to occur partially during specified segments.

> “What we want, then, is a way of describing those coarticulatory effects which do not involve phonological manipulation of segmental feature values, but

> instead involve quantitative interactions in continuous time and space" Keating (1990: 453).

Thus, the window model assigns a range of possible articulatory values, referred to as 'window' to all segments. More specifically, the segment's window size represents all its possible contextual variability. This results in specified segments being associated with narrow windows and unspecified segments with wide windows. A narrow window will allow for some coarticulatory effect during a specified segment. For example, because English vowels are unspecified for nasality they are assigned wide windows and allow for large contextual variability with respect to the amount of nasalisation. The [+nasal] feature is not assigned a maximally wide window size, as the velum is not allowed maximal lowering. Nasal and oral consonants are assigned narrow windows. This is so because they are specified for the feature [±nasal] and, thus, would allow for minimum contextual variation. An interpolation mechanism is, then, introduced in the model to connect unspecified segments with those specified for the articulating feature. Supporting evidence comes from nasalisation in English, where the velum rises gradually during a vowel in [NVN] sequences (Cohn 1990).

Thus, the window model can readily account for segment-induced coarticulation reduction in terms of window size. For example, since the high vowel /i/ is specified for the anticipated feature [–round] it is assigned a narrow window size. This narrow window will only allow for little coarticulation as opposed to the total blocking introduced by feature spreading and Henke's look-ahead assumptions. When, on the other hand, a segment, i.e., /p/ is not specified for the anticipated rounding feature [± round] its associated window will be wide for rounding and will consequently allow maximal contextual variability. Windows would, therefore, allow for a permissible range of effects rather than maintaining a fixed feature value specification.

The innovation in the window model is that it relates phonological and phonetic representations through a mediation mechanism (Cohn 1990, Farnetani & Recasens 1999). Keating (1990: 451-453) notes that quantitative coarticulatory data are often given unsatisfactory phonological treatments in the coarticulation literature. In this regard, Keating argues that binary feature accounts, which assume categorical feature spreading failed to explain continuously varying coarticulatory effects in time and space. Similarly, previous data on pharyngealisation are given primarily phonological treatment by different investigators. This is because pharyngealisation appeared to extend over long spans of utterance, and the effects are thought to be totally blocked by theoretically incompatible (opaque) phonemes such as the high front vowel /i/. However, as will be reviewed in Chapter 3, there exist some data that suggest gradual effects of pharyngealisation during the high front vowel /i/ (Ghazeli 1977, Bukshaisha 1985). Segments, which are thought to be opaque to pharyngealisation, appear to attenuate the effect rather than totally block it. Importantly, quantitative assessment of such effects in the pharyngealisation literature is still lacking.

The look-ahead view as posited in the window model is directly relevant to the present study because it can account for the observed pharyngealisation effects during /i/. For example, it has been reported that a word containing the high vowel e.g. /bifiiD/ might be entirely pharyngealised (Ghazeli 1977, Bukshaisha 1985). The look-ahead model as modified by Keating readily accounts for pharyngealisation effects during /i/ throughout the entire word. Keating's model assigns a narrow window of possible degree of tongue backing to the high vowel /i/. This may well allow for minimal pharyngealisation effects during and even before /i/ as previously observed in words such as /bifiiD/ "will overflow", /niʃiiT/ "active" (Bukshaisha 1985), see Chapter 3 for further discussion.

A key diagnostic for a phonetic coarticulatory effect is to assess how the magnitude may be predictable from the temporal proximity to the trigger. This will show that phonetic coarticulation gradually increases in magnitude as the trigger is approached. As will be discussed in Chapter 3 below, there is some data suggesting that pharyngealisation decreases in magnitude with the temporal distance from the trigger (Ghazeli 1977, Bukshaisha 1985). Unfortunately, these observations have not been given adequate descriptions. Quantifying such effects considering the temporal distance from the trigger will be closely carried out in the present dissertation on pharyngealisation to see if pharyngealisation extent is a phonetic coarticulatory mechanism that increases as the trigger is approached.

2. 2. 3 Coproduction and articulatory phonology

Coproduction and articulatory phonology assumptions share with the phonetic look-ahead model that the effects of coarticulation gradually increase in time, i.e., as the trigger is approached (Fowler 1980, Browman & Goldstein 1986; 1989; 1990; 1992). Fowler (1980) notes that an adequate theory of coarticulation must acknowledge timing as an inherent property of segments, and that segments are classified into consonants and vowels which are independently controlled, and consonantal gestures are superimposed on the vowel gestures (Ohman 1965, 1966). More clearly, Ohman examined VCV utterances in American English and Russian where [C = stop consonant]. His results show that the F2 transitions in VC and CV do not solely depend on the intervocalic C and the neighbouring V but also on properties inherent in the transconsonantal vowel. On this basis, Ohman concluded that it is a vowel-to-vowel diphthongal gesture on which the consonantal gesture is superimposed. Thus, coarticulation in VCV utterances is a result from simultaneous instructions for vowels and consonants. In Ohman's examination, the tongue was viewed as incorporating three independently controlled articulatory channels (the apical, the dorsal and the tongue body). These channels receive and execute independent invariant neural instructions. In the light of such observations, Fowler (1980: 129) maintains that, "True coproduction occurs in speech, and that the capacity for coproduction derives from an adaptive property of speech that the two classes of articulatory gestures, consonants and vowels, are products of different (coordinated) neuromuscular systems". This was the basic concept underlying coproduction theory.

In coproduction accounts input units in speech production are dynamic gestures. This means that gestures have their intrinsic duration and are therefore allowed to overlap in time with adjacent gestures, unlike static vocal tract configurations assumed in the feature-based models. Gestures in coproduction need not be modified at the execution level. Thus, Fowler rejects feature speculations that a translation process need bridge the gap between mental and physical representation of speech where the speech plan issues spatially defined targets, and a central clock specifies when the articulators move to achieve these articulatory goals. Alternatively, to Fowler, within a coproduction account the gestures as phonological units need not be altered at the plan level, and no central clock is needed. The plan, therefore, specifies the articulatory goal to be executed. These gestures, according to Fowler, must be serially ordered actions in the plan, specified dynamically and context-free. The kinematics of articulatory movements is determined by the dynamic specifications of gestures. Thus, the temporal structure of adjacent gestures would in turn allow them to overlap in time.

A basic concept in the coproduction account is that neighbouring gestures overlap rather than just being altered by each other in a higher-level planning stage. Fowler argues against the assumptions that segments are timeless and are planned discretely within a given sequence. In this regard, Fowler discusses data in Bell-Berti & Harris (1978) demonstrating that anticipated lip rounding begins at a fixed time before the trigger regardless of the duration of the preceding sequence of segments. This, to Fowler, provides evidence that articulatory parameters for a segment extend beyond its acoustic boundaries, as defined in terms of constriction onset and release. Consequently, segments are co-produced with other segments that precede and follow them Fowler (1980: 117). On this basis, coarticulation proceeds from local interactions between overlapping gestures.

The task dynamic model is a speech production model, originally developed to account for non-linguistic movements Hawkins (1992: 9). It is based on biological and physical parameters of co-ordinated movements. Recently, the task dynamic model has been applied to account for speech production and has been successfully useful in modelling speech gestures (Hawkins 1992, Saltzman & Munhall 1989). In a task dynamic language, phonological units in the speech system are dynamically defined articulatory gestures as they characterise articulator movements, i.e., constriction formation and release within the vocal tract (Saltzman 1991, Fowler & Saltzman 1993). A task dynamic description of a given articulator movement is based on the task aimed at rather than just that of the articulator involved. Task variables describe articulatory constrictions (required tasks of articulators), and tract variables describe the variables associated with specific articulatory subsystems.

Articulatory phonology is a linguistic gestural component of a computational model developed at Haskins Laboratories (e.g., Browman & Goldstein 1986; 1989; 1990;

1991, 1992). The gestural system in articulatory phonology is defined in terms of articulator constriction formation, and release in the vocal tract. The term “tract variables” is the formal classification of dimensions of gestures, which was originally introduced, in the task dynamic model. Thus, linguistic gestures within articulatory phonology are classified as eight tract variables: (Lip protrusion, lip aperture, tongue tip constriction location, tongue tip constriction degree, tongue body constriction location, tongue body constriction degree, velic aperture and glottal aperture). Gestures, in articulatory phonology terms, are phonological primitives that have their intrinsic duration and that can overlap in space and time with adjacent gestures (Browman & Goldstein 1989). “Because gestures are characterisations of spatiotemporal articulatory events, it is possible for them to overlap” Browman & Goldstein (1989: 1). The processes for coordination that describe the organizations of gesture classes, i.e., vowels and consonants occur via phasing principles, where each gesture is represented on a separate class tier, i.e., vowel or consonant tier. These phasing principles coordinate neighbouring gestures with one another. In other words, the onset of a gesture is synchronised with a time point in a phase of a preceding gesture. This, according to Browman and Goldstein (1989: 160) results in a gestural score. A representation of a gestural score illustrates the duration of individual gestures and the duration of overlap among these gestures.

In general, coproduction and articulatory phonology accounts speculate that articulator movements result from simultaneous neural commands for distinct gestures. Thus, they view coarticulation as partial overlap of commands for adjacent segments. Importantly, they postulate that coarticulatory effects are local, rather than long-distance, as posited by feature-based models.

There is another view in the phonetic literature where coarticulation may incorporate two phases (Perkell & Chiang 1986). The hybrid model posited by Perkell & Chiang assumes that look-ahead and coproduction may coexist as two phases in a single coarticulatory process. Perkell & Chiang in their hybrid model describe anticipatory coarticulation as incorporating two phases. The first is a slow phase, consistent with the look-ahead predictions, which varies as a function of duration. The second phase is consistent with coproduction predictions in that it is fast and depends on the dynamics of articulators involved, which starts at a fixed time point before the trigger. Its initiation time prior to the trigger is constant and does not vary with the duration of the intervening sounds.

To summarise, this section discussed some relevant models of speech production. These models have been proposed to account for the magnitude of coarticulation extent. It becomes clear that there are two fundamentally distinct views of coarticulation. The first is a phonological feature spreading, which spreads categorically regardless of the duration of the affected sound(s). The second view is a phonetic coarticulatory process, where coarticulation is gradual and increases with the temporal proximity to the trigger. The gradient effect of coarticulation can be accounted for in terms of the look-ahead model that assumes an increase in magnitude of anticipatory coarticulation as the trigger is approached. Another view of a gradient effect comes in articulatory phonology. The look-ahead and articulatory phonology views are similar in that they both assume a gradual increase in magnitude of the effect as the trigger is approached. However, they differ in terms of the way they refer to these input units. The look-ahead model assumes discrete invariant units, whereas articulatory phonology takes gestures as input to the model. The look-ahead assumes unlimited temporal extent of the effect. In contrast, articulatory phonology and coproduction assume a limited extent. In addition, it has also been noted that coarticulation may incorporate two phases: a slow phase consistent with look-ahead predictions, and time-fixed phase that is consistent with coproduction predictions. This implies that more than one coarticulatory mechanism might be available to speakers.

It becomes clear that categorical spreading of pharyngealisation that does not attenuate with duration is readily accounted for in terms of the spread of phonological features. However, a gradient effect of pharyngealisation can be readily accounted for in terms of the look-ahead model of coarticulation and/or gesture overlap.

2. 3 *Coarticulation* domain

In section 2.2 above, I reviewed the different predictions of models of speech production that are relevant in the present study. There are two fundamentally distinct model predictions: First, categorical magnitude as assumed by the feature spreading model, where the effects are equally distributed regardless of the duration of the affected sound(s). Second, a gradient process of coarticulation as posited in the look-ahead and coproduction models, where the effects gradually increase as the trigger is approached. These model predictions will be considered in identifying the potential domain of pharyngealisation, a major aim in the present study.

It is undertaken in the present study to examine anticipatory pharyngealisation across a hierarchy of boundary levels (syllable, word, phrase and intonation phrase) in an attempt to figure out the potential domain of pharyngealisation. In this section I explore how to best identify the potential domain of coarticulatory phenomena in the speech record. Three relevant issues are discussed: domain definitions (planned vs surface), model predictions (categorical vs gradient magnitude of coarticulatory effects), and two domain possibilities (single vs hierarchically gradient effects). By the end of this chapter, an appropriate way for identifying the potential domain of coarticulation will be proposed.

2. 3. 1 Definitions of domain

An adequate model of speech production is expected to precisely describe the potential domain of coarticulation because it sheds light on the size of the programming units in speech production. The domain of coarticulation has been discussed in the phonetic literature (e.g., Kozhevnikov & Chistovich 1965, Benguerel & Cowan 1973, Whalen 1990, Magen 1997) and it is clear, as the present section shall reveal, that an appropriate approach to identifying the potential domain of coarticulation in general is still lacking.

The present study examines anticipatory pharyngealisation effects across a hierarchy of boundary levels in an attempt to identify the potential domain of pharyngealisation. The implication of examining coarticulation is that the pattern of coarticulation magnitude might reflect the size of the programming units in speech plan. For example, if speakers intend to make coarticulatory effects within a certain linguistic unit, such a domain unit might be indicative of an organizational unit in the speech plan. It is important to make predictions regarding the physical realisation of such underlying units in the speech stream, as they can reliably facilitate identifying the potential domain unit in the speech signal.

I distinguish between two domain definitions in order to see how one can best infer the planned domain from the surface domain in the speech signal. First, the planned domain is the linguistic unit to which speakers intend to confine coarticulatory effects. Second, the surface domain is the temporal extent of coarticulation in the surface phonetic signal. As will be discussed below, the planned domain might differ from the surface domain. It is crucial to tell apart the planned/surface domain definitions because an experimenter has to examine the surface domain in the speech signal in order to infer the actual size of the planned domain unit.

It is also important to consider the model predictions regarding the magnitude of coarticulation (i.e., categorical vs gradient magnitude) reviewed in section 2.2 above because they let us know what to expect to see in the surface domain from which we seek to infer the planned domain. What follows from these two model predictions is that there are two possibilities for patterns of coarticulation within a single planned domain unit. First, a categorical planned domain unit, where the effects are equally spread throughout that domain unit. Marginal effects are possible between such categorical domain units because the articulators cannot move instantaneously from one articulatory position to another. Secondly, a gradient planned domain unit, where the effects gradually increase as the trigger is approached. In order to identify the planned domain from the surface domain, one expects that the magnitude of the effects is larger within the planned domain unit than between them, regardless of whether that planned domain unit shows a categorical or gradient magnitude.

The planned/surface domain variation can be exemplified by two instances: a) the planned domain can be larger than the surface domain; b) the planned domain can be shorter than the surface domain. In what follows I explore these two instances of planned/surface variation.

The instance of the planned domain unit being larger than the surface domain can result from coarticulatory resistance, i.e., the intervention of an incompatible feature, which may limit the temporal extent of coarticulation in the surface signal, even though coarticulation or feature spreading might have been planned to occur throughout a larger domain. This can be exemplified for pharyngealisation by the presence of a high front vowel, which is thought to be resistant to pharyngealisation. For example, in the word [Tiin] "mud" the effects of pharyngealisation might be blocked even in a dialect that takes the word as the domain of pharyngealisation (Card 1983). Although Card demonstrates that her Palestinian subjects pharyngealise entire words, she reports that pharyngealisation effects are only confined to the trigger /T/ in the word /Tiin/. This type of coarticulatory resistance on the high vowel makes the surface domain shorter than the planned domain unit in this particular word. In the present experimental study, in order to avoid instances where the planned domain is larger than the surface domain, it is crucial to control for segments that potentially resist coarticulatory effects so that the examined data shows maximal temporal and spatial extent of coarticulation. In contexts where maximal temporal extent of coarticulation is allowed, it is possible to find marginal effects between the planned domain units. In this case, the actual planned domain is shorter than the surface domain. To exemplify the instance of the planned domain being shorter than the surface domain, let us assume that the word is the domain of a given coarticulatory phenomenon. Speakers might intend to extend coarticulatory effects over the entire word. There are two possibilities for the physical realisation of the magnitude of coarticulation within the word. According to the model prediction discussed above, the magnitude of the effects will appear either as categorical or as gradient throughout the entire planned domain, i.e., the word. In the instance of the categorical magnitude domain marginal effects are possible between words because the articulator cannot move simultaneously from one articulatory position to another. In the instance of the gradient domain, it is unclear whether marginal effects are possible or not. The appearance of such marginal effects might depend on the temporal distance of the measurement point from the trigger. Thus, given these two planned/surface domain definitions, one can reliably infer the planned domain, which is characterised by relatively larger magnitude of coarticulatory effects.

A major problem in the phonetic literature is that the term "domain" is not used consistently. It is often unclear whether the term refers to the planned domain, to the surface domain or whether it refers to both (Kozhevnikov & Chistovich 1965, Magen 1997). In order to illustrate the inconsistent use of the term domain, I review two major studies (Kozhevnikov & Chistovich 1965, Magen 1997). For example, Kozhevnikov & Chistovich (1965) define the planned domain (the syllable), where the magnitude is relatively larger and more stable within the syllable than across syllable boundaries. In Magen (1997), however, no such planned/surface distinction is made.

Kozhevnikov & Chistovich (1965) examined labial anticipatory coarticulation in Russian. The assumption underlying the study was that the anticipatory coarticulation directly reflects the size of the programming units in speech production. Thus, if anticipatory coarticulatory effects extend over a number of segments preceding the trigger, this means that the motor control system may have access to information concerning units larger than the segment itself. Kozhevnikov & Chistovich (1965) demonstrated that in CV, CCV, CCCV sequences, where [V] is [+round], the rounding gesture began as early as the onset of the first consonant in the test sequence. They concluded that the lip protrusion gesture was organized in CV-syllable types, i.e., CV, CCV, and CCCV. Thus, a central postulation in the articulatory syllable model introduced in Kozhevnikov & Chistovich (1965) is that consonants are programmed with the following vowel, i.e., the articulatory commands for the entire syllable are instructed simultaneously with the start of the syllable once these commands are non-competing. On the basis of these findings, Kozhevnikov & Chistovich (1965) propose that the syllable is the planned domain of coarticulation. Kozhevnikov & Chistovich argue that CV-type syllable is the programming unit in speech production within which a high magnitude of coarticulation is predicted. Kozhevnikov & Chistovich's model does not rule out minimal effects between such CV syllables. These marginal effects have not received sufficient attention in the phonetic literature on coarticulation. Of course, the point is not that these minor effects are uninteresting; on the contrary, they constitute crucial evidence for the surface domain being larger than the planned domain unit. Kozhevnikov & Chistovich's model assumes a relatively stable magnitude throughout the entire CV syllable. However, they gave no explanation for the marginal effects found between their assumed CV syllables. Kozhevnikov & Chistovich's findings are consistent with the planned/surface distinction discussed in this section, where the planned domain is the CV-type syllable and marginal effects between such domain syllables are possible. In contrast, there are other studies that do not distinguish between the planned and the surface domain definitions (Magen 1997).

Magen (1997) examined the extent of vowel-to-vowel coarticulation in English in /bV1bəbV3b/ sequences. V1 and V3 were either /i/ or /a/ and primary stress on the stressed syllable was marked by an accent mark on V1 or V3. The test sequences were embedded in sentence initial and preceded by ‘the’, sentence medial, or sentence final positions. Magen observed vowel-to-vowel coarticulatory effects extending from one full vowel (either V1 or V3) through the medial schwa into the midpoint of the other full vowel. These results indicate that V-to-V coarticulation extends across a foot boundary comprising a full vowel and the preceding/following schwa. Magen concluded that the foot is not the domain of coarticulation. A major problem with Magen’s account is that in her definition the planned and surface domains are not distinguished. On the basis of our definitions of the planned and the surface domain types, there are two possible interpretations to Magen’s findings. First, the foot is the domain of coarticulation if the effects found across the foot unit are marginal compared to the larger magnitude found within the foot unit. Secondly, if the magnitude of the effects is relatively stable within and across the foot unit, then the domain size might be larger than the foot unit.

So far, I argued that in order to identify the planned domain of coarticulation, it is important to acknowledge that the planned domain might be larger or smaller than the surface domain, as it appears in the speech signal. It is also crucial to consider the predictions of current speech production models regarding the magnitude of coarticulation because they assume a relatively larger magnitude within than outside the planned domain unit. Then I discussed two possibilities of a single planned domain of coarticulation (categorical vs gradient). I, then, exemplified two instances for the planned/surface domain variation. Finally, two major studies are reviewed to exemplify the inconsistent use of the term domain.

In order to appropriately infer the single planned domain unit from the surface domain in the speech signal, it is crucial for our data to control for segments that bear a contradictory feature to avoid instances of the planned domain being larger than the surface domain. In such a controlled data design, however, the temporal extent of coarticulation might be maximal, which can result in possible marginal effects beyond the planned domain unit. The magnitude of the effects within a single planned domain unit, whether categorical or gradient, will be relatively larger than any possible effects between such planned domain units. Nevertheless, as will be discussed in the next sub-section, there is an alternative view that there is no single planned domain of coarticulation, but the magnitude of the effects gradually decreases as a function of prosodic boundary strength.

2.3.2 The effect of prosodic boundary strength on coarticulation

Recently, it has been acknowledged that coarticulatory resistance can be due to prosodically driven strengthening, depending on the prosodic boundary level (e.g. McClean 1973, Recasens 1984, Hardcastle 1985, Krakow 1989; 1993, Sproat & Fujimura (1993), Byrd & Saltzman 1998, Cho 2004, Pan 2007).

Krakow (1989) provided support for prosodically induced variation in coarticulation magnitude, i.e., within word nasals induced larger magnitude of nasalisation on the preceding vowel than nasals across word boundaries. Krakow examined patterns of nasalisation by manipulating the location of word boundaries across matched phonetic sequences for word initial, medial and final nasals. Krakow's data included the nasal [m] in sequences like: [V#mv], [V.mV], [Vm#], [Vm.V]. Krakow provided evidence that prosodic boundary strength (within words vs across word boundaries) significantly influenced the magnitude of velar lowering on a vowel preceding a nasal consonant. Thus, Krakow concludes that within word nasals induced larger magnitude of nasalisation on the preceding vowel than nasals across word boundaries.

Support for boundary induced coarticulation resistance comes in McClean (1973). McClean examined the onset of anticipatory velar nasalisation in [CV#VN] sequences spanning a hierarchy of boundary types at [#], i.e., major syntactic boundaries including marked phrase, clause or sentence boundary and less marked syntactic boundaries including word and syllable boundaries. McClean reported that velic movement was delayed (relative to the onset of the first vowel in the sequence) more by stronger (higher) boundaries than by weaker (lower) boundaries.

Further support for boundary-induced resistance to coarticulation comes in a study of vowel-to-vowel coarticulation in English in Cho (2004). Cho explored whether coarticulatory resistance varies across different prosodic boundaries. The test sequences in the data were the following pairs: (/i#bi/, /a#ba/, /i#ba/, and /a#bi/), where (#) represents a hierarchy of boundary types (prosodic word, intermediate phrase, intonation phrase). This way of varying the prosodic boundary allows keeping the same segmental composition, but with different boundary-induced duration variation. The articulatory movements, i.e., tongue height and backness were tracked using an EMA system and the kinematic signals were lined up with the acoustic signal for acoustic landmark detection. Cho reported that the magnitude of coarticulation is less across higher prosodic boundaries than across lower ones. Cho found more resistance to carryover coarticulation from /a#/ to /#i/ across higher prosodic boundaries than across lower prosodic boundaries. It is noteworthy that the hierarchical decrease in coarticulatory magnitude, according to Cho, was duration-independent. Cho proposed that this prosodically induced decrease in coarticulation magnitude is a phonetic signature of the nested prosodic hierarchy.

It becomes clear that there are two possible views regarding the domain of coarticulation. The first view is that there is a single planned domain unit, which will surface with either categorical or gradient magnitude of the effects. The second view, however, is that there is no single domain unit that speakers aim for but the magnitude of the effects will gradually decrease, depending on the prosodic boundary strength.

A major goal in the present study is to examine pharyngealisation effects across a hierarchy of prosodic boundary levels (syllable vs word vs phrase vs intonation phrase), keeping the test sequence constant in the four boundary conditions. Each of the four boundary conditions in our data will serve as a prosodic domain candidate for pharyngealisation. Thus, there are two possible hypotheses to be tested, a) a single planned domain unit that speakers intend to pharyngealise, and 2) no single domain unit but the effects gradually decrease in magnitude depending on the prosodic boundary level. As will be reviewed in Chapter 3, different pharyngealisation domain units have been proposed in previous research. The present study is an attempt to provide a clearer account for the planned domain of pharyngealisation.

2. 4 Conclusion

It is undertaken in the present study to investigate the magnitude and planned domain of anticipatory pharyngealisation. In this chapter, I have reviewed relevant theoretical issues regarding magnitude and the planned domain of coarticulation/spreading. Regarding the magnitude of the effects, it becomes clear that there are two fundamentally different views of coarticulation. The first is a phonological feature spreading, which results in a *categorical* pattern regardless of the duration of the affected sound or sequence of sounds. A key diagnostic for feature spreading is to assess how the magnitude of spreading varies as a function of the duration of the affected sound sequence before the trigger. Evidence for this view came from experimental data showing that the anticipatory effects may extend as early as six segments prior to the trigger. Crucially, a major problem with such investigations is that they failed to quantify the spatial magnitude along its temporal dimension, a key diagnostic for categorical feature spreading. Thus, categorical spreading will surface as an equally distributed effect throughout the affected portion of utterance.

The second view is a gradient phonetic coarticulatory process, where the effects gradually increase with the approach to the trigger. This type of effect can be found in two distinct models of coarticulation, i.e., the look-ahead model and articulatory phonology. Both types of model are similar in that they posit a gradual effect that increases with the approach to the trigger. They differ in terms of their input units, features vs gestures, respectively. They also differ in terms of the temporal extent of the effect. The look-ahead model assumes an unlimited extent. However, the coproduction model assumes a limited extent of the effect. A key diagnostic of the gradient magnitude of coarticulation is to assess how the magnitude might decrease as a function of the duration of the affected sound(s).

Regarding the domain of coarticulation, I have argued that it is important to distinguish two conceptually distinct domain definitions, i.e., the planned vs the surface domain. The planned domain refers to the unit within which speakers intend to confine the effects. The surface domain is the physical realisation of the domain in the surface phonetic signal. I have also argued that it is important to consider the model predictions regarding the magnitude of the effects in order to infer the planned domain from the surface domain. More specifically, the model predictions, whether categorical or gradient, predict that the magnitude of the effects is larger within a single planned domain unit relative to any possible effects between such planned domain units. I have also exemplified instances where the planned domain can be shorter or larger than the surface domain.

An alternative view, however, is that there is no single planned domain unit but the magnitude of the effects gradually decrease as a function of prosodic boundary strength. For example, stronger prosodic boundaries such as the intonation phrase are expected to totally block the effects. In contrast, across weaker prosodic boundaries such as the syllable, the effects of coarticulation are expected to be maximal. Intermediate boundary levels such as the word and phrase are expected to attenuate the effects of coarticulation.

In the next chapter, I review previous studies on pharyngealisation in Arabic and it will be discussed that there are conflicting claims regarding the magnitude and the domain of coarticulation.

Chapter 3. Pharyngealisation in Arabic (Literature Review)

The present Chapter reviews previous data regarding pharyngealisation in different Arabic dialects. It appears that in previous investigations, models of speech production have not been thoroughly considered regarding the magnitude and domain of pharyngealisation extent. I, therefore, attempt to relate some of these findings to the predictions of the relevant models of speech production discussed in Chapter 2 above. The outline of the present chapter is as follows. Section 3.1 is a brief definition of pharyngealisation. Section 3.2 presents the articulatory/acoustic exponents of pharyngealisation. In section 3.3 I discuss the extent of pharyngealisation with a special focus on the magnitude of pharyngealisation effects about which there are conflicting reports and claims. For example, some of these data provide evidence for categorical spread of features; others provide support for a gradient coarticulatory process of pharyngealisation. Section 3.4 discusses previous discrepancies regarding the domain of pharyngealisation.

3. 1 Background

The traditional term ‘emphasis’ refers to a secondary articulation that is very common in Arabic. Emphasis refers to the narrowing of the pharynx by the tongue body as a secondary articulation to produce phonemic contrast (Hoberman 1995). The phonemic inventory of Arabic includes a set of underlying pharyngealised coronals known as emphatics or pharyngealised phonemes (Al-Ani 1970, Ghazeli 1977, Card 1983, Younes 1982, Bukshaisha 1985, Herzallah 1990, Davis 1995, Al-Masri 2010). The emphatic phonemes contrast with their plain, i.e., non-emphatic counterparts. The pharyngealised sounds in Libyan Arabic will be referred to in higher case conventions [S, T, D, TH and DH] in this study. The plain counterparts are transcribed as [s, t, d and dh].

The presence of an underlying emphatic in a given utterance induces a degree of influence on neighbouring sounds, which is commonly referred to as pharyngealisation. For example, words like [baaT] “underarm” and [baat] “he slept” contrast in terms of pharyngealisation effects over the entire word, which are triggered by the word-final /T/ as opposed to its plain cognate /t/. We review previous data primarily in an attempt to find out how these data can be accounted for by current models of speech production. This implies figuring out which of these data is consistent with categorical feature spreading assumptions, and which supports a gradient coarticulatory process. I also review data regarding the domain of pharyngealisation, where conflicting reports have been presented in the literature.

The outline of the remainder of this chapter is as follows. In section 3.2, I review the articulatory and acoustic manifestations of pharyngealisation. In section 3.3, I discuss some findings relevant to pharyngealisation magnitude. It becomes clear that previous data on pharyngealisation magnitude are consistent with two fundamentally distinct types of coarticulation mechanisms. The first type is a categorical spread of phonological features. The second type is a gradient process of phonetic coarticulation. It turns out that a distinction between phonological and phonetic characterisations of pharyngealisation extent is called for. Section 3.4 presents some claims and data regarding the pharyngealisation domain. Different domains have been proposed in previous research, i.e. syllable, word and phrase. It becomes clear that a way to best identify the potential domain of pharyngealisation is still lacking.

3.2 The articulatory and acoustic manifestations of pharyngealisation

Pharyngealisation in Arabic, traditionally known as emphasis, is a distinctive feature in Arabic. Early Arab grammarians described it as ‘ʔitbaq’. In modern linguistics pharyngealisation is identified as ‘spreading and raising’ of the tongue (Lehn 1963: 29), and ‘covering or lidding’, see Card (1983) for discussion.

Recent technology and laboratory techniques provided more accurate and elaborate details of pharyngealisation. For example, Marcais (1948), as cited in Card (1983: 13) examined the articulatory configuration of pharyngealisation using palatograms and radioscopy. He reported that pharyngealisation involves muscular tension and retraction of the tongue root towards the back of the pharynx.

Ali & Daniloff (1972) studied cinefluorographic data on the articulation of pharyngealised consonants in the Arabic dialect spoken in Baghdad. They observed that the primary articulator for pharyngealisation is the tongue dorsum and/or the root of the tongue. They reported a simultaneous depression of the palatine dorsum and a backward movement of the pharyngeal dorsum.

Ghazeli (1977) studied articulatory and acoustic data from Libyan, Tunisian, Egyptian and Jordanian speakers. As shown in (Figure 3) below, Ghazeli's X-ray films show that the secondary articulation of emphatic consonants is characterized by: a) backward movement of the tongue toward the back pharyngeal wall at the level of the second cervical vertebra, and b) depression of the palatine dorsum rendering a wider oral cavity, see (Figure 3).

Ghazeli found that the greatest constriction for the pharyngealised consonants takes place in the upper pharynx. Although Ghazeli discussed fine-grain differences in the degree of tongue backing among pharyngealised consonants, he reported that the general shape of the tongue is almost the same in all of them Ghazeli (1977: 127). In addition, activities of the posterior part of the genioglossus and the geniohyiod are reported to contribute to form the tongue shape at the oro-pharynx during the production of pharyngealised sounds (Kuriyagawa et al 1988: 120-22).

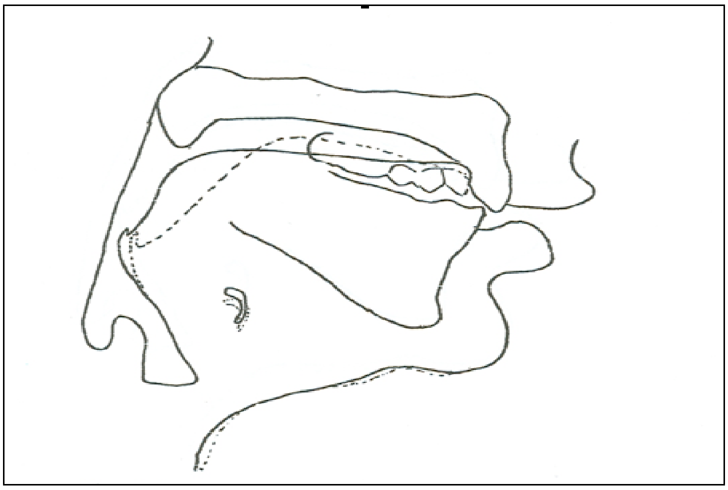

Figure 3: Vocal tract shape during the production of /T/ dotted line vs. /t/ solid line after Ghazeli (1977:69)

Laradi (1983) examined articulatory, i.e., videofluorograghy and endoscopy data recorded from Libyan Arabic speakers. She reported a constriction at the level of the epiglottis. The maximum narrowing, according to Laradi, extends downwards in the pharynx rendering a small laryngopharynx. Laradi found a rearward tongue dorsum displacement towards the back wall of the pharynx. Laradi also observed a depression in the tongue front and dorsum Laradi (1983: 245-247).

Giannini & Pettorino (1982) examined acoustic and radioscopic data from Iraqi Arabic. They found that during the pharyngealised sounds there is a constriction in the lower pharynx occurring at the level of cervical vertebra 4 and 5.

Laufer & Baer (1988) investigated pharyngealisation in Arabic and Hebrew. They provided fiberoptic endoscopy data showing a constriction in the lower pharynx. Laufer & Baer reported that there is a backward tongue root movement during the articulation of pharyngealised sounds. Laufer & Baer also reported the epiglottis forms a constriction with the pharynx wall. They also noted that the maximum narrowing occurs between the retracted epiglottis and the back pharyngeal wall.

In addition, Al-Tamimi & Heselwood (2011: 185) provided articulatory evidence for a narrow constriction made by the lower part of the tongue postero-dorsum in the area above the tongue root. This narrow constriction takes place at the level of CV2.

Esling (2005) reported that the main articulator involved in a pharyngealised vocal tract configuration is not solely the tongue. Esling reported that pharyngealisation involves a pharyngeal constriction, which results with raising the larynx and retracting the tongue. Furthermore, Hassan & Esling (2011) provided laryngoscopic evidence for a higher degree of stricture at the pharyngeal articulator.

Hassan & Esling (2011: 232) reported laryngoscopic evidence that the pharyngealised segments are characterised by a lower larynx height and a retraction of the tongue accompanied with a tongue dorsum raising. They noted that the front-to-back depth of the pharynx is consequently reduced and the pharyngeal space is vertically extended.

In previous research there are three different positions regarding the realisation of emphatic articulations. Firstly, in some studies, emphasis is defined as velarisation, where the back of the tongue is constricted against the velum (Gairdner 1925: 15-20; Ferguson 1956: 446-451). Second, other studies define emphasis as uvularization (Zawaydeh 1997; Shahin 1997; Zawaydeh & de Jong 2011), where the back of the tongue is raised towards the uvula. Third, the position taken in this thesis is that emphasis is defined as pharyngealisation (Giannini & Pettorino 1982; Laufer & Baer 1988; Hassan & Esling 2011; Zeroual et al 2011; Al-Tamimi & Heselwood 2011). For example, Hassan & Esling (2011) provide articulatory and acoustic evidence that pharyngealisation includes articulatory adjustments in the shape of the pharynx.

Acoustically, pharyngealisation is manifested by a compact spectrum, i.e., F2 lowering and F1 raising in vowels following or preceding pharyngealised sounds, see (Figure 4). Laufer & Baer (1988)'s articulatory data revealed a constriction in the lower pharynx in pharyngealised tokens, as opposed to their plain cognates. These findings were also confirmed by their acoustic results. More specifically, their acoustic data are consistent with their acriculatory findings in that there is a compact spectrum, i.e., substantial F2 lowering and some raising of F1 (Laufer & Baer 1988: 191).

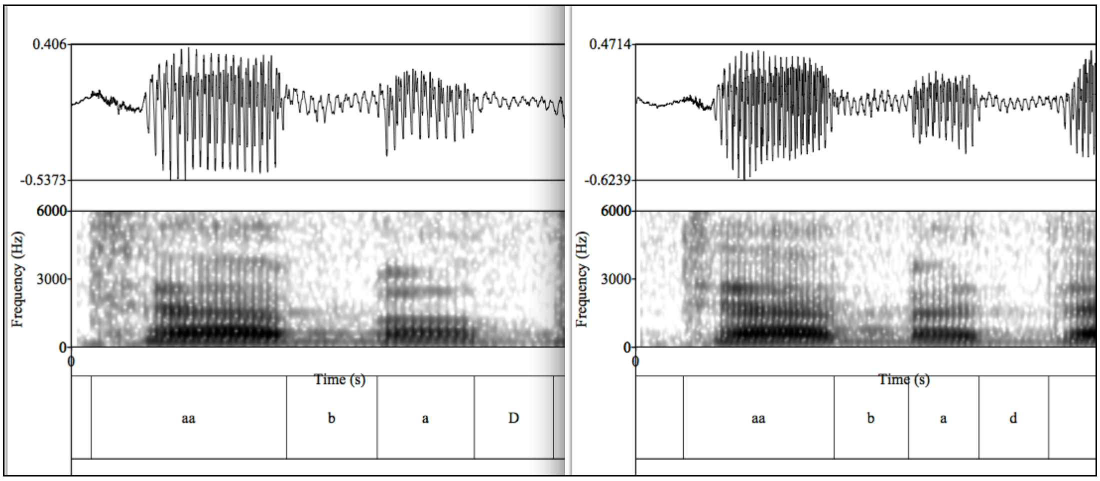

Figure 4: A spectrogram display of test (underlined) sequences in (a) pharyngealised [kitaab**a**#Daayʕa] "lost writing" and (b) plain [kitaab**a**#daafja] "warm writing". The emboldened pre-trigger vowel /a/ shows substantial F2 lowering

Thus, there is robust evidence that pharyngealisation can be reliably detected by F2 lowering in pharyngealised contexts, compared to their plain counterparts (Ghazeli 1977; Younes 1982, Giannini & Pettorino 1982; Card 1983; Bukshaisha 1985; Yeou 1997; Zawaydeh 1999; Kriba 2010; Embarki et al 2011; Hassan & Esling 2011; Zawaydeh & De Jong 2011). All these studies confirm that when a vowel falls within the scope of pharyngealisation, the F2 of that vowel is substantially lowered as shown in (Figure 4). According to Obrecht (1968: 12), cited in Younes (1982: 115) “F2 variations were the most powerful cue factor [in identifying an emphatic consonant]”. Recently, Hassan & Esling (2011: 217), in their articulatory and acoustic study, state that, “Lowering of F2 has been the most reported acoustic exponent of emphatics for different Arabic varieties”. In addition, Al-Tamimi & Heselwood (2011) provided videofllurosсopic evidence that the F2 lowering is compatible with the constriction in the mid region of the oropharynx. They also noted that the F1 raising is compatible with the retraction of the epiglottis.

A recent acoustic investigation of pharyngealisation in Libyan Arabic is presented in Kriba (2010). Kriba showed that pharyngealisation in Libyan Arabic can be accounted for by locus equations (LE). Locus equations were originally introduced in (Lindblom 1963) to infer the articulatory configuration from the formant structure. LE is a linear regression analysis plotting the F2 onset values along the y-axis and F2 midpoint values along the x-axis. The line-of-best-fit in the regression equation yields slope and y-intercept values that correspond to plain and pharyngealised consonants. Kriba found that the slope and y-intercept are significantly lower for the emphatic than the plain context. Kriba’s interpretation was that the pharyngealised consonants exert coarticulatory effects on the neighbouring vowels and this pharyngealisation effect is manifested by F2 lowering.

Thus, there is robust evidence that F2 lowering can be manipulated as a reliable acoustic cue for pharyngealised utterances. Thus, in the present study, F2 values will be taken as a reliable acoustic measure to quantify anticipatory pharyngealisation effects across a hierarchy of prosodic boundary levels.

The next section discusses previous data in terms of the magnitude of pharyngealisation extent in order to see how these data may relate to models of speech production. It is worth noting that the predictions of these models have not been thoroughly tested against data on pharyngealisation extent. Such testing requires quantification of the spatio-temporal extent to see how these data fit with the predictions of a given model of coarticulation.

3.3 The magnitude of pharyngealisation extent

The present study undertakes to assess pharyngealisation magnitude considering the duration of the affected sound(s) preceding the pharyngealised trigger. This will be primarily to tease apart what might be phonological from what appears to be phonetic regarding the magnitude of pharyngealisation.

It has been discussed in Chapter 2 above that a key diagnostic to the magnitude of the effects is to quantitatively test whether or not the magnitude varies as a function of the duration of the affected sound(s). Previous findings primarily introduced phonological interpretations for pharyngealisation data. None of the previous experimental studies systematically assessed how the magnitude of pharyngealisaton extent may vary along its temporal axis in order to distinguish phonological from phonetic pharyngealisation effects. The next two sub-sections review some data on pharyngealisation magnitude from different dialects of Arabic. Unfortunately, these data did not receive quantitative analysis to see how the magnitude may vary as a function of the temporal distance from the trigger. Importantly, assumptions and predictions in models of speech production were not closely considered in interpreting previous pharyngealisation data. I present herein some of these data in an attempt to relate them to the predictions of relevant models of speech production.

3.3.1 Phonological feature spreading

As was discussed in Chapter 2 above, a phonological spread of binary features results in categorical, i.e., equally distributed magnitude of pharyngealisation, regardless of the duration of the affected sound(s). Experimental data in support of phonological feature spreading of pharyngealisation is presented in previous research (e.g., Younes 1982; Bukshaisha 1985). It should be emphasised here that none of the reviewed data received F2 measurements along the duration of the affected sound(s). Instead, most previous investigators introduced F2 comparisons of the pharyngealised and plain tokens. These data were not subject to statistical analysis.

For example, Younes (1982) carried out an acoustic study on pharyngealisation in Palestinian Arabic. A main concern regarding Younes' data is that the author was one of two participants in his study. As will be shown below, Younes' data are not based on carefully controlled minimal pair comparisons. Rather, in his analyses, Younes compares, for example, three occurrences of the vowel /a/ in pharyngealised tokens with only one occurrence of the same vowel /a/ in a plain control. In addition, the segmental composition in Younes' data was not carefully controlled to minimise any segmental influence. Thus, Younes' F2 measurements are based on one control plain word vs several pharyngealised test words. Younes (1982: 118) presented F2 measurements for vowels preceding a syllable final (tautosyllabic) pharyngealised trigger. The control word Younes presented is [malaak] "owner", where the F2 values of the second vowel [aa] are 1500 Hz, 1530 Hz and 1520 Hz for the onset, mid and offset points, respectively. In the pharyngealised word /balaaS/ "thief", the vowel [aa] to the left of the pharyngealised /S/ has an F2 value of 900 Hz at the three measurement points, i.e., onset, mid and offset, respectively. This token and other pharyngealised ones are all compared to the only one plain word /malaak/, where the F2 measurements at the three measurement points were 1500 Hz, 1530 Hz, 1350 Hz, respectively. Another example examined by Younes is the word /faaTH/ "it flowed". The F2 values at the three measurement points are 1010 Hz, 1020 Hz, 1030 Hz, respectively. Younes presents other data where /aa/ and /ii/ are preceding a syllable initial (heterosyllabic) pharyngealised trigger. For example, in the word /balaa.Sa/ "thief" the vowel [aa] to the left of the trigger /S/ has an F2 value of 990 Hz, 980 Hz and 990 Hz, respectively. The first vowel [a] preceding the pharyngealised trigger in the word /fa.THat/ "it overflowed" has an F2 value of 1000 Hz, 990 Hz and 1000 Hz at the onset, mid and offset points, respectively. These data items illustrate an equally distributed pharyngealisation magnitude throughout the affected vowel.

Although very limited in number, the examples examined by Younes are representative of two instances of position in the syllable, i.e., tautosyllabic vs heterosyllabic pharyngealised triggers. These two cases show that the magnitude of pharyngealisation is equally distributed throughout these long vowel sounds. These findings are consistent with a phonological, i.e., categorical feature spreading mechanism. Additional measurements carried out by Younes examining a consonant separated from the trigger by a vowel show that the geminate [ll] in /ballaaS/ "thief" has an F2 value of 770 Hz, 780 Hz, 790 Hz at the onset, mid and offset points, respectively. Another example of this type is exemplified by the geminate [ll] in /balliiT/ "a tile layer". The three measurement points in /ll/ show F2 values of 850

Hz, 840 Hz and 850 Hz, respectively. Although Younes does not consider closely model predictions, his data suggest a categorical spread of pharyngealisation. This is so because the three points indicate almost equally distributed pharyngealisation magnitude of F2 lowering. Interestingly, the /balliiT/ example shows that pharyngealisation extends from the word-final pharyngealised trigger through the specified long vowel /ii/ to the preceding /l/.

Younes observes that pharyngealisation is not limited to the vowel directly preceding the trigger. Rather, he reports long-range pharyngealisation that extends from a pharyngealised trigger to segments outside the syllable in which the pharyngealised trigger is located. For example, in the word /banfuTH/ “I shake” (ibid: 132), the three measurement points in the first vowel [a] show F2 values of 1050 Hz, 1060 Hz and 1060 Hz, respectively. Another word he presented was [baT.lub] “I ask for”, where F2 values of the first vowel [a] are 1000 Hz, 1020 Hz and 1030 Hz, respectively. The first vowel [a] in the word [ban.Sub] “I put” has F2 values 990 Hz, 1000 Hz and 990 Hz, respectively. Younes Compares the F2 values of [a] in the pharyngealised contexts with those of [a] in the plain control [ban.kul] “I transport”. The [a] plain control has F2 values of 1290 Hz, 1419 Hz and 1440, respectively.

The word /balaaS/ shows that the vowel [a] in the first syllable has F2 values of 770 Hz, 780 Hz and 790 Hz, respectively. The F2 values in these words are consistent with feature spreading postulations, where pharyngealisation seems to spread by a phonological rule resulting in an equal magnitude throughout the entire vowel, regardless of the duration of the affected sound(s). Note that the F2 values in both words, i.e., [banfuTH] and [balaaS] are different. The lack of F2 stability in these test words might be due to the lack of controlling the segmental composition. It is also possible that the lack of stability in the F2 value is due to syllable structure. Both test words have different syllable structures, i.e., CVC.CVC and CV.CVVC, respectively. Weakness in Younes’ experiment arises because his data are not based on minimal pair comparisons to attribute any F2 drop to pharyngealisation. In addition, Younes’ data are based on recordings from the author himself (speaking Palestinian Rural Arabic) and another male from the West Bank. In addition the data examined by Younes are not subject to statistical analyses to make objective generalisations.

Other examples that suggest a feature spreading mechanism come from Qatari Arabic (Bukshaisha 1985). Bukshaisha examined words like [bifiid] “will benefit” vs. [bifiiD] “will overflow”. Her measurements show that the vowel [ii] immediately preceding the trigger has an F2 value of 200 Hz lower in the emphatic than in the plain context. This suggests that the high vowel /i/ is categorically pharyngealised, although it is theoretically incompatible with pharyngealisation. Bukshaisha does not note that there is any transition in F2 values, which suggests an equally distributed pharyngealisation magnitude throughout the entire vowel.

The data discussed in this section suggest that pharyngealisation extends categorically often in the low vowel /a/ and sometimes in the high vowel /i/. They also suggest a long range of the spread of pharyngealisation. These findings seem to be compatible with feature spreading assumptions. However, as will be discussed in the next sub-section, other previous data show that pharyngealisation is gradual in magnitude providing counterevidence against feature spreading predictions.

3.3.2 Phonetic coarticulation

Although pharyngealisation has often been given phonological treatment, there are facts regarding the gradient nature of pharyngealisation magnitude (Ghazeli 1977, Bukshaisha 1985). Some, but not all, of the data reported in previous studies suggest a gradient phonetic process of coarticulation. These data show that the magnitude of pharyngealisation increases with the approach to the trigger. However, quantification of such gradient magnitude of pharyngealisation is still lacking. In other words, none of the previous studies considered if pharyngealisation magnitude might co-vary with the duration of the affected sound(s).

Although Younes’ (1982) data primarily provide evidence for a categorical spread of pharyngealisation through the affected sound(s), some of his test items show a gradient pharyngealisation effect. In the word /ʕabiiT/ “unruly”, Younes (1982: 120), the F2 values of /ii/ are 1850 Hz at the vowel onset, 2010 Hz at vowel midpoint and 1180 Hz at the offset. These data suggest that the final portion of the vowel might be more pharyngealised than the rest of the vowel interval. This finding suggests that the vowel might be entirely pharyngealised but with gradual increase in pharyngealisation magnitude as the trigger is approached.

Bukshaisha (1985) shows that pharyngealisation gradually increases as the trigger is approached. Bukshaisha notices that pharyngealisation extends from the word final pharyngealised trigger throughout the entire word in, for example, the word /mafaaTH/. It seems that Bukshaisha's measurements are taken at the vowel midpoint because one F2 value is presented for each test vowel. The vowel [aa] preceding the trigger has an F2 value of 1100 Hz. The vowel [a] in the first syllable has an F2 value of 1200 Hz. This example may suggest that the farther the vowel from the trigger the smaller the magnitude of pharyngealisation. In addition, Bukshaisha compares the words [niʃiid] "anthem" and [niʃiiT] "active". These words show a gradually increasing magnitude of pharyngealisation as the trigger is approached. For example, the vowel /ii/ preceding the trigger in [niʃiiT] has an F2 value of 1500 Hz at its offset point and gradually increases to reach a steady state value of 2200 Hz. Overall, her conclusion is that the effect of pharyngealisation is not blocked by the intervening sounds /ʃ/ and /ii/ extending gradually to the word-initial /n/. Bukshaisha also notes that /n/ shows very little pharyngealisation effect without introducing its F2 values. This is consistent with a look-ahead mechanism as posited in the window model. Sounds that are specified as [+high], i.e., /ʃ/ and /i/ are assigned narrow windows to allow for pharyngealisation effects. Bukshaisha's experiment has a number of experimental flaws. A serious one is the lack of controlling of the segmental composition. For example, the inclusion of /ʃ/ and /i/ in test items such as in the word /niʃiiT/ might contribute to minimising the magnitude of anticipatory pharyngealisation. Another limitation in Bukshaisha's experiment is that she examined a limited amount of data. In addition, Bukshaisha does not explain where her measurement points are taken. Furthermore, Bukshaisha's data is not subject to statistical analyses and the distance from the trigger in ms is not considered. These limitations in Bukshaisha's study make her finding rather questionable.

Ghazeli (1977) reports more pharyngealisation in the pre-trigger [i] in [biTHiiʕ] than in the pre-trigger [ii] in [bifiiTH] despite the fact that they both precede the pharyngealised consonants. Ghazeli attributes this difference in pharyngealisation magnitude to vowel duration differences (the first [i] in [biTHiiʕ] being 95 ms and the second [ii] in [bifiiTH] being 210 ms. Ghazeli does not show how these measurements are taken, though. Furthermore, Ghazeli compares the degree of pharyngealisation in the first [i] in both words [biTHiiʕ] and [bifiiTH] where the duration of [i] is constant. His measurements reveal that the pre-trigger [i] in [biTHiiʕ] is more pharyngealised than the first [i] of [bifiiTH]. In this case Ghazeli attributes the degree of pharyngealisation to the temporal distance (measured in ms) from the trigger /TH/. Although Ghazeli's measurements do not quantify the pharyngealisation effect, this pattern suggests a gradient pattern, where pharyngealisation magnitude decreases with the temporal distance from the trigger. Ghazeli does not explain how many points during each test vowel are measured. In addition, Ghazeli's data do not include measurements of duration. Moreover, Ghazeli does not show statistical assessment to account for the decrease of pharyngealisation as a function of the temporal distance from the trigger. These observed effects during the high vowel /i/ seem to be in line with the look-ahead assumptions as posited in the window model. A narrow window is assigned to the vowel and consequently allows for some pharyngealisation degree. Although these data are not subject to quantitative analyses, they seem to suggest a graded effect resulting from the temporal proximity to the pharyngealised trigger.

The data reviewed so far present conflicting results regarding the magnitude of pharyngealisation. Some of these data suggest that pharyngealisation is a categorical process resulting from phonological feature spreading. However, other data suggest a phonetic coarticulation that increases with the approach to the pharyngealised trigger. This gradient pattern of pharyngealisation seems consistent with the look-ahead predictions posited in Keating (1990). A major problem with these data is that they lack assessment of how the magnitude of pharyngealisation may vary with the temporal distance from the trigger, i.e., by measuring the duration of the affected sound(s). Other problems arise, as these data are not subject to statistical analyses. It turns out that a quantitative assessment of the magnitude of pharyngealisation extent is still lacking. This is needed to make a clear distinction between categorical phonological feature spreading and gradient phonetic coarticulatory processes.

3.4 The domain of pharyngealisation

The second aim in the present study is to search for the planned domain of pharyngealisation. The planned domain of pharyngealisation refers to the linguistic unit to which speakers intend to confine pharyngealisation effects. Previous studies agree that pharyngealisation extends beyond the pharyngealised trigger, but they disagree about how far it extends and consequently what linguistic unit serves as its domain. The discrepancies in proposed domains might be due to dialectal variations, different data and experimental techniques. Importantly, previous investigators seem to have different definitions of the domain of pharyngealisation. Thus, in our definition, the planned domain of pharyngealisation is the linguistic unit to which a speaker intends to confine pharyngealisation effects. In contrast, the surface domain is the physical realisation of the domain in the phonetic speech signal. This does not rule out some minimal effects outside the domain unit. Therefore, the planned domain of pharyngealisation might be shorter than the surface domain because articulators cannot move instantaneously from one articulatory position to another. In contrast, the planned domain might be larger than the surface domain due to coarticulatory resistance. Therefore, in order to present an accurate account of the planned domain it is crucial that the segmental composition in the test sequences is tightly controlled. It is important that a variety of prosodic domain candidates are examined keeping constant the test sequences to search for the planned domain of pharyngealisation.

3.4.1 The syllable

It has been reported that the possible syllables in Arabic are CV, CVC, CVV and CVVC (Younes 1982: 39). The syllable approach defines pharyngealisation as a feature of the syllable and its minimal span is the sequence CV (Lehn 1963, Broselow 1976). Because these investigators spoke of minimal effects, this syllable view does not seem to strictly confine pharyngealisation to the syllable, as there might be some pharyngealisation effects between syllables. Such minimal effects may well depend on the type of segments involved. In this view pharyngealisation is neither a feature of consonants nor of vowels but a feature of syllables. Lehn (1963: 38) states that, “An utterance of more than one syllable may have no syllable, or all syllables, or any one or more of its syllables with emphasis". He cites examples from Egyptian (Cairene) Arabic, e.g., [Darab] "he hit" where pharyngealisation spreads from the word-initial emphatic /D/ over the entire word (i.e., two syllables). Another example cited by Lehn is the word [bukra] "tomorrow", where pharyngealisation covers the second syllable in which the pseudo-emphatic consonant i.e., /r/ occurs. Crucially, some of Lehn's data include /r/, which induces a backing effect on adjacent vowels (Ghazeli 1977, Card 1983). Problems with Lehn's analysis arise in that the syllable view does not seem to be distinguished from the word hypothesis discussed below. In addition, Lehn's data are not experimental but they are based on impressionistic observations, though, Lehn's view that the syllable is the domain of pharyngealisation is widely cited. A precise definition for the domain of pharyngealisation needs to be based on comparable data items that solely include the pharyngealised sounds (that use pharyngealisation as a secondary articulation) compared with their plain cognates. This is to make certain conclusions that any effect is attributable to the existence of the emphatic segment.

The claim of the syllable as the domain of pharyngealisation can also be found in Broselow (1976). Broselow cites sequences such as, for example, [faDDal#ilwalad] "he preferred the boy" and [faDDa#lilwalad] "silver to the boy". These sequences show that the final consonant [l] in [faDDal] is rendered pharyngealised when it syllabifies in the rime of the syllable that contains the pharyngealised trigger. However, /l/ loses pharyngealisation when re-syllabified as the onset of the following syllable in the sequence [faDDa#lilwalad/. Broselow argues that when [l] is syllabified directly as onset of the syllable that does not contain the pharyngealised trigger it is never within the scope of pharyngealisation. Although Broselow argues that the syllable is the domain of pharyngealisation, the blocking of pharyngealisation effect, in this example, coincides with the word boundary. Thus, the blocking may well be attributable to the word boundary itself, rather than the syllable boundary. Watson (1999: 290) states that in the dialect of Abha, spoken in Saudi Arabia, pharyngealisation rarely spreads across the neighbouring vowel. Watson does not include a description of how this was diagnosed and she does not illustrate examples that support this claim.

In addition, Ali & Daniloff (1972) carried out an articulatory X-ray examination on data from the Arabic dialect spoken in Baghdad. Ali & Daniloff conclude that the spread of anticipatory pharyngealisation is a deliberate syllable-tied process. In Ali & Daniloff's definition for the syllable as a domain, the syllable boundary does not necessarily block the effects. Rather, the effects may extend as a feature of an entire syllable or syllables, but not individual consonant or vowel phonemes. Their results reveal that pharyngealisation extends from a pharyngealised sound to the surrounding vowels and open syllables and never extends over a monosyllabic word of a CVCC structure. Ali & Daniloff examined test words like [Ta.baa.ʃiir] "chalk". They note that pharyngealisation spreads from the word-initial trigger throughout the first two syllables. Ali & Daniloff attribute the blocking of pharyngealisation to the syllable boundary. Nevertheless, it is still possible that the blocking is due to the segments [ʃ] and [i], which are specified for [+high] and thus articulatorily incompatible with pharyngealisation. The third syllable in the word [Ta.baa.ʃiir] has [ʃ] as onset and followed by [ii]. Both [ʃ] and [ii] are incompatible with pharyngealisation as they are specified for the feature [+high]. Thus, the blocking of pharyngealisation may well be attributable to these two segments rather than to the syllable boundary itself. This lack of control in Ali & Daniloff's data weakens their claim that the blocking of pharyngealisation is solely attributable to the syllable boundary. In addition, Ali & Daniloff's study shows that in CVC sequences, where the syllable onset is an underlyingly pharyngealised trigger, pharyngealisation affects only the following vowel but not the syllable-final consonant. This latter CVC example in Ali & Daniloff appears compatible with the predictions of the CV-type articulatory syllable (Kozhevnikov & Chistovich 1965). The model assumes that consonants are programmed with the following vowel. The articulatory commands for the entire CV syllable sequence are simultaneously issued at the onset of the syllable. This makes pharyngealisation extend in the CVC sequence from the syllable onset to the nucleus, but not to the coda, as shown in Ali & Daniloff's data.

Ghazeli (1977: 121) shows that pharyngealisation is stronger within syllables than across them. For example, the [l] in [Sal.ɦin] "good-PLURAL" is more pharyngealised than that in [Sa.liɦ] "good-SINGULAR". According to Ghazeli, this view stems from the assumption that pharyngealisation degree is larger within syllable boundaries than across syllable boundaries. Ghazeli’s acoustic measurements show that the second formant of [l] in [Sal.ɦin] is 100 Hz lower than when it is not within the same syllable containing the trigger /S/ as in [Sa.liɦ]. Moreover, in Cairene Arabic, the word /Saɦbak/ “your friend” (Saɦb-friend, –ak YOUR) could be rendered [Saɦ.bak] where only the first syllable (i.e., which contains the underlying emphatic /S/) is pharyngealised (Cohen 1969, as cited in Ghazeli 1977: 119). Cohen, on the basis of such data, argues that only segments that are contained within the same syllable as the pharyngealised trigger are maximally pharyngealised. Thus, pharyngealisation effects are minimal if they are found across syllable boundaries.

Younes (1982) examined whether pharyngealisation extends across syllable boundaries, i.e., the syllable that contains the trigger to other syllables, and whether the magnitude of pharyngealisation within the syllable is equally spread. These were, to Younes, the criteria that the potential domain of pharyngealisation must meet. Although Younes’ had a good methodology to diagnose the pharyngealisation domain, his study was based on recordings read by him and by another male speaker. Another limitation in his study is that his study does not include a carefully controlled data items. For example, Younes compared F2 measurements for the emphatic contexts in /ballaaS/ “thief, M.” and /ballaaSa/ “thief, F.” to the F2 measurements for the word /malaak/ “owner”. Another example in Younes was a comparison of the emphatic words /ʕabiiT “unruly, M” and /ʕabiiTa/ “unruly, F.” with the plain control /ʃafiik/ “proper name”. These examples in Younes show that a careful control for the segmental composition is lacking. For example, he presented F2 values of the vowel [aa] to the left of the trigger /S/ in [ballaaS] “thief”, where the F2 value at the onset, mid and offset was 900 Hz 900 Hz 900 Hz, respectively. He also presented F2 values for the hetero-syllabic vowel [aa] in [balaa.Sa] “thief, F.”, where the F2 values were 990 Hz 980 Hz, and 990 Hz, respectively. The F2 values for the plain context were those of [aa] in [malaak] owner” 1500 Hz, 1530 Hz and 1520 Hz, respectively. Younes presented other F2 values for the tautosyllabic vowel [aa] in [faaD] “it, M. flowed”, where the F2 values were 1010 Hz, 1020 Hz and 1030 Hz, respectively. He presented F2 values for the hetero-syllabic vowel [aa] in [faa.Dat] “it, F. flowed”, where the F2 values are 1000 Hz, 990 Hz and1000 Hz, respectively. These F2 values in [faaD] and [faa.Dat] are compared to the F2 values for [aa] in [faat] "he entered", which were 1490 Hz, 1480 Hz and 1470 Hz, respectively. On the basis of these data in Younes (1982: 120), he notes that the pharyngealisation domain is not the syllable as the effects extend beyond the syllable boundaries, as shown in these examples. Younes also notes that when pharyngealisation is induced by a tautosyllabic pharyngealised trigger its magnitude is slightly larger than when induced by a hetero-syllabic pharyngealised trigger. In addition, Younes notes that these F2 values do not consistently correlate with the presence or absence of a syllable boundary, as was shown in the case of [faaD] vs. [faa.Dat].

Younes (1982: 122) takes the observation that the magnitude of pharyngealisation within syllable boundaries is not equally distributed as evidence against considering the syllable as the domain of pharyngealisation. For example he presented F2 values for [ii] in [Siib] "hit", where the onset, mid and offset points are 1100 Hz, 2000 Hz and 1940 Hz, respectively. F2 values for [ii] in [ʕabiiT] "unruly" are 1850, 1990 Hz and 1180 Hz, respectively. F2 values for [ii] in [balliiT] "tile layer" are 1250 Hz, 1750 Hz and 1300 Hz, respectively. These data, however, do not include a carefully controlled segmental composition to present a reliably precise pattern. In addition, they include L-R effects as in [Siib] and R-L effects as in [ʕabiiT] and [balliiT]. A major problem with Younes' data is that it was recorded from the author himself and another male speaker, and the data was not carefully controlled in terms of the segmental composition. In addition, Younes' F2 measurements were not subject to statistical analysis.

One problem with defining the syllable as the domain of pharyngealisation is that different domain types, i.e., the word and the phrase have been claimed in other studies. The syllable view of the domain does not seem to vary from the word view in some cases. In addition, what weakens the syllable argument is the fact that some test items lack carefully controlled segmental composition. This is crucial in order to precisely define the potential domain of pharyngealisation. Importantly, two major studies often cited in favour of the syllable as pharyngealisation domain are not based on experimental data – Lehn (1963) and Broselow (1976). The only experimental account for the syllable as the domain of pharyngealisation comes in

Ali & Daniloff (1972). As was discussed above, the study is not based on careful control for the segmental composition and for syllable boundary manipulation.

3.4.2 The word

The claim that the word is the domain of pharyngealisation is more common in the literature than those in support of other domain types (Ghazeli 1977, Card 1983, Herzallah 1990, Davis 1995, Zawaydeh 1999, Shahin 2002, Watson 2002, Bin-Muqbil 2006, Hassan 2005, Al-Masri 2010). Card (1983) in a study examining four Palestinian speakers, reports that pharyngealisation extends from the trigger in both directions throughout the entire word. Card's results are based on emphatic/plain comparisons but are not subject to statistical analyses. (Ghazeli 1977:92) notes that pharyngealisation effects may spread across boundaries within the word, i.e., morpheme and syllable boundaries making the entire word as its domain. Data from Libyan Arabic in Ghazeli suggest that the morphemes (/-at/ = feminine marker, and /-a/ = third person masculine object pronoun) when added to the verb /Sam/ "fasted" = /Sam-at-a/ "she fasted it" the resulting word is [Samata], which, according to Ghazeli, is entirely pharyngealised. Other data for within word boundaries are cited in (Davis 1995). Davis states that bound morphemes may differ in the way they interact with the spread of pharyngealisation effects. For example, the inflectional negative prefix /ma-/ in [mayaSSaSish] may surface as either pharyngealised or plain. The derivational prefix /ma-/ in [manaafiTH] must be pronounced as pharyngealised.

Ghazeli claims that word boundaries block pharyngealisation effects. Ghazeli's claim is based on data that do not allow for testing the effects across word boundaries. For example, Ghazeli examined anticipatory pharyngealisation in the phrase [beet # iTTahir] "Al-Tahir's home". The second word in the sequence contains a pharyngealised trigger /T/, which is preceded by the word-initial high front vowel /i/ and then by a word boundary. The blocking of anticipatory pharyngealisation cannot be solely attributable to the word boundary, as other segmental factors are not tightly controlled for, i.e., the high vowel /i/. This weakens the claim that word boundaries block pharyngealisation effects. Ghazeli's definition of the domain differs from that of Younes in that pharyngealisation effects must be contained within the domain unit regardless of their magnitude. In other words, all elements within the domain of pharyngealisation are not necessarily equally pharyngealised in Ghazeli's approach. This is clear in Ghazeli's account, where although morpheme and syllable boundaries restrict pharyngealisation he concludes that the word serves as the domain of pharyngealisation effects. As was discussed above, Ghazeli observed that the magnitude of pharyngealisation effects gradually decreases across syllable and morpheme boundaries. The observed gradual decrease in the magnitude results with the word, which is the domain of pharyngealisation, showing a gradually varying magnitude.

Data from Iraqi Arabic suggest that pharyngealisation extends throughout the entire word (Hassan 2005). Hassan's acoustic data included one, two and three syllable words. In each minimal pair, they included either an emphatic or a non-emphatic consonant. Hassan shows that pharyngealisation extends either forwards or backwards making the word as its domain. Hassan's results contradict Ali & Daniloff's claim that the syllable is the domain of pharyngealisation in Iraqi Arabic, although Hassan examined some items, which were included in Ali & Daniloff (1972) such as the word [Ta.baa.ʃiir] "chalk". Thus, such a discrepancy within the same dialect might be due to different experimental techniques, different methodologies. It might also be due to language change or different styles or speaker behaviour.

In addition, in Cairene Arabic, according to (Watson 2002), the whole phonological word is rendered pharyngealised in the presence of an underlying emphatic segment, [Subyaan] "boys" (ibid: 274) but Watson does not include how this was diagnosed.

Although many investigations agree that the word serves as the domain of pharyngealisation, there are some claims that contradict this word claim, such as the syllable and the phrase. In addition, it has been clarified in this section that previous data seem to lack careful control for the segmental composition and lack also statistical analysis to confirm that the word is the domain of pharyngealisation. It is, therefore, still requiring a close assessment to ascertain that the word is the domain of pharyngealisation.

3.4.3 The phrase

In Qatari Arabic it has been shown that pharyngealisation does not respect word boundaries, suggesting that the phrase is the domain of pharyngealisation (Bukshaisha 1985: 265-267). For example, in the phrase [beet # Taayir] “a flying home”, the [ee] vowel in the first word is pharyngealised. Its F2 value is 1500 Hz as opposed to 1800 Hz in the non-pharyngealised environment (i.e., F2 is lowered by 300 Hz). The word-final [t], which is underlyingly plain, is assimilated to the post boundary pharyngealised trigger [T] allowing pharyngealisation to extend to the preceding [ee]. Bukshaisha also notes that the pharyngealisation effect of [T] spreads to all following segments within the word. Another example in Bukshaisha is the phrase /bas # iSiir/ “will happen”. Bukshaisha’s acoustic data show that the underlying pharyngealised /S/ exhibits a strong influence on the preceding and following vowels. The F2 value of /a/ in the first word /bas/ is lowered from 1500 Hz to 1250 Hz. Although the pharyngealised /S/ is preceded by a syllable boundary, a high front vowel, and then a word boundary, it exerts a strong effect (250 Hz lowering) in /a/. Thus, despite the combination of these three factors (the syllable boundary, the high front vowel and the word boundary) anticipatory pharyngealisation extends across word boundaries in this example. A problem with Bukshaisha’s finding is that her results were based on only three tokens to test anticipatory pharyngealisation across word boundaries. In addition, Bukshaisha’s results were based on emphatic/plain F2 comparisons without any statistical analyses.

Younes (1982: 135) presented some data that clearly show pharyngealisaton effects across word boundaries. Measurements in the phrase [ʔaʒa # Saalaħ] “Saalah came” compared with [ʔaʒa # saalim] “Salim came” show that the word-final [a] has a gradual effect of pharyngealisation. More clearly, the degree of F2 drop is larger at the vowel offset (1260 Hz vs. 1530 Hz). At the mid point the amount of F2 lowering decreases (1370 Hz vs 1520 Hz). At the onset point, however, there is very little pharyngealisation effect when compared to the plain counterpart (1460 Hz vs 1550 Hz). Another test phrase that suggests a gradual effect across word boundaries is [banaat # Saalaħ] “Saalih’s daughters” vs [banaat # saalim] “Salim’s daughters”. The second [aa] in [banaat] in the pharyngealised context has F2 values of 1420 Hz, 1380 Hz, 1260 Hz for the onset, mid and offset points, respectively. These are compared with the F2 values in the plain context, i.e., 1480 Hz, 1490 Hz, 1490 Hz, respectively. Another minimal pair examined in Younes (1982) is [banaat # iSSali] “the good man’s daughters” vs [banaat # issalim] “the Salim daughters”. The F2 values in the second vowel are 1480 Hz for the onset, 1490 Hz for the mid, 1510 Hz for the offset point compared to the plain counterparts 1420 Hz, 1500 Hz, 1630 Hz. This shows a 200 Hz drop at the offset point, a 100 Hz drop at the mid point and no effect at the onset point of the vowel. These measurements show a phonetic pharyngealisation effect across word boundaries. On the basis of such findings, Younes argues against the phrase as the domain of pharyngealisation because the elements within the phrase are not equally pharyngealised.

Card (1983) examined pharyngealisation in Palestinian Arabic and she noted that when the trigger occurs word-initially anticipatory pharyngealisation effects are likely to affect the preceding word, although Card argues for the word as the domain of pharyngealisation. However, in her study Card was not interested in quantifying the magnitude of the effects across word boundaries to see how they might vary from those effects observed within word boundaries. It is possible that the across word boundary effects are different in nature from when they are found within word boundaries.

To summarise, previous studies provide conflicting reports regarding the domain of pharyngealisation. One possibility is that this domain discrepancy is due to different definitions of the domain. It is also possible that these conflicting claims are due to experimental confounds. It also becomes clear that many of these studies examined a limited number of items. In addition, many of these results, for example, Ghazeli (1977) Card (1983), Younes (1982) and Bukshaisha (1985) were not subject to statistical analyses. Taken together, all these experimental shortcomings may well contribute to weaken previous claims regarding the domain of pharyngealisation. It is also possible that different dialects may take different domains of pharyngealisation.

It becomes clear that there is a need for a close assessment of pharyngealisation domain. Examining a variety of pharyngealisation domain candidates in carefully controlled data is still lacking. The present study undertakes to assess anticipatory pharyngealisation across a hierarchy of prosodic boundary types, i.e., syllable, word, phrase and intonation phrase. This will be an attempt to find out if there is a single planned domain of pharyngealisation or if the magnitude of pharyngealisation gradually increases as a function of prosodic boundary level.

3. 5. Conclusion

Previous research on pharyngealisation provided information about the acoustic and articulatory manifestations of pharyngealisation. It has been shown that pharyngealisation extends beyond the pharyngealised trigger up to as early as six sounds prior to the trigger. Clearly, despite these findings, previous research on pharyngealisation suffers from certain limitations. Some of these limitations are conceptual and others are methodological in nature. These are summarised below where relevant.

Firstly, this chapter shows that previous research on pharyngealisation has not closely considered the theoretical concepts in speech production models. It is very crucial to test pharyngealisation data against the predictions and assumptions of current models. It becomes clear in the present chapter that previous studies on pharyngealisation extent have introduced contradictory findings regarding the magnitude of pharyngealisation. For example, some of these results suggest that pharyngealisation may extend categorically regardless of the duration of the affected sound(s). Others suggest that pharyngealisation is a phonetic process of coarticulation that increases in magnitude as the trigger is approached. Thus, it is still unclear as to whether pharyngealisation is a phonological feature spreading or a process of phonetic coarticulation. It will be undertaken in the present study to tease apart phonological from phonetic characterisations of pharyngealisation magnitude. A key issue, which was not considered in previous studies in this regard, is to consider the duration of the pre-trigger test sequence in ms. This allows quantifying the magnitude of pharyngealisation as to whether it is a categorical feature spreading or a phonetic coarticulatory effect that decreases over time. Thus, a distinction between phonological and phonetic characterisations of pharyngealisation extent is still lacking.

Second, it becomes clear in this review that previous studies provide conflicting findings concerning the domain of pharyngealisation. Three domain types have been reported, i.e., the syllable, the word and the phrase. One possibility is that this domain discrepancy might be due to dialectal variations, an issue, which is beyond the scope of this thesis. Another possibility is that these discrepancies are attributable to experimental confounds. This is likely because previous data seem to lack careful control of segmental composition and boundary type. Importantly, the domain discrepancy seems to be due to different domain definitions. One view is that all elements within the domain unit are equally pharyngealised. Another view is that all effects observed must be contained within the domain regardless of whether they are equal in magnitude or not. In addition, many previous studies examined a limited number of items, and sometimes using data from the researcher themselves. In addition, many previous results, for example, Ghazeli (1977), Card (1983) and Bukshaisha (1985) were not subject to statistical analyses. Taken together, all these conceptual and experimental limitations may well contribute to weaken previous claims regarding pharyngealisation extent and domain.

The present dissertation seeks to tell apart what might be phonological from what might be phonetic regarding pharyngealisation magnitude. It is also undertaken to search for the planned domain of pharyngealisation across a hierarchy of prosodic boundary strengths. In the next Chapter, I introduce the experimental methodology I take in order to answer these two main research questions.

Chapter 4. Methodology

4.1 Research questions

The first research question in the present study is to find out if the magnitude of pharyngealisation is categorical or gradient. Previous research and data on pharyngealisation are consistent with two fundamentally different sources of the anticipatory pharyngealisation: 1) phonological feature spreading that extends categorically throughout a specific domain, and 2) phonetic coarticulation that extends in a gradient magnitude. It became clear in previous chapters that teasing apart phonological and phonetic characterisations of pharyngealisation magnitude is still lacking. As discussed in Chapter two, there is a body of theoretical assumptions and model predictions that can be drawn on in interpreting experimental data. Unfortunately, these were not seriously considered in previous research on pharyngealisation. In this study, carefully controlled quantitative data are presented and interpreted in light of current models of speech production.

The second research question relates to the planned domain of pharyngealisation. As discussed in Chapter three, divergent claims in the literature about the domain of pharyngealisation may be due, at least in part, to experimental confounds. Carefully controlled data are presented here to search for the potential domain of pharyngealisation in a hierarchy of boundary level, i.e., syllable, word, phrase and intonation phrase. The rationale underlying this is to see how to best define the domain of anticipatory pharyngealisation.

The research questions are summarised below:

a) Is pharyngealisaton a phonological feature spreading mechanism or a phonetic coarticulatory process? Considering the temporal distance of the measurement point from the trigger is a key methodological strategy to tease apart both distinctions.

b) What is the planned domain of pharyngealisation? If there is no specific single domain unit of pharyngealisaton, is there a hierarchical effect as a function of prosodic boundary strength?

In addition, the present study seeks to introduce a quantitative description of pharyngealisation in Libyan Arabic. To my knowledge no such formal account exists.

4.2 Model prediction

Feature-spreading accounts (Daniloff & Hammarberg 1973) assume that pharyngealisation will spread categorically as long as there is no contradictory feature intervening. A categorical feature spreading of anticipatory pharyngealisation will surface as an equally distributed magnitude throughout whatever domain it takes regardless of the duration of the affected sound(s). This means that the increase in the duration of the affected sound(s) will not contribute to decreasing the magnitude of the effect of pharyngealisation. Feature spreading accounts posit that the high vowel /i/ will block/largely attenuate pharyngealisation effects, as it is specified for [–pharyngealisation].

Within a phonetic model of coarticulation (Henke 1966, Keating 1990), it is assumed that movement towards the pharyngealisation target will start as soon as possible, depending on the absence of contradictory feature intervention. The model assumes that the magnitude of pharyngealisation will increase as the trigger is approached. This implies a decrease in pharyngealisation magnitude with the temporal distance from the pharyngealised trigger. This will surface in a smooth trajectory of pharyngealisation connecting specified segments. Another view of a gradient phonetic coarticulatory process comes in articulatory phonology. In this view pharyngealisation is a local gradient effect increasing with the approach to the pharyngealised trigger.

4.3 Speakers

Six male Libyan speakers took part in this study. They belong to two major varieties of Libyan Arabic (four from the western region of Tripoilitania and two from the eastern region of Cyrenaica). All participants were postgraduate students in different UK universities. Their age was between 20-40 years old and they volunteered to participate in this study. They reported no history of speech or hearing problems. All subjects were uninformed as to the purpose of the study. They were instructed to repeat any utterance that was unsatisfactory either to them or to the experimenter.

4.4 Speech samples

Evidence that syntactic manipulation can bring about hierarchically varying boundary strength came from Kainada (2010). In her thesis, Kainada investigated the effect of boundary strength on the acoustic manifestation and suprasegmental processes. She used a principled methodology of manipulating syntactic structure above the word level to design varying degrees of boundary strength, as proposed in Nespor & Vogel (1986). The lowest prosodic level in Kainada's data was a clitic group incorporating an independent lexical word preceded by a clitic. On the next higher level, the construction was a pre-boundary adjective followed by a post boundary noun (corresponding to a phonological phrase boundary). The pre-boundary adjective belongs to a prepositional phrase and the post-boundary noun served as an object of the verb of the main clause. On the third higher level there was a pre-boundary adjective in the right edge of a subordinate clause followed by a post-boundary noun at the left edge of a main clause starting with a noun phrase (corresponding to an intonation phrase). For the highest boundary level, Kainada used the same construction in the intonation phrase condition but both the main and subordinate clause were longer (corresponding to an utterance boundary).

Kainada's results provided support for the hierarchical nature of prosodic constituent structure. For example, this hierarchy is mirrored in the variation in the duration of pre-boundary syllables. In addition, Kainada reported hierarchical decrease in coarticulatory patterns from lower to higher boundary levels. Furthermore, Kainada reported that F0 scaling at the level of the phrase illustrated a varying effect in favour of a hierarchical prosodic structure, with lower pre-boundary H peak scaling across higher boundary levels. Thus, theoretical support that syntactic information can affect phonological processes exists.

In the present experiment, the occurrence of the pharyngealised sounds within word boundaries, i.e., the syllable condition is either word finally or medially. The syntactic categories of these independent words are either [noun], [verb] or [adjective]. A variety of morphological constructions, i.e., stems plus affixes or affix-free stems are created. Syllables in Libyan Arabic can have short vowels, e.g., VCC, CV, CVC, CVCC, CCV, CCVC, CCVCC and CCCVCC. Syllables can also have long vowels, e.g., VVC, CVV, CVVCC, CCVV, CCVVC and CCCVVC Laradi (1983: 25-26).

In the word boundary condition a pre-boundary noun is [stem #] in some cases, e.g., [dabaaba # Taayra] [tank (Fem.) # flying] “a flying tank”. In other cases it is [stem + suffix] followed by a word initial pharyngealised trigger, e.g., [arabi + Taayer], [Arab (Msc) + flying] “a flying Arab”. The post-boundary adjective containing the trigger is always [stem + suffix]. It should be noted that Arabic affixes never contain a pharyngealised phoneme. Therefore, because Arabic prefixes never contain a pharyngealised sound, the adjective is always a prefix-free stem. This is mainly to have the trigger in the initial position for the post-boundary adjective and is preceded by the pre-boundary test sequence at the end of the noun.

The phrase boundary condition always incorporates a pre-boundary [noun + suffix #]. The post-boundary verb [stem + suffix] starts with a pharyngealised trigger, e.g., [dabaaba # Taarit] [tank (Fem.) # flew] “the tank flew”.

The intonation phrase boundary condition incorporates a pre-boundary noun [stem #] in some cases, e.g., [Hasb kalaam iddabaaba #] “according to the tank”. In other cases it is [stem + suffix] followed by a word initial pharyngealised trigger, e.g., [Hasb kalaam il-arabi #] “according to Arab”. The post-boundary proper name always starts with a pharyngealised trigger, e.g., [# SalaaH]; [# Taahir] and [# Diyaa], i.e., proper names.

Condition	**Pharyngealised**	**Plain**
Within word (syllable)	[m**abaa.**Dish] “it did not lay eggs”	[m**abaa.**dish] “it did not wear out”
C1: [NP[N# ADJ]]: (Word)	[dibb**aaba**#Daayʕa] “a tank that is missing”	[dibb**aaba**#daafya] “a warm tank”
C2: [S[NP]#[VP]]: (Phrase 2)	[ibn ʕam il-dab**aaba**#Daaʕ] “the cousin of the tank went missing”	[ibn ʕam il-dab**aaba**#daab] “the cousin of the tank melted”
C3: Parentheticals: (Full Intonational phrase)	[binnisba li-dibb**aaba**#Daaʕ] “According to the tank, went missing”	[binnisba li-dibb**aaba**#daab] “According to the tank, melted”

Table 2: The four data conditions used in this study. C1 – C3 conditions are syntactically defined

Stimuli were presented to speakers and read from randomized lists written in Arabic. Subjects were asked to read the lists two times in a normal speech rate. Whenever the participants or the experimenter noted any suspicious articulation, i.e. stammering, unusual pause etc., the token was then said again.

4.5 Recording and digitizing

Data were recorded in the studio of the Department of Linguistics and English Language, The University of Edinburgh. The data were recorded with a portable (M-AUDIO Microtrack 2) and a high quality unidirectional dynamic (audio-technica ATM73a) microphone with a windshield attached to it. The microphone was head-worn, placed very close to the speaker’s mouth and positioned on either side to avoid unwanted air puffs. These recordings were made at 16-bit resolution with a 40 kHz sampling rate. All data were transferred to a laptop and saved in WAV files. The number of items in each condition submitted to statistical analyses was as follows:

[aba]: syllable condition = 8, word condition = 21, phrase condition = 16, intonation phrase condition 15.

[abi]: syllable condition = 2, word condition = 9, phrase condition = 16, intonation phrase condition = 16.

[iba]: syllable condition = 9, word condition = 15, phrase condition = 17, intonation phrase condition = 19.

[ibi] syllable condition = 3, word condition = 12, phrase condition = 15, intonation phrase condition = 15.

Table 3: Total number of minimal pairs in the four vowel contexts and four boundary conditions. Each item is recorded twice. The number of these data is multiplied by 2 (plain/emphatic) gives the total data analysed in the present experiment.

4.6 Segmentation

Editing of the sound files, segmentation and formant tracking were performed onscreen using the Sound Edit function in Praat (Boersma and Weenink 2005), with the following settings: for (spectrogram) analysis window length 5 ms, dynamic range 30 db; (for formant) maximum formant 5000 Hz [suitable for all male subjects], number of formants 5, analysis window length 25 ms, dynamic range 40 db, and pre-emphasis from 50 Hz, using the Burg algorithm.

Segmentation criteria followed in the present study were based on identifying constriction onsets and releases as outlined in Turk et al (2006). First-pass segmentation was performed on zoomed out spectrogram displays for defining general boundary regions (within an accuracy of 5-10 ms) as shown in (Figure 5).

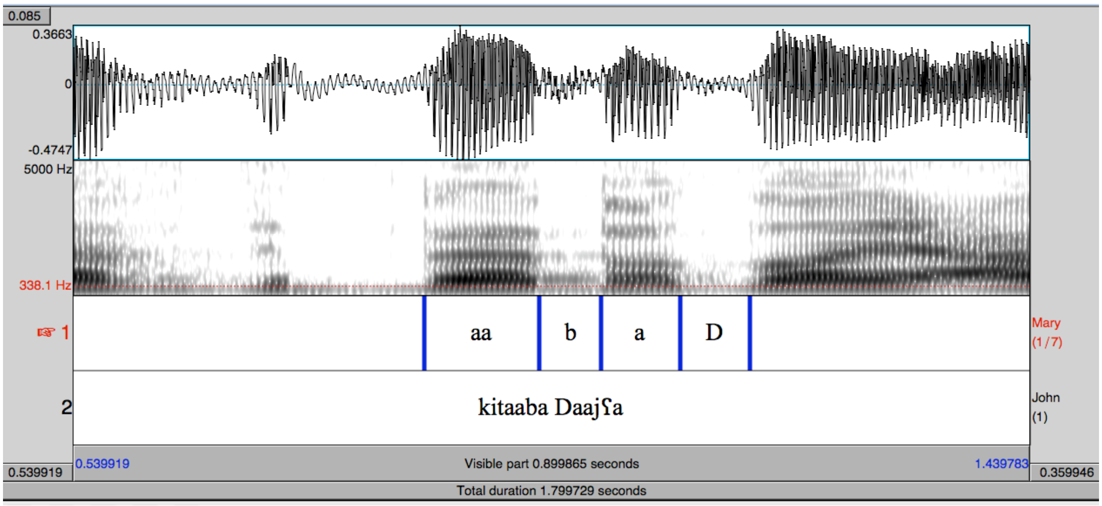

Figure 5: First-pass segmentation was based on spectrogram display.

A fine-grained segmentation procedure was then performed by more zoomed in waveform displays as illustrated in (Figure 6).

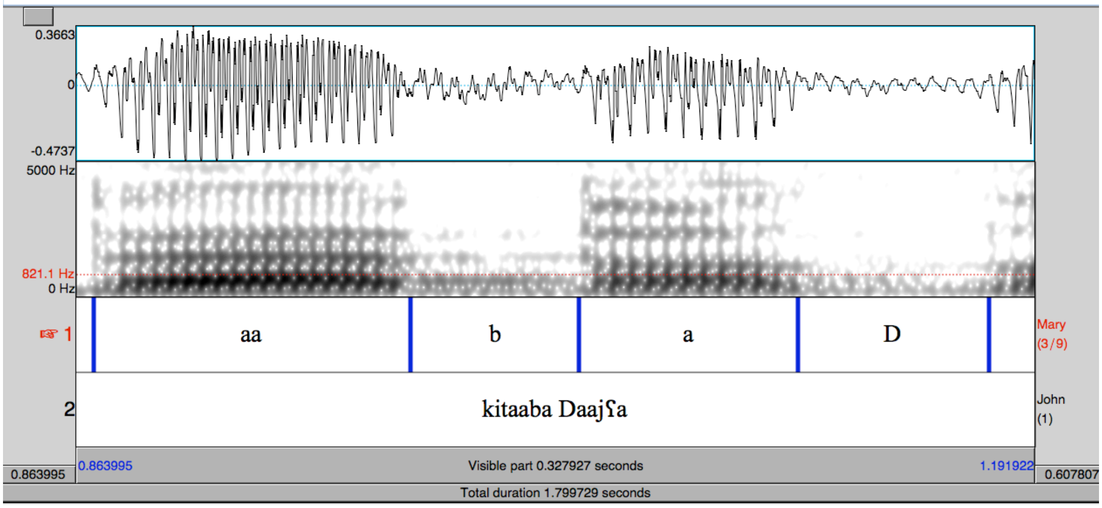

Figure 6: A zoomed-in waveform for fine-grained constriction onset labelling.

In all our test sequences ([VbV+ EMPHATIC]) stop constriction onsets were defined at F2 offset, which coincides with an overall dip in magnitude as shown in (Figure 5). Stop constriction release was defined at the first release burst. If the burst of the stop release was not clear then it was marked near the point of F2 onset. The VOT interval was included as part of the duration of the following vowel. This is so to make reliable comparability of [T vs. t], for example, with [ðˤ vs ð; S vs. s] and [D vs. d] (i.e., voiceless stops, fricatives and voiced stops, respectively). Fricative boundaries, e.g. [TH, DH, S, s] were marked at onsets/offsets of frication energy. There is one case where a vowel is preceded by a pharyngeal, e.g., /ʕabiiT/ “stupid”. No segment boundary was marked between a vowel and a preceding pharyngeal. This was due to the difficulty of approximant segmentations see Turk et al (2006).

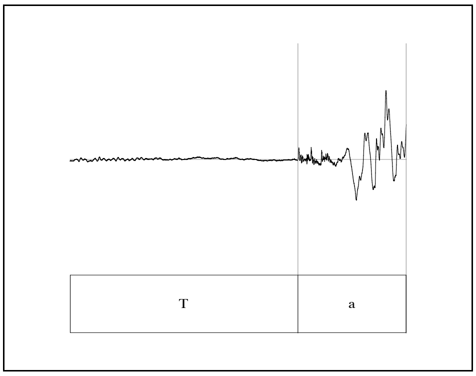

Figure 7: VOT is part of the vowel interval in CV sequences in the phrase [kitaaba # taayba] “cooked writing”

In pre-pause positions (i.e. the end of intonation phrase), the segmentation criterion for vowels was based on continuous F2 energy see (Figure 8). The plain/emphatic (triggers) were marked at their constriction release phase in post-pause locations. This is due to the difficulty of determining constriction onsets in a reliable way. This will contribute to increasing the duration of the pre-boundary pause interval.

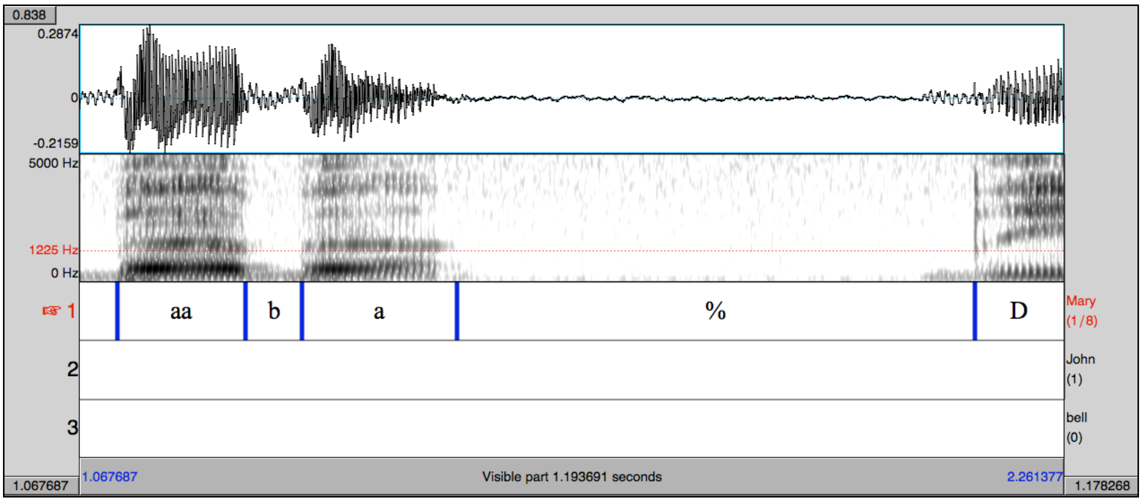

Figure 8: Segmentation criteria for vowels in pre-pause locations were based on continuous F2 energy.

In our data, each sound file will incorporate a single test item including the carrier phrase, but only our test sequences [VbV+Emph] were segmented. A point tier was added just below the segmentation tier. On the point tier three measurement points were allocated (e.g., Onset, mid-point and offset at both test vowels). Vowel onset and offset measurement points were defined 15 ms away from the neighbouring consonants constriction onset and release. This was mainly to avoid direct consonant information in our F2 measurements, see (Figure 9).

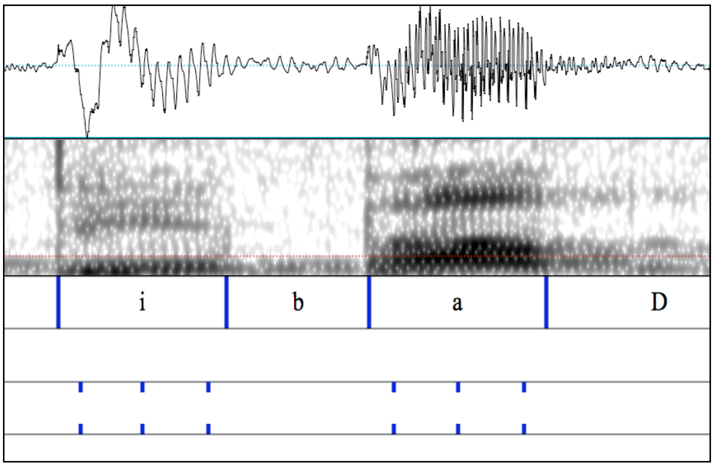

Figure 9: A spectrogram of the sequence [iba+D] shows three measurement points marked in both vowel intervals (onset, midpoint, offset).

Through the use of scripting syntax, Praat allows automation of formant tracking. A script (written by Michael Bennett) was used to automatically track F2 at all marked measurement points. The script then transfers F2 values to a spreadsheet. Formant values were verified manually. Extreme F2 values were checked and they were corrected in the original data sheet. This was carried out separately for each speaker, in each vowel context and in each boundary condition. The data then were submitted to statistical analyses.

4.7 Analysis and statistical tools

Data outlined here were submitted to linear mixed effects modelling using the R open-source language and environment for statistical computing (R Development Core Team 2011). The Lme 4 package was used for parameter estimation and model evaluation. Analyses were run separately, at each measurement point for each vowel context, i.e., ([aba], [abi], [iba], [ibi]), with F2 as the dependent variable. Five possible independent variables (three fixed, two random) were deemed to be of possible interest in the phonetic analysis of anticipatory pharyngealisation. Fixed factors were plain/emphatic, boundary and duration. The models included random intercept adjustments for subject and item. In order to assess for speaker and item variability, the regression models were compared with models that contained additional random effects, i.e., by-subject random slopes for the effect of boundary level on duration, the effect of duration as well as the effect of boundary level on pharyngealisation. A model that included three-way interaction (plain/emphatic by-boundary by-duration), all possible two-way interactions (i.e., plain/emphatic by-boundary, plain/emphatic by-duration, boundary by-duration), and main effects for the three fixed factors was justified by the anova function provided in the *lme* 4 *package* for model comparison. P-values were obtained using the (*pvals.fnc)* function in *lmer*, using Markov chain Monte Carlo (MCMC) sampling.

As mentioned in (Table 4), there are three independent fixed factors in our analysis of pharyngealisation: plain/emphatic, boundary level and final vowel duration (including the pause in the intonation phrase boundary condition). The predictor estimates for the boundary condition parameter represent the effect on the test sequence in the emphatic context across word boundary as compared to that in a plain context across syllable, phrase and IP boundary. The predictor estimate for the three-way interaction represents the increment or decrement in F2 value predicted by the model when the test sequence occurs in a plain context, its position is either across syllable, phrase and IP boundary, compared to when it is emphatic and across word boundary. In models that include final vowel duration the predictor estimate for the interaction indicates pharyngealisation in Hz as predicted by duration measured in ms.

In order to examine the duration variation across the four boundary conditions, a model was fit for V1 duration (including the pause in IP condition) as a dependent variable. This is carried out separately for each vowel context. One independent variable was included, i.e., boundary. In addition, a best-fit model was constructed for the data at V2 onset. This is primarily to assess the total duration of the phonetic test sequence. The dependent variable was the entire test sequence. The independent variable was boundary type. (Table 4) illustrates all variables used in our data analyses.

Dependent variable	**Independent variables**	
F2 measurements	**(Fixed)**	**(Random)**
Final duration of the test sequence	Vowel sequence (aba, abi, iba, ibi)	Subject
Total duration of the test sequence	Boundary (syllable, word, phrase, IP)	
	Plain vs. Emphatic	Item
	Final vowel duration. This includes IP pause duration including the duration of the following constriction. This was due to due to the difficulty to determine constriction onsets following pauses.	
	Total duration of the test sequence	

Table 4: A summary of variables constituting our statistical analyses.

Chapter 5. Results

The first issue in the present experiment is to assess whether pharyngealisation is phonological or phonetic. Phonological pharyngealisation can be realised by an equally distributed magnitude of pharyngealisation, i.e., F2 lowering regardless of the duration of the affected sound(s). In contrast, phonetic pharyngealisation can be realised in a gradual increase in magnitude as the trigger is approached. A key diagnostic in the present experiment is to quantify how the magnitude of pharyngealisation may vary with the duration of the sound(s) being affected.

The second issue underlying the present experiment is to search for the planned domain of pharyngealisation. This is assessed in a hierarchy of presumed boundary types, i.e., syllable, word, phrase and intonation phrase. The planned domain of pharyngealisation is the linguistic unit to which speakers intend to confine pharyngealisation effects. Marginal effects outside this domain unit are possible because the articulator cannot move instantaneously from one articulatory position to another. For this reason, the surface domain of pharyngealisation might be larger that the planned domain. Other cases, where the surface domain might be shorter than the planned domain are also possible because of segmental and/or prosodic coarticulatory resistance.

We first start the analysis by assessing if the duration (i.e., the pre-trigger vowel duration and the entire duration of the test sequence) varies among the different boundary conditions. An assessment of the duration of the pre-trigger vowel with reference to boundary level was carried out in the test sequence: [VbV + EMPHATIC TRIGGER]. This is a key strategy to distinguish phonological feature spreading from phonetic coarticulation. More specifically, if the magnitude of pharyngealisaton spreads in an equally large degree regardless of the duration factor it is, then, a feature spreading. If the duration contributes to decreasing the magnitude of pharyngealisation, then, it is a process of phonetic coarticulation. This analysis was carried out separately for each vowel context, i.e., [aba], [abi], [iba] and [ibi].

The same procedure was carried out for the total duration of the test sequence. The duration of the pre-trigger vowel will later be included as a covariate to test for the magnitude of pharyngealisation extent at the onset of the first vowel in the sequence. The duration of the entire test sequence will be included as a covariate to assess the magnitude of pharyngealisation extent at the onset point of the first vowel in the sequence. These two steps will provide quantitative assessment of pharyngealisation magnitude during whatever vowel(s) that may fall within the scope of pharyngealisation. In addition, the analyses carried out here will seek to define the domain of pharyngealisaton.

5.1 Duration analysis

Let us first establish the claim that the pre-trigger vowel, in each vowel context, varies in duration among the four prosodic boundary conditions.

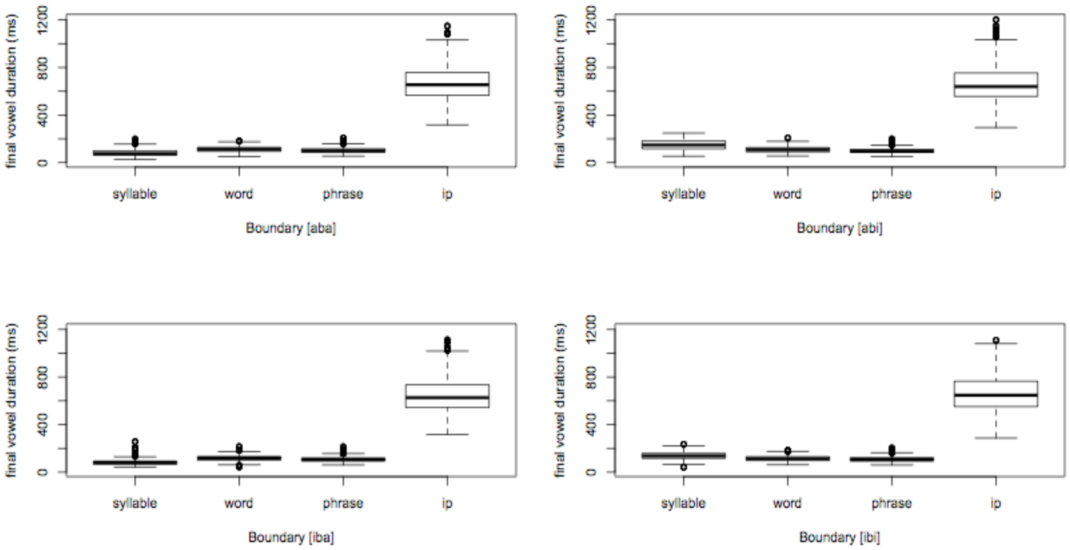

Figure 10: Variation in the duration of the final vowel as a function of boundary level

As illustrated in (Figure 10), each panel shows the variation among the four boundary conditions in each vowel context. There is a three-way boundary distinction, i.e. IP>(word and phrase)>syllable in two vowel contexts, i.e. [aba] top left panel and [iba] bottom left panel. In [abi] top right panel and [ibi] bottom right panel, there is a three-way boundary split, i.e., IP>syllable>(word and phrase). This suggests that there is no word/phrase distinction in all the four vowel contexts. Thus, the word and phrase conditions show closely similar pattern of final duration in all vowel contexts. The syllable condition in [abi] and [ibi] displays larger final vowel duration than word and phrase boundary conditions. As was clarified in the methodology chapter above, we remind that in our test sequences [V2bV1 # Emphatic trigger], across syllable boundary, each of V1 (the pre-trigger or the ultimate vowel) and V2 (the penultimate vowel) included, in some cases, phonologically different vowel lengths, as it was impossible to control for vowel length within words. Thus, the data included words like [hab**a.**Tit] "it landed" and [mab**aa.**Dish] "did not lay eggs" (the underlined vowels are referred to as ultimate vowel (V1), and pre-ultimate vowel (V2) in (Figures 11-14) below. In addition, across syllable, word, phrase and IP boundaries, V2 was not in all cases comparable as data items included two different phonological vowel quantities (long and short). For example, in the word [dab**aa**ba # EMPH] "tank" V2, which is the penultimate vowel, is longer than that in the word [hal**a**ba # EMPH] "ring". Other examples were [ʃal**a**bi # EMPH] "proper noun" and [ʃal**aa**bi # EMPH] "proper noun". In addition, all V1 segments were underlyingly short across the word, the phrase and the IP boundaries. However, this was not the case for the syllable condition, as it was impossible to have always exactly comparable sequences *within* words. Thus, in the syllable condition, the number of tokens that included [VbVV] sequences was nine, and the number that included [VbV] sequences was 12 tokens.

To statistically examine this pattern, a linear mixed effects model was constructed for the pre-trigger vowel duration (including the pause in the IP boundary condition) as a dependent variable separately in each vowel context. One independent variable was included, i.e., boundary. (Table 5) shows that in [aba] vowel contexts, the predictor estimate for the intercept is 106 ms, referring to the word boundary condition. The duration of the pre-trigger vowel does not significantly vary in the word and the phrase conditions. This means that the word and the phrase boundary conditions do not significantly differ in terms of pre-trigger vowel duration. The pre-trigger vowel duration increases by 563 ms in the IP boundary condition. In the syllable condition, the duration of the pre-trigger vowel decreases by 23 ms compared to the word condition. Thus, the main effect of the syllable and the IP is significant ($p<0.05$) and

($p<0.05$), respectively. This gives evidence that only the syllable and IP conditions significantly differ from the reference level in the model, i.e., the word condition.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	106.751	107.012	70.63	147.064	0.0002	0.0000
Syllable	-23.589	-23.698	-45.12	-2.168	0.0310	0.0312
Phrase	4.266	3.885	-16.90	25.153	0.7250	0.6890
IP	563.172	562.847	542.49	584.442	0.0001	0.0000

Table 5: Linear mixed effects results at V1 onset point for the pre-trigger vowel duration across the four boundary conditions in [aba] vowel contexts

An additional analysis was carried out to assess the total duration of the test sequence in [aba] vowel condition. Results in (Table 6) show that the total duration of the test sequence is 237 ms in the syllable condition, 296 ms in the word condition, 294 ms in the phrase condition and 859 ms, including the pause in the IP condition.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	296.508	296.846	249.95	343.83	0.0001	0.0000
Syllable	-59.178	-59.124	-92.36	-26.39	0.0006	0.0007
Phrase	-1.942	-2.518	-35.27	32.36	0.8784	0.9150
IP	563.737	563.257	529.36	598.02	0.0001	0.0000

Table 6: Linear mixed effects results at V2 onset point for the total duration across the four boundary conditions in [aba] vowel context

Turning to the [abi], results reveal that the pre-trigger vowel across a syllable boundary is longer than that across word and phrase boundary types. This pattern was not predicted because the syllable boundary condition was thought of as a weaker boundary type. (Table 7) shows that the predictor estimate for the intercept is 108 ms, referring to the pre-trigger vowel duration in the word condition. The duration of the pre-trigger vowel in the phrase boundary condition is 106, as it decreases by only 2 ms. However, it is 669 ms in the IP condition including the pause, as it increases by 561 ms. Across the syllable boundary the duration is 150 ms, as it increases by 42 ms compared to the word condition. Thus, the main effect of the syllable and IP is significant (p<0.05). This gives evidence that only the syllable and IP conditions significantly differ from the word condition in terms of final vowel duration. This means that word and phrase boundary conditions group together in terms of the final vowel duration.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	108.11	108.311	57.20	157.69	0.0006	0.0000
Phrase	-1.75	-1.725	-22.36	18.57	0.8494	0.8592
Syllable	42.53	42.403	13.92	70.17	0.0040	0.0022
IP	561.61	561.519	542.70	582.83	0.0001	0.0000

Table 7: Linear mixed effects results at V1 onset point for the pre-trigger vowel duration across the four boundary conditions in [abi] vowel contexts

An additional analysis was carried out to assess the total duration of the phonetic test sequence in [abi] vowel context. Results in (Table 8) show that the total duration of the test sequence is 326 ms in the syllable condition, 277 ms in the word condition, 290 ms in the phrase condition and 862 ms, including the pause in the IP condition. These results confirm the pattern in (Figure 10) above that the final [i] is longer in the syllable condition than that in the word and phrase conditions. As was clarified earlier, this is due to the inclusion of phonologically long as well as short /i/s in the syllable boundary condition.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	277.39	277.41	210.74	346.18	0.0001	0.0000
Syllable	49.08	49.50	-9.96	108.93	0.1002	0.1238
Phrase	12.23	12.01	-37.37	60.72	0.6176	0.6420
IP	585.02	584.90	535.91	634.28	0.0001	0.0000

Table 8: Linear mixed effects results at V2 onset point for the total duration across the four boundary conditions in [abi] vowel contexts

Turning to the [iba] vowel context, results in (Table 9) suggest a three-way boundary distinction (IP>word = phrase>syllable). The predictor estimate for the intercept is 113 ms, referring to the word condition. The duration of the pre-trigger vowel in the phrase condition is 112 ms. It is 656 ms across IP boundary. In the phrase condition the pre-trigger vowel duration decreases by 2 ms from that in the word condition. Across syllable boundary the pre-trigger vowel duration is (83 ms). The main effect of the syllable and IP is significant (p<0.002) and (p<0.000), respectively. This gives evidence for a three-boundary distinction in terms of final vowel duration (IP>word = phrase>syllable). These results indicate no significant word/phrase boundary distinction.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	113.218	113.279	77.00	148.07	0.0001	0.0000
Syllable	-30.220	-30.231	-45.46	-14.71	0.0006	0.0001
Phrase	-1.408	-1.104	-14.04	12.23	0.8674	0.8263
IP	542.422	542.661	528.98	555.65	0.0001	0.0000

Table 9: Linear mixed effects results at V1 onset point for the pre-trigger vowel duration across the four boundary conditions in [iba] vowel contexts

An additional analysis was carried out to assess the total duration of the entire test sequence in [iba] contexts. Model results in (Table 10) show a three-way boundary distinction (i.e., IP>word = phrase>syllable). The total duration of the test sequence is 260 ms across syllable boundary, 292 ms across word boundary, 282 ms across phrase boundary, and 838 ms in the IP boundary condition.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	292.33	292.20	247.56	335.925	0.0001	0.0000
Syllable	-32.28	-32.24	-49.09	-15.355	0.0006	0.0001
Phrase	-10.80	-10.27	-24.05	4.478	0.1526	0.1092
IP	546.29	546.78	532.05	561.415	0.0001	0.0000

Table 10: Linear mixed effects results at V2 onset point for the total duration across the four boundary conditions in [iba] vowel contexts

Turning to the [ibi] vowel context, results in (Table 11) reveal a three-way boundary distinction (IP>syllable> word = phrase). The predictor estimate for the intercept is 110 ms, referring to the word condition. The duration of the pre-trigger vowel is similar in the word and phrase conditions, where it is 114 ms in the phrase condition. The duration of the pre-trigger it is 661 ms across IP boundary. Across the syllable boundary the pre-trigger vowel duration increases by 28 ms compared to the word condition. The main effect of the syllable is significant (p<0.01) and for the IP boundary is significant (p<0.000). This gives evidence for a three-boundary distinction in terms of final vowel duration (IP >syllable> word = phrase). These results confirm that here is no word/phrase boundary distinction on the one hand. On the other, the syllable boundary condition has longer final vowel duration than the word and phrase conditions. The predictor estimate for the IP boundary shows that it has the longest final duration.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	109.975	110.264	69.943	152.62	0.0002	0.0000
Syllable	27.672	27.493	4.223	51.01	0.0230	0.0148
Phrase	4.071	4.028	-8.874	17.22	0.5462	0.5318
IP	550.997	551.029	537.656	564.26	0.0001	0.0000

Table 11: Linear mixed effects results at V1 onset point for the pre-trigger vowel duration across the four boundary conditions in [ibi] vowel contexts

An additional analysis was carried out to assess the total duration of the phonetic sequence in [ibi] vowel context. Model results in (Table 12) show a three-way boundary distinction (i.e., IP>word = phrase>syllable). The total duration of the test sequence is 344 ms across syllable boundary, 289 ms across word boundary, 290 ms across phrase boundary, and 849 ms in the IP boundary condition.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	289.288	289.567	241.27	338.26	0.0001	0.0000
Syllable	55.095	54.724	25.86	82.50	0.0004	0.0000
Phrase	1.103	1.151	-13.34	15.54	0.8748	0.8769
IP	559.773	559.739	544.73	573.92	0.0001	0.0000

Table 12: Linear mixed effects results at V2 onset point for the total duration across the four boundary conditions in [ibi] vowel contexts

To summarise, results of the duration analyses confirm a three-way boundary distinction in each of the four vowel contexts [aba], [abi], [iba], and [ibi]. In [aba] and [iba] vowel conditions, the three-way boundary split is (IP>(word and phrase)>syllable). However, in [abi] and [ibi], the three-way boundary distinction is (IP>syllable>(word and phrase)). As discussed above, this might be attributable to the fact that the syllable boundary condition includes phonologically long as well as short vowel types. This was primarily due to the fact that within word boundaries it was not possible to control for vowel length and obtain enough data items.

5.2 Pharyngealisation magnitude

The results outlined in this section show that pharyngealisation extends across the syllable, word and phrase boundary types. No pharyngealisation effects are found across the intonation phrase boundary. As shown in (Figures 11-14), the magnitude of pharyngealisation varies as a function of prosodic boundary level.

As to the first research question, quantification of the magnitude of pharyngealisation extent reveals that within word boundaries, i.e., in the syllable condition, pharyngealisation is present on both test vowels and its magnitude does not decrease with the increase of vowel duration, suggesting a categorical spreading of the phonological [pharyngealisation] feature. However, across word boundaries, i.e., in the word and phrase boundary conditions the effect of pharyngealisation is only present on the pre-trigger vowel and increases in magnitude as the trigger is approached, suggesting a gradient process of phonetic coarticulation. The finding that in the IP condition there is no pharyngealisation effect suggests that post-lexical pharyngealisation is determined by the temporal proximity to the trigger.

As to the second research question regarding pharyngealisation domain, these results show that the word is the potential domain of pharyngealisation. This is because the magnitude of pharyngealisation is maximal and equally distributed within words, regardless of the duration of the affected vowel(s). However, between such domain units, i.e., across word and phrase boundaries there is some pharyngealisation effect, which increases as the pharyngealised trigger is approached.

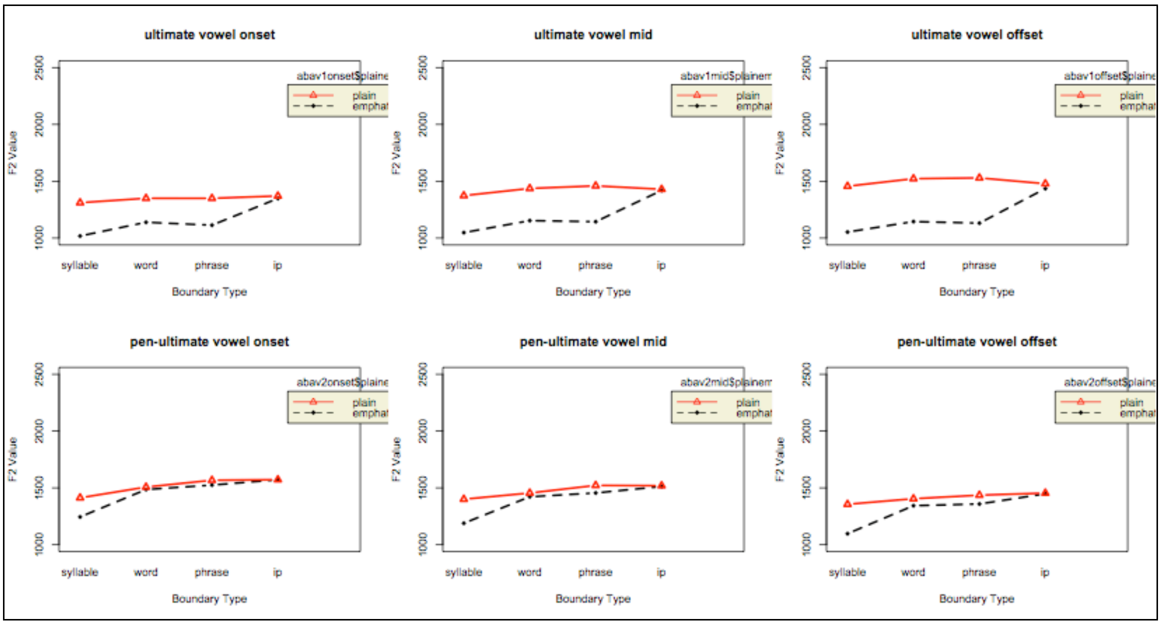

Figure 11: Pharyngealisation across the different boundary levels in [aba#Emphatic trigger] contexts

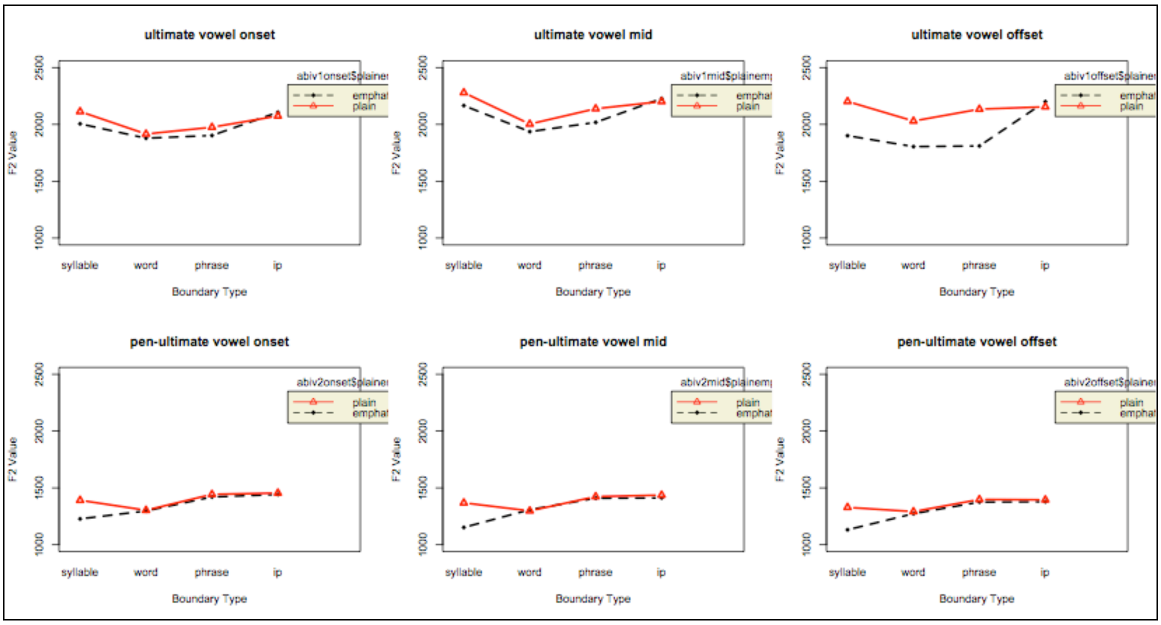

Figure 12: Pharyngealisation across the different boundary levels in [abi#Emphatic trigger] contexts

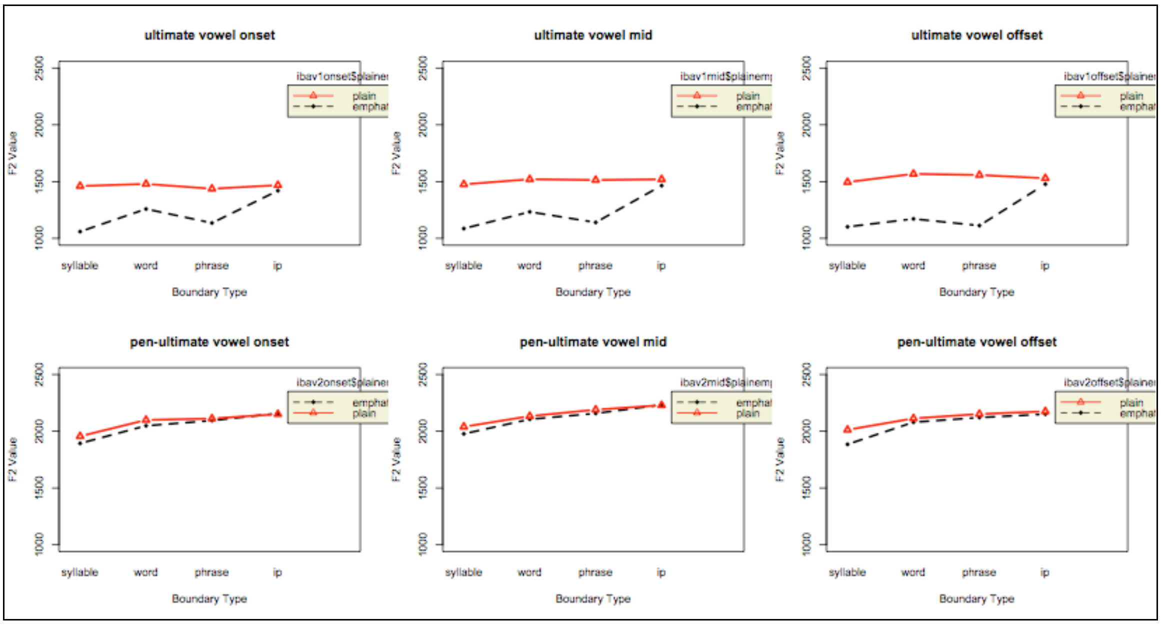

Figure 13: Pharyngealisation across the different boundary levels in [iba#Emphatic trigger] contexts

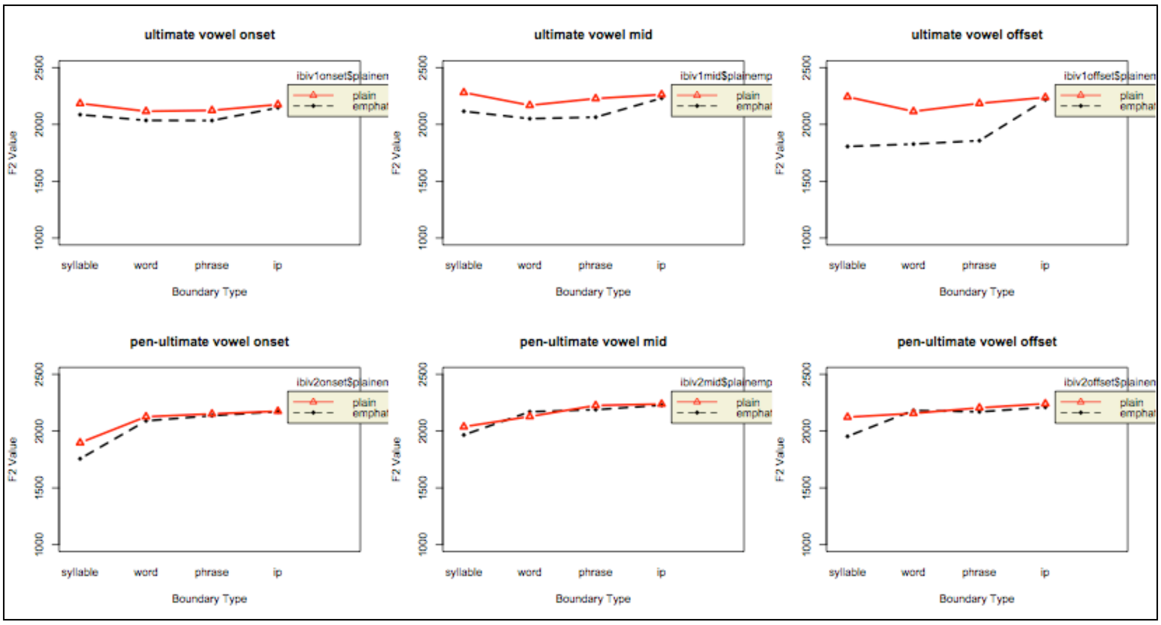

Figure 14: Pharyngealisation across the different boundary levels in [ibi#Emphatic trigger] contexts

In order to examine the magnitude of pharyngealisation extent in the [aba] vowel context, a linear mixed effects model to the data points at V1 onset was constructed. Thus, the model included boundary and plain/emphatic as independent variables and the duration factor as a covariate. This is mainly to assess how pharyngealisation might be predictable from the temporal proximity to the emphatic trigger in the different boundary conditions. The model also included random intercept adjustment for subject and item.

(Figure 15) suggests that at the onset point of the pre-trigger vowel the magnitude of pharyngealisation across the syllable boundary does not decrease with the duration of the vowel, suggesting a phonological spread of pharyngealisation. However, in the word and phrase boundary conditions the magnitude of pharyngealisation decreases as a function of vowel duration, suggesting a phonetic process of pharyngealisation.

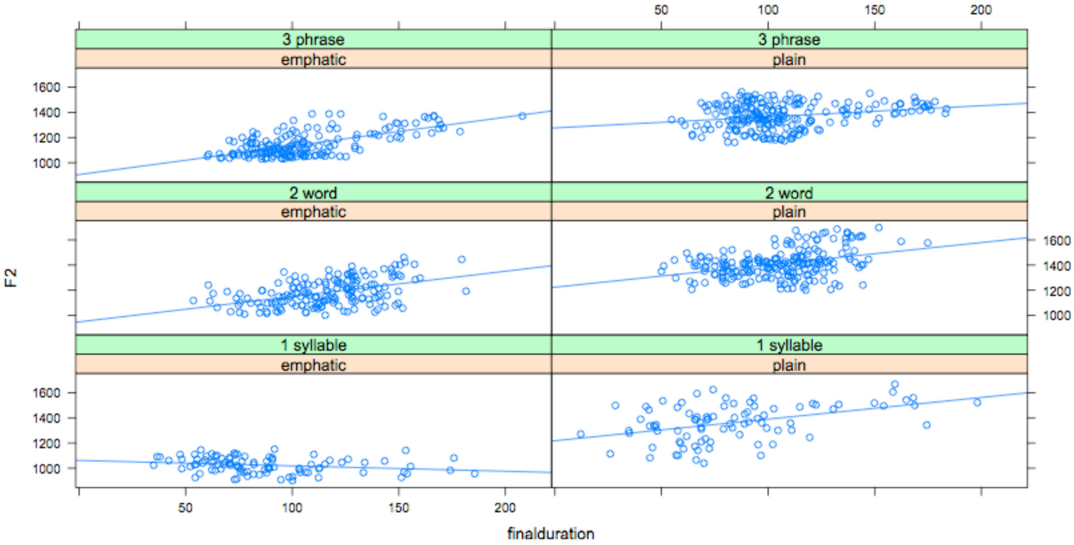

Figure 15: Three-way interaction (final duration by-plain/emphatic by-boundary level) in [aba] sequences at V1 onset point. These lines are best-fit regression lines

To test the statistical reliability of the pattern in (Figure 15), the results in (Table 13) show that the magnitude of anticipatory pharyngealisation is systematically related to the duration of V1 (the pre-trigger vowel) across word and phrase boundaries. However, in the syllable boundary condition, the magnitude of anticipatory pharyngealisation appears to be duration-independent, as it is not influenced by the pre-trigger vowel duration. The three-way interaction, i.e., plain/emphatic by-boundary by-final duration is significant for both the syllable condition ($p<0.05$) and the phrase condition ($p<0.05$). The parameter estimates for the three-way interaction show that in the syllable condition the effect significantly increases by 1 Hz for every one (ms) increase in the final vowel duration. In the phrase condition, however, the effect decreases by 1 Hz per every one ms increase in final vowel duration ($p<0.05$). These results confirm the pattern shown in (Figure 15), where a negative slope fits the data points in the syllable condition, and a positive slope fits the data points in the word and the phrase conditions. This suggests that the magnitude of pharyngealisation across a syllable boundary does not decrease with the vowel duration, consistent with a categorical feature spreading throughout the pre-trigger vowel. However, across word and phrase boundary conditions the increase in duration contributes to the decrease in pharyngealisation magnitude, suggesting a gradient phonetic process.

For the syllable condition, the size of the effect increases regardless of the pre-trigger vowel duration, consistent with phonological feature spreading. In the word and phrase conditions, however, results show that the effect on the onset of the pre-trigger vowel, i.e., V1 decreases with the duration of the final vowel, suggesting a gradient phonetic effect. This provides evidence that the relationship between duration and pharyngealisation magnitude varies according to boundary level. The predictor estimate of the intercept is 981, which refers to F2 values at the onset of pre-trigger vowel preceding the word boundary. The two-way interaction, i.e., by-plain/emphatic by-boundary at all boundary levels is significant ($p<0.05$). The size of the effect for the plain/emphatic is 1245 Hz. This means that it increases by 263 Hz, compared to the intercept. The two-way interaction, i.e., final duration by-boundary is significant, i.e. for the syllable boundary it is ($p<0.05$), and ($p<0.05$) for the phrase boundary condition. These results confirm that the magnitude of anticipatory pharyngealisation is realised differently among the four boundary types. More specifically, there is no pharyngealisation effect across the IP boundary. The effect increases with duration in the syllable boundary condition. However, the effect decreases as a function of duration in the word and the phrase boundary conditions, suggesting a duration-dependent mechanism.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	981.5792	981.8178	896.0378	1070.9738	0.0001	0.0000
Plainemph	263.9045	263.4535	174.6849	354.0551	0.0001	0.0000
IP	233.4607	233.1017	137.3319	323.3199	0.0001	0.0000
Final duration	1.7560	1.7559	1.1952	2.3768	0.0001	0.0000
Plainemph:Phrase	97.9549	98.1551	-23.9381	206.8933	0.0982	0.0952
Syllable:Final duration	-1.7206	-1.7231	-2.5489	-0.9248	0.0002	0.0000
IP:Final duration	-1.5475	-1.5470	-2.1376	-0.9284	0.0001	0.0000
Plainemph:Syllable:Finaldur	1.1108	1.1134	-0.0063	2.1778	0.0478	0.0495
Plainemph:Phrase:Finaldur	-1.0130	-1.0140	-2.0065	0.0595	0.0572	0.0529

Table 13: Linear mixed effects results for pharyngealisation at [aba] V1 onset point across the four boundary conditions

These results suggest that anticipatory pharyngealisation spreads categorically across the syllable boundary. However, results give evidence that across the word and phrase boundaries pharyngealisation is predictable from the vowel duration, where its magnitude increases as the trigger is approached. This means that across word and phrase boundaries pharyngealisation is a gradient phonetic process. This is consistent with the view that post-lexical coarticulation is a phonetic process determined by the temporal proximity to the emphatic trigger, and lexical pharyngealisation is a phonological feature spreading. (Figure 15) above shows the data points at V1 onset measurement point. (Figure 15) shows that in the word and phrase conditions a line having a positive slope fits the data points. This indicates that as the duration of the final vowel increases the magnitude of pharyngealisation decreases in the word and phrase conditions. In the syllable condition, however, a line having a negative slope fits the data points. This suggests that the increase in final duration contributes to the increase in pharyngealisation magnitude in the syllable condition, which was not predicted. To further assess this pattern, a simple linear regression was carried out to predict the F2 value from the duration factor alone for the syllable condition. Results show that the final duration was not significant (p<0.619).

An additional assessment was carried out at V2 onset, where the effects are only found in the syllable boundary condition. This is to assess the temporal extent of pharyngealisation across the different boundary levels.

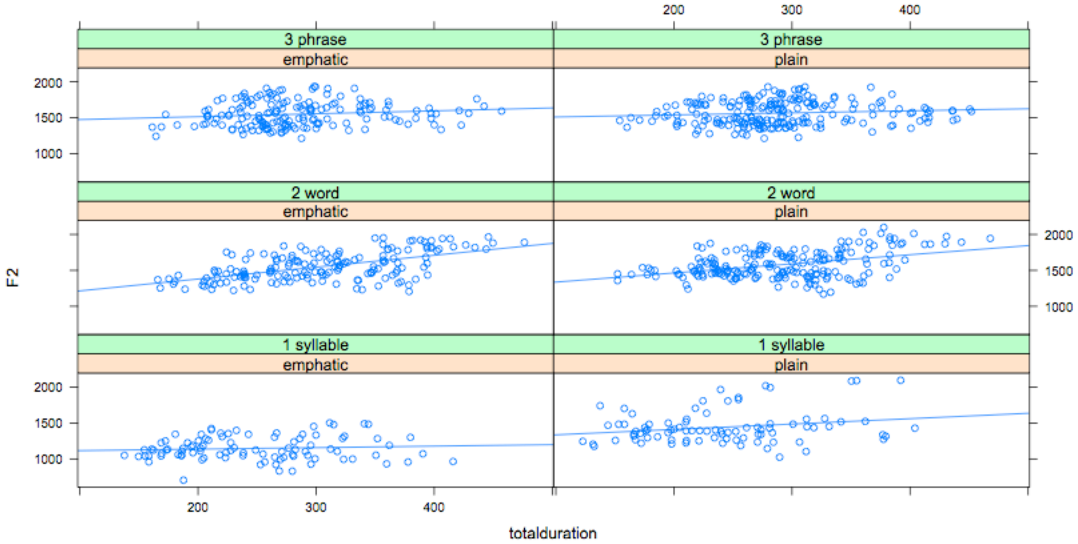

Figure 16: Three-way interaction (total duration by-plain/emphatic by-boundary level) in [aba] sequences at V2 onset point

(Figure 16) plots the data points at V2 onset to test for any pharyngealisation in the syllable, word and phrase boundary conditions. These are shown in the bottom panel, mid panel and top panel, respectively. The bottom panel illustrates that there is a pharyngealisation effect in the syllable condition that does not decrease with the temporal distance from the pharyngealised trigger (the total duration of the test sequence).

To test this pattern statistically, a linear mixed effects model was constructed with F2 as a dependent variable. The model included plain/emphatic, boundary as independent variables, and the total duration as a covariate (Table 14). The two-way interaction (F2 by-boundary by-total duration) shows a tendency towards significance for the syllable boundary (p<0.08). The main effect for the syllable boundary is significant (p<0.05). The main effect for the plain/emphatic is significant (p<0.05). This suggests that there is pharyngealisation effect across the syllable boundary. However, results show that there is no significant pharyngealisation effect across the word, the phrase and the IP boundary conditions in the penultimate vowel (V2).

The mean duration of the pre-trigger vowel is 106 ms and 110 ms in the word and phrase conditions, respectively. The mean duration of the entire sequence is 237 ms in the syllable condition as was shown in (Table 5) and (Table 6) above. Thus, these results show that in the syllable condition anticipatory pharyngealisation extends categorically as far as 237 ms prior to the pharyngealised trigger, while it does not extend farther than 106 ms across the word boundary, and 110 ms across the phrase boundary, respectively. As (Figure 16) illustrates above, the syllable condition displays a slightly negative interaction between the degree of pharyngealisation (F2 lowering) and the total duration of the test sequence, i.e. extending the onset of the emphatic trigger to the V2 onset point. More specifically, the increase of duration does not seem to contribute to a decrease in pharyngealisation magnitude across the syllable boundary.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	1278.7673	1272.2511	1156.9644	1399.2855	0.0001	0.0000
Plainemph	114.6862	115.6681	10.8085	214.4224	0.0258	0.0260
Syllable	-274.0160	-268.5345	-407.1119	-129.7957	0.0001	0.0004
Total duration	0.8743	0.8966	0.6271	1.1703	0.0001	0.0000
Syllable:Total duration	-0.3987	-0.4007	-0.8291	0.0581	0.0800	0.0819

Table 14: Linear mixed effects results for pharyngealisation at [aba] V2 onset point

These results suggest that both vowels in [aba] vowel context are categorically pharyngealised in the syllable condition regardless the temporal distance from the pharyngealised trigger. This gives evidence that pharyngealisation spreading in the syllable condition (i.e., within word boundaries) is a phonological process. It also indicates that post-lexical pharyngealisation, i.e., across the word and phrase boundaries is a phonetic process determined by the temporal proximity to the emphatic trigger.

Turning to the [abi] vowel context, recall that in [abi] vowel context there is a three-way duration split, i.e., (IP>syllable>word = phrase) as was shown in the right upper panel in (Figure 10) above.

A linear mixed effects model was fit to the data points in the [abi] vowel context at the pre-trigger vowel offset measurement point. Model results reveal that in [abi] vowel contexts there is significant pharyngealisation effect at the offset point of the pre-trigger vowel in the syllable, word and phrase boundary conditions. However, no pharyngealisation effect is found on the steady state and the onset point of the pre-trigger vowel in the four boundary conditions. There is no evidence for pharyngealisation effects across an intonation phrase boundary.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	1539.634	1532.461	1222.4849	1836.7577	0.0001	0.0000
Plainemph	635.470	646.253	359.5714	946.0262	0.0001	0.0000
Plainemph: Syllable:finalduration	3.796	3.879	0.2159	7.1260	0.0298	0.0309
Plainemph: Phrase:finalduration	2.812	2.900	-0.3029	5.8125	0.0682	0.0682
Plainemph: IP:finalduration	3.861	3.954	1.1830	6.4560	0.0030	0.0031

Table 15: Linear mixed effects results for pharyngealisation at V1 offset point in [abi] vowel context

An additional analysis was carried out on the first vowel in the test sequence. A linear mixed model for the data at V2 onset was constructed. The model included plain/emphatic, boundary as independent variables, and total duration as a covariate. Results in (Table 16) show that the three-way interaction is only significant for the syllable boundary condition ($p<0.05$). This means that across syllable boundary pharyngealisation effects extend to the beginning of the test sequence, although it is 326 ms away from the emphatic trigger. Interestingly, although pharyngealisation extends from the trigger to the beginning of the test sequence, it does not appear during the intervening /i/. The parameter estimate for the three-way interaction (by-plain/emphatic by-boundary by-final duration) across the syllable boundary indicates that the effect decreases by 2 Hz for every one ms increase in final vowel duration.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	1431.3882	1435.1248	1218.8229	1652.7311	0.0001	0.0000
Syllable	-624.4435	-631.1982	-1037.2773	-200.4218	0.0034	0.0327
Plainemph: Syllable	734.6366	713.0192	240.6710	1192.4637	0.0046	0.0016
Syllable:Total duration	1.4410	1.4814	0.3201	2.6390	0.0140	0.0112
Plainemph: Syllable:Total duration	-1.4713	-1.4301	-2.8819	0.0050	0.0510	0.0355

Table 16: Linear mixed effects results for pharyngealisation at V2 onset point across all boundary conditions in [abi] vowel contexts

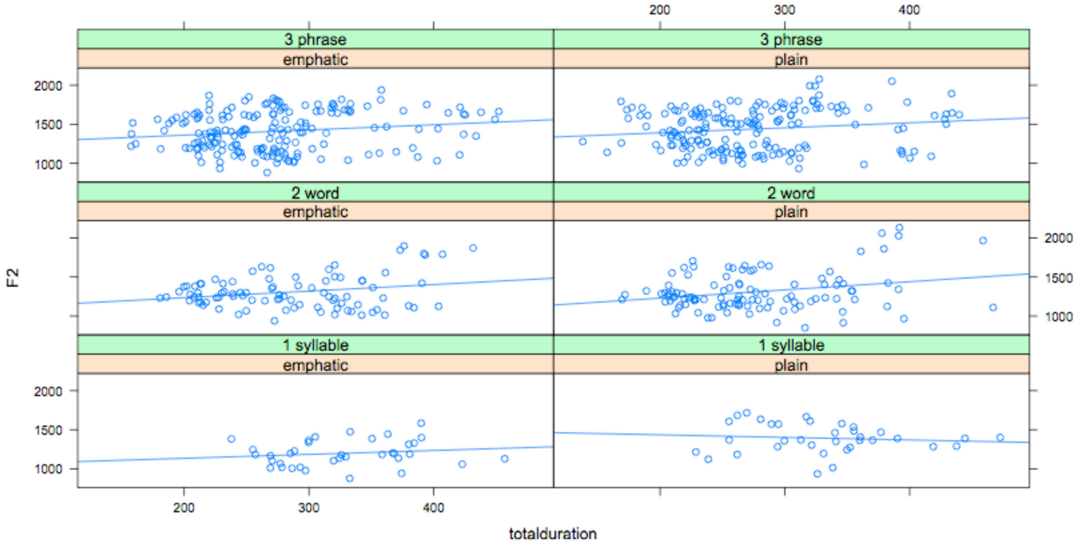

Figure 17: Three-way interaction (total duration by-plain/emphatic by-boundary level) in [abi] sequences at V2 onset point

The spreading of pharyngealisation in [abi] vowel contexts seems to extend from the emphatic trigger to V2 onset. This was only found in the syllable condition, where pharyngealisation decreases slightly with the increase in duration (Figures 17-18). This effect is significant (p<0.05), as shown in the three-way interaction in (Table 16).

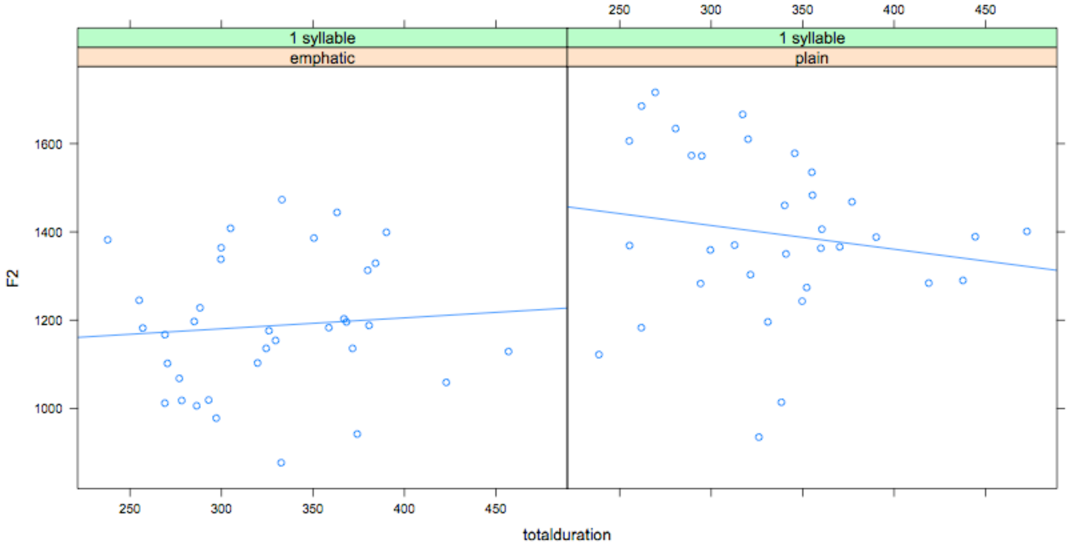

Figure 18: Three-way interaction (duration by-plain/emphatic by-boundary level) in [abi] sequences at V2 onset point across syllable boundary

Results for the [abi] vowel context in the word and phrase conditions reveal that anticipatory pharyngealisation is only found at the pre-trigger vowel [i] offset, and does not appear on the rest of the vowel portion. In the syllable boundary condition, however, in spite of the intervening vowel [i], the spreading of pharyngealisation effects extend categorically as early as three segments (a total duration of 326 ms), see (Tables 7-8) above for the total duration of the test sequence in [abi] vowel environment.

Turning to the [iba] vowel environment, (Figure 19) shows that pharyngealisation effects appear to be categorical in the syllable condition.

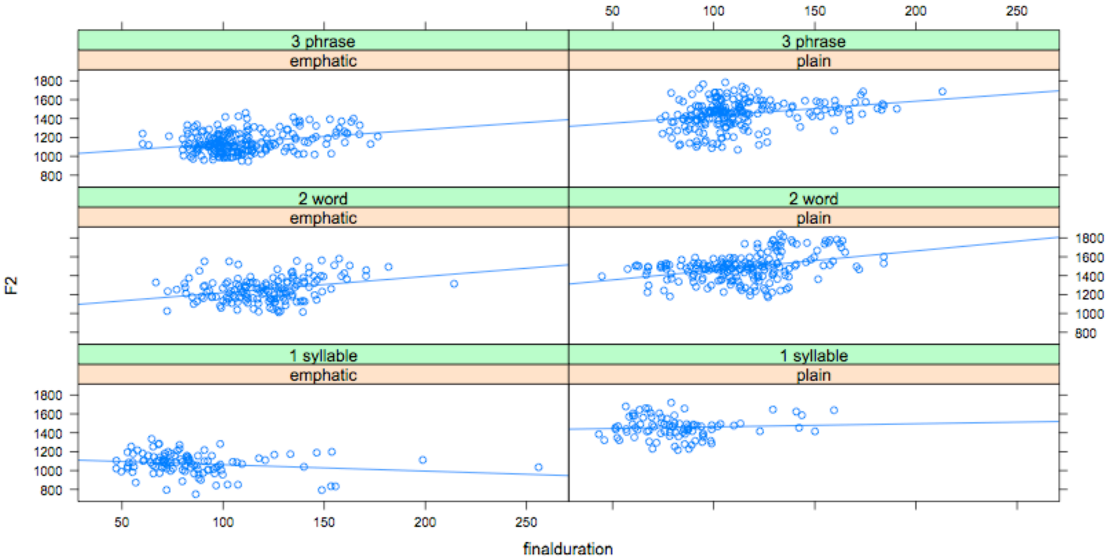

Figure 19: The interaction of F2 by final duration in [iba] contexts across syllable, word and phrase boundaries at V1 onset point

To test the statistical reliability of the pattern shown in (Figure 19) above, a linear mixed effects model was constructed at the pre-trigger vowel onset point. The model results in (Table 17) reveal that pharyngealisation effect extends categorically across the syllable boundary. No significant effects of pharyngealisation are found across the word, phrase and IP boundary types.

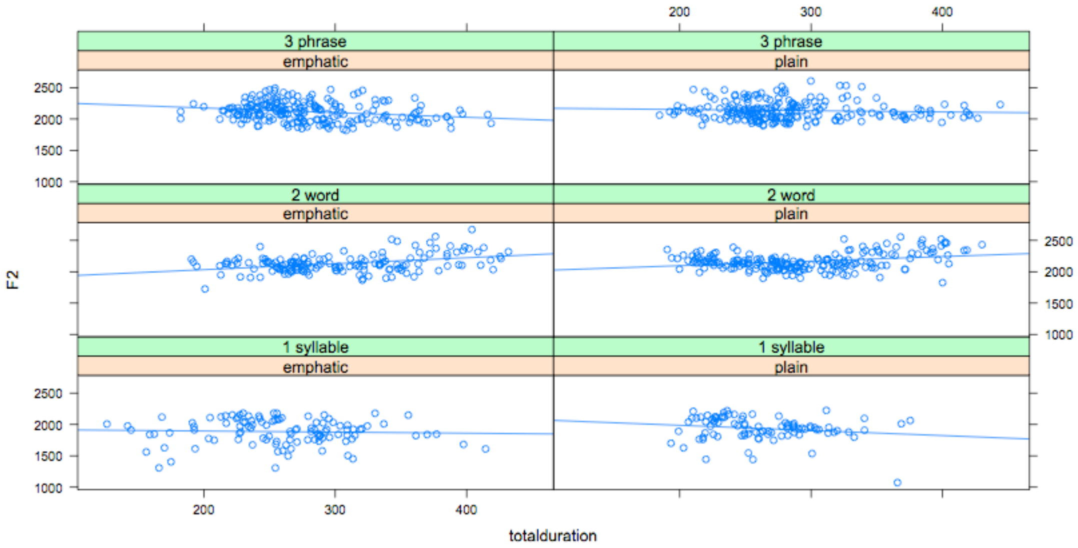

Figure 20: The interaction of F2 by total duration in [iba] contexts across syllable, word and phrase boundaries at V2 onset point

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	1101.1335	1107.7826	971.9628	1249.2653	0.0001	0.0000
Plainemph	210.7328	211.2172	87.6320	339.4084	0.0002	0.0009
Finalduration	1.2692	1.2283	0.3867	2.0561	0.0038	0.0025
Syllable:Finalduration	-1.2789	-1.1196	-2.3045	0.0279	0.0632	0.0323

Table 17: Linear mixed effects results for pharyngealisation at V1 onset point in [iba] vowel context

An additional analysis was carried out for the data points at V2 onset. Results in (Table 18) show that the main effect of the syllable is significant ($p<0.05$). The results may suggest that pharyngealisation effects are only found across the syllable boundary and the extent of pharyngealisaton is categorical, as it does not decrease with the increase of the entire duration of the test sequence, see (Figure 20) above.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	2122.5648	2121.5960	1992.7276	2252.6846	0.0001	0.0000
Syllable	-332.1692	-331.3576	-493.6492	-178.2259	0.0001	0.0000

Table 18: Linear mixed effects results for pharyngealisation at V2 onset point across all boundary conditions in [iba] vowel context

Turning to the [ibi] vowel context, (Figure 21) suggests that in [ibi] vowel context, pharyngealisation at the pre-trigger vowel onset co-varies with duration in the word and phrase conditions in that pharyngealisation magnitude decreases with duration, suggesting a phonetic effect. However, in the syllable boundary condition anticipatory pharyngealisation does not decrease with duration, suggesting a categorical spread of anticipatory pharyngealisation is a phonological process within word boundaries.

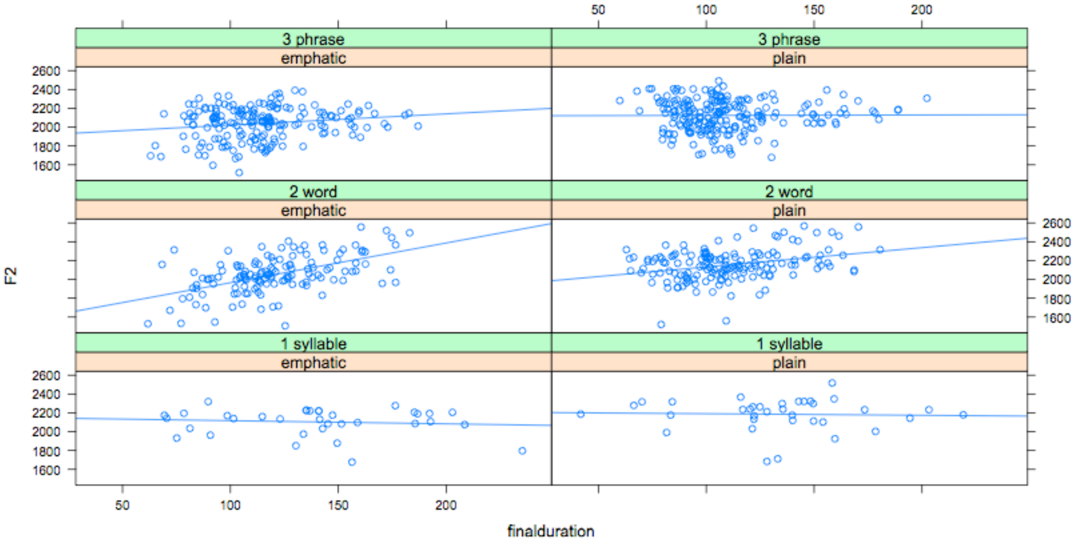

Figure 21: The interaction of F2 by final duration in [ibi] contexts across syllable, word and phrase boundaries at V1 onset point

To test the statistical reliability of the pattern shown in (Figure 21), a model was fitted to the data at V1 onset point. The model results in (Table 19) show that the three-way interaction tends towards significance for the syllable boundary condition ($p<0.08$), and for the phrase boundary condition ($p<0.06$). The predictor estimate for the three-way interaction shows that the effect increases by 2 Hz per every (1 ms) in the syllable condition, and by 2 Hz in the phrase condition. Results also show a significant main effect for the syllable (p<0.05), word (p<0.05), and phrase (p<0.05). These results suggest a significant pharyngealisation effect at the pre-trigger vowel onset in the syllable, word and phrase boundary conditions. They also indicate that in the word and phrase conditions the increase in final vowel duration contributes to the attenuation of pharyngealisation magnitude, suggesting a gradient phonetic effect. Recall that in [ibi] vowel context there is a three-way duration split, i.e., (IP<syllable<word = phrase), see (Figure 10). It is possible that when factors, i.e., segmental and distance from the trigger combine the spread of pharyngealisation is more constrained.

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	1594.937	1595.221	1457.3488	1728.7671	0.0001	0.0000
plainemph	328.971	327.910	167.2781	480.1184	0.0001	0.0000
Syllable	503.587	502.365	310.7392	709.7072	0.0001	0.0000
Phrase	355.820	355.383	184.6460	516.5500	0.0001	0.0000
Final duration	3.993	3.990	2.9744	4.9779	0.0001	0.0000
plainemph: Syllable:Final duration	1.770	1.752	-0.2557	3.8209	0.0986	0.0888
plainemph: phrase:Final duration	1.668	1.663	-0.1184	3.3280	0.0638	0.0592

Table 19: Linear mixed effects results for pharyngealisation at V1 onset point across all boundary conditions in [ibi]

Further analysis was carried out for data points at V2 onset point and a model was constructed. As shown in (Table 20), results show that the two-way interaction, i.e. plain/emphatic by-boundary is significant for the syllable boundary (p<0.05). The parameter estimate of plain/emphatic by-boundary shows that across the syllable boundary the size of the effect of pharyngealisation increases by 510 Hz, when compared to the word boundary condition. Results also show a significant main effect for the syllable boundary on F2 values (p<0.05). This implies that pharyngealisation effects are only found in the syllable boundary condition. There are no effects across word, phrase and IP boundaries at V2 onset measurement point.

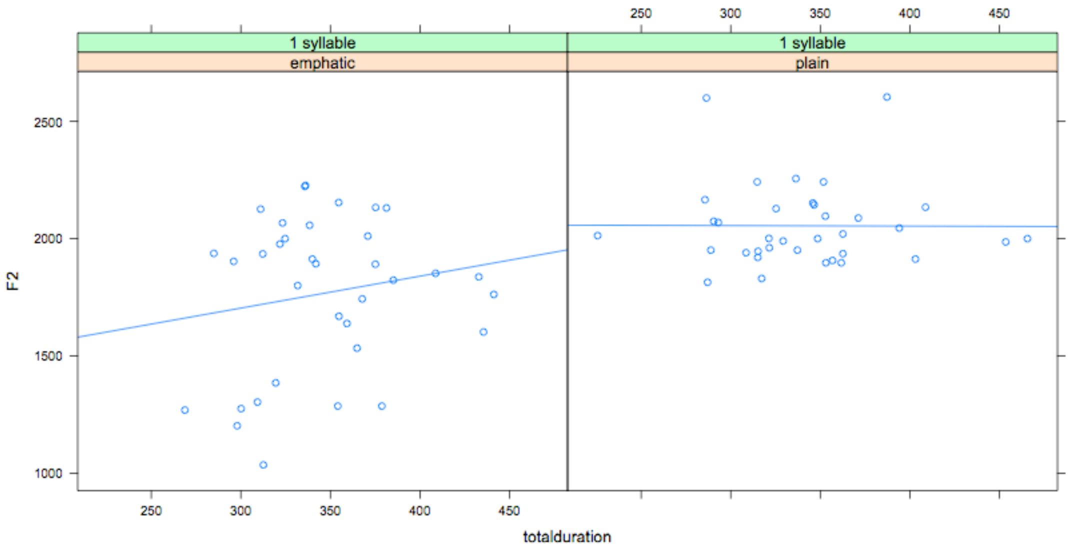

Figure 22: The interaction of F2 by final duration in [ibi] contexts across the syllable boundary at V2 onset point

	Estimate	MCMCmean	HPD95lower	HPD95upper	pMCMC	Pr(>|t|)
(Intercept)	2088.0544	2084.3013	1943.7135	2226.2285	0.0001	0.0000
Syllable	-793.7636	-794.4631	-1141.8976	-421.4473	0.0001	0.0000
plainemph: Syllable	510.0591	513.7174	56.3488	952.5104	0.0268	0.0284
Syllable:Total duration	1.0736	1.0804	0.0324	2.0635	0.0388	0.0401

Table 20: Linear mixed effects results for pharyngealisation at V2 onset point across all boundary conditions in [ibi]

As shown in (Figure 22), at V2 onset across the syllable boundary anticipatory, pharyngealisation decreases with duration. This is the only vowel context that shows that in the syllable condition, pharyngealisation is influenced by duration. Recall the results in (Table 12) illustrate that the total duration of the test sequence for the syllable condition is longer than it is in the word and the phrase conditions. It was noted that the entire duration of the test sequence in the syllable is 344 ms, whereas it is 289 ms in the word condition. As shown in (Table 20), counter to the feature spreading view, the data points at the penultimate vowel onset show that pharyngealisation decreases as a function of duration in the syllable condition, i.e., within word boundaries. The attenuation of pharyngealisation magnitude in this case cannot be solely attributable to duration, as pharyngealisation might be constrained by a combination of duration and the high front vowel /i/.

To summarize, the results reported herein show that pharyngealisation in the four vowel environments [aba], [abi], [iba], [ibi] spreads across the syllable, word and phrase boundary conditions. However, no effects found in the IP boundary condition. Concerning the first research question regarding the magnitude of pharyngealisation extent, it has been found, in three out of four vowel contexts, that in the syllable condition, pharyngealisation effects are categorically present on both test vowels. The increase of vowel duration does not seem to contribute to decreasing the magnitude of pharyngealisation, suggesting a phonological feature spreading mechanism. However, in the word and phrase boundary conditions the spread of pharyngealisation decreases with the increase of vowel duration, suggesting a gradient process of phonetic coarticulation. A major finding in this section is that anticipatory pharyngealisation within word boundaries is qualitatively different from that across word boundaries.

As to the second research question regarding the domain of pharyngealisation, it has been found herein that the word serves as the potential domain of pharyngealisation effects. This argument stems from the observation that pharyngealisation magnitude within word boundaries does not decrease with duration.

5.3 Speaker and item variability

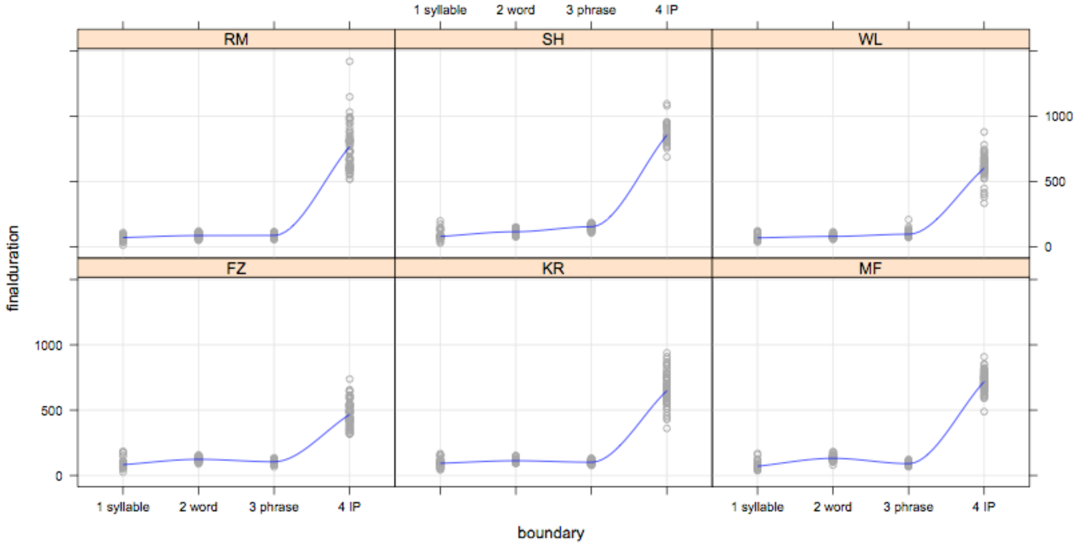

Figure 23: variation in final vowel duration across the different boundaries by the different subjects

(Figure 23) suggests that subjects’ performance in terms of final vowel duration is generally uniform. However, speakers (FZ) and (MF) show slightly longer final vowel in the word than in the phrase condition. The other four speakers seem to have closely similar final vowel duration patterns among the different boundary conditions.

A linear mixed effects model that included final duration as a dependent variable, and boundary as an independent variable was constructed to allow the slope of the effect of boundary to vary across subjects (i.e., by-subject slope for boundary), and across items (i.e., by-item slope for boundary). Variability is assessed in terms of the standard deviation (Baayen 2008).

Random effects:

Groups	Name	Variance	Std.Dev.	Corr		
Item	(Intercept)	0.0000	0.0000			
	Boundary syllable	281.4592	16.7767			
	Boundary phrase	5.3563	2.3144	-1.000		
	Boundary IP	1226.4599	35.0208	-1.000	1.000	
Subject	(Intercept)	358.2698	18.9280			
	Syllable	84.6695	9.2016	-1.000		
	Phrase	641.6945	25.3317	-0.496	0.496	
	IP	17592.0108	132.6349	-0.246	0.246	0.597
Residual		3604.6922	60.0391			

Table 21: Mixed effects result in [iba] at V1 onset for final duration. The model includes a random slope for speakers and a random slope for items

(Table 21) illustrates the by-subject random intercepts and the by-subject random slopes for boundary. These results show that the standard deviation for the by-item slope for the syllable boundary is 17, for the phrase is 2 and for the IP is 35. This means that in each different boundary condition, there is little variability in final vowel duration across items. Results also illustrate that the standard deviation for the by-subject random slope in the syllable condition is 9, in the phrase is 25 and in the IP is 132. This reveals some subject variability in terms of final vowel duration in the IP condition. This might suggest that some subjects produced longer pauses following an IP boundary.

Additional analysis is carried out to assess if pharyngealisation magnitude varies among speakers and data items.

Groups	Name	Variance	Std.Dev.	Corr
Item	(Intercept)	33.621	5.7983	
	Plain/emphatic	38.665	6.2181	1.000
Subject	(Intercept)	2767.975	52.6116	
	Plain/emphatic	2220.001	47.1169	0.170
Residual		7464.882	86.3995	

Table 22: Mixed effects result in [aba] at V1 onset for pharyngealisation. The model includes a random slope for speakers and a random slope for items

(Table 22) illustrates the by-subject random slope and the by-item random slope for plain/emphatic. These results show that the standard deviation for the by-item slope for plain/emphatic is 6. This indicates that there is little variability of pharyngealisation across different items. These results also reveal that the standard deviation for the by-subject random slope for the plain/emphatic is 47.

As shown in (Figure 24), it appears that subjects tend to pharyngealise utterances differently from one another. Thus, due to the different ranges of pharyngealisation magnitude produced by different speakers, each speaker produced slightly different pharyngealisation patterns, but in the same direction.

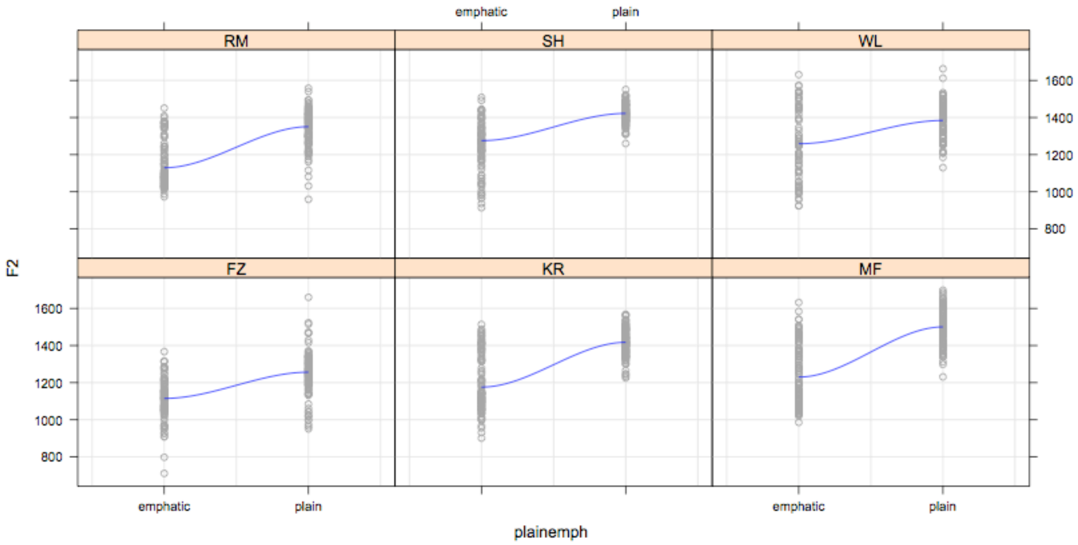

Figure 24: variation in pharyngealisation magnitude among speakers at V1 onset across all boundary conditions in the [aba] vowel context.

Turning to the influence of duration on pharyngealisation magnitude, (Figure 25) reveals that there is some speaker variability, which will be assessed here.

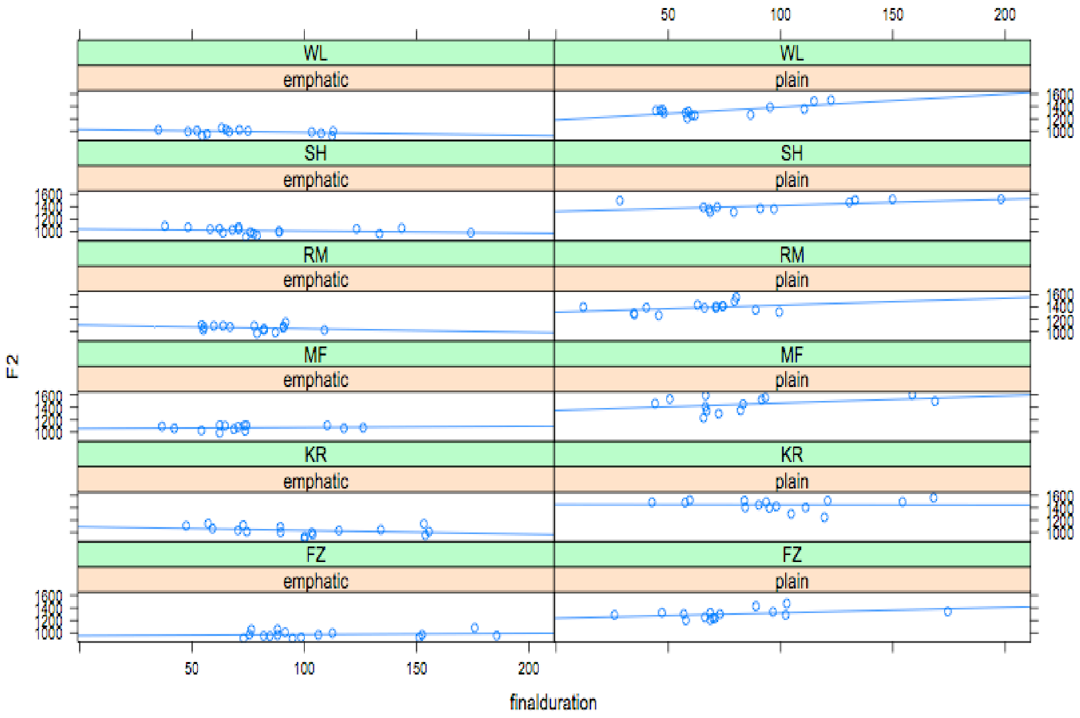

Figure 25: Pharyngealisation (F2) as a function of duration in the [aba] syllable condition at V1 onset. Each row represents one subject

As shown in (Figure 25), in the syllable condition speakers seem to show uniform patterns of pharyngealisation magnitude as influenced by duration. Nevertheless, (Figure 26) suggests some degree of variability among speakers in the word condition. For example, speaker (RM) shows a pattern where pharyngealisation does not decrease with the increase in final vowel duration. This means that for RM pharyngealisation magnitude is categorical across the word boundary. Speaker (FZ) has a pattern, where the influence of duration on pharyngealisation magnitude is slightly less, when compared to the other four speakers.

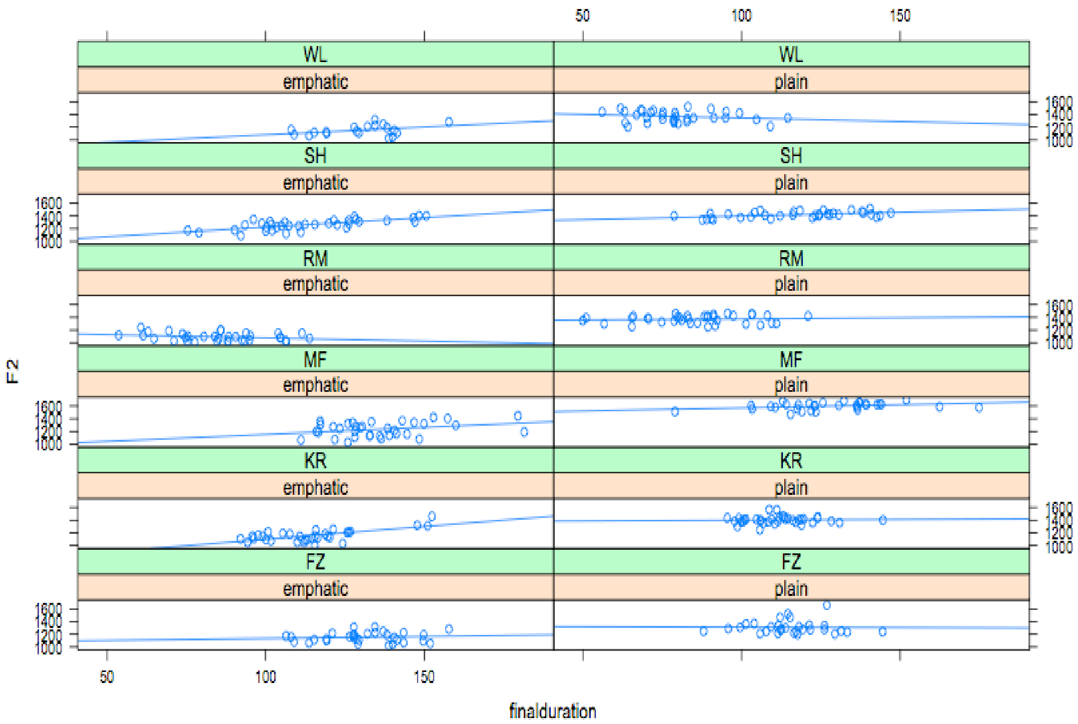

Figure 26: Pharyngealisation (F2) as a function of duration in the [aba] word condition at V1 onset. Each row represents one subject

In order to statistically assess this pattern, a linear mixed effects model was constructed for F2 as a function of duration at V1 onset in the [aba] vowel condition. The model allows the slope of the effect of duration to vary across speakers.

Groups	Name	Variance	Std.Dev.	Corr
Subject	(Intercept)	0.0	0.000	
Final duration		0.0	0.000	
Plain/emphatic		5676.3	75.341	
Word		11167.9	105.678	0.831
Residual		10101.2	100.505	

Table 23: Mixed effects result in [aba] at V1 onset for pharyngealisation. The model includes a random slope for speakers and a random slope for items

The results in (Table 23) reveal some speaker variability in the word boundary condition. The standard deviation for the word boundary is 105. This gives evidence that the influence of duration on pharyngealisation varies slightly among speakers as far as the word boundary condition is concerned.

Further analysis was carried out to assess whether the by-item and the by-subject random slopes are significant. An anova test comparing the models that include these random slopes with the model that does not include them was carried out.

```
Data: abav1onset
Models:
                         Df    AIC     BIC      logLik     Chisq   Chi Df  Pr(>Chisq)
Without random slopes:  19    15451   15549    -7706.5
With random slopes:     23    15402   15521    -7677.9    57.176   4        1.137e-11 (0.05)
```

Table 24: ANOVA test comparing the model that includes by-item and by-subject random slopes for plain/emphatic with the model that does not include these random slopes

(Table 24) shows that the increase in the degree of freedom in the model that includes by-item and by-subject random slopes for the plain/emphatic is justified by the increase in log-likelihood.

To sum up, the general pattern reported herein is that the magnitude of anticipatory pharyngealisation within words is categorical, resulting from a feature spreading of the phonological [pharyngealisation] feature. In contrast, across word boundaries, the magnitude of pharyngealisation is found to be gradient, resulting from phonetic coarticulation. The finding that there is no pharyngealisation effect across an intonation phrase boundary implies that pharyngealisation across word boundaries are determined by the temporal distance from the pharyngealised trigger.

5.4 Conclusion

The results outlined above show that pharyngealisation is found on both vowels when the pharyngealised trigger occurs in the same word (syllable condition). There are effects of pharyngealisation on the pre-trigger vowel across word and phrase boundaries. No evidence of pharyngealisation across an IP (always accompanied by a potential pause).

As to the first question regarding the magnitude of pharyngealisation extent, with words, pharyngealisation magnitude seems to be stable, regardless of the temporal distance from the pharyngealised trigger. This suggests that pharyngealisation within word boundaries is a categorical spread of phonological features. In contrast, in the word and phrase conditions, the magnitude of pharyngealisation decreases with temporal distance from the pharyngealised trigger. The lack of pharyngealisation effects on the pre-trigger vowel across an IP boundary may be due to its temporal distance from the trigger. This suggests that anticipatory pharyngealisation across word boundaries is a gradient process of phonetic coarticulation.

As to the second question regarding the planned domain of pharyngealisation, these results suggest the word as a potential candidate for pharyngealisation domain because pharyngealisation effects are categorically distributed over the entire word. The marginal effects observed across word boundaries are consistent with the view that the surface domain might be larger than that, which is actually planned by the speaker.

In addition, these results show that, in each boundary condition, there is little variability in the pre-trigger vowel duration across items. These results show considerable variability among subjects in terms of pre-trigger vowel duration in the IP condition, suggesting that some subjects produced longer pauses following an IP boundary. There is little speaker variability in the way duration influences pharyngealisation magnitude. For example, speaker (RM) shows categorical effect across word boundary. Speaker (FZ) shows less effect of duration on pharyngealisation magnitude than the other four speakers.

Chapter 6. Discussion

The present study examined anticipatory pharyngealisation across a hierarchy of prosodic boundary types (i.e. Syllable vs. Word vs. Phrase vs. IP) in Libyan Arabic. The phonetic test sequence [VbV+Emphatic trigger] was manipulated in four vowel contexts, i.e., [aba; abi; iba; ibi]. F2 value was measured at onset, mid and offset in both test vowel intervals. The duration of the pre-trigger vowel and of the total test sequence were considered.

The first research question was to examine whether the magnitude of anticipatory pharyngealisation reflects a categorical spread of phonological features or a gradient process of phonetic coarticulation. The second research question was to seek how to best identify the planned domain of anticipatory pharyngealisation.

6.1 Pharyngealisation magnitude

As to the first research question regarding the magnitude of anticipatory pharyngealisation effects, the results reported above demonstrate a clear difference between lexical pharyngealisation and post-lexical pharyngealisation. In other words, within word boundaries, i.e., in the syllable condition, anticipatory pharyngealisation extends categorically throughout two syllables prior to the pharyngealised trigger, regardless of the temporal distance of the measurement point from the pharyngealised trigger. Measurements of the duration of the test sequence suggested that in the syllable condition, anticipatory pharyngealisation, namely, in the [abi] condition, extends as early as 326 ms prior to the pharyngealised trigger. These results suggest that anticipatory pharyngealisation is a categorical spread of the phonological [pharyngealisation] feature within a word. In contrast, across word boundaries, i.e., in the word and phrase boundary conditions, it was found that pharyngealisation is present on the pre-trigger vowel in a gradient magnitude that varied gradually with the temporal distance of the measurement point from the pharyngealised trigger. This suggests a gradient process of phonetic coarticulation across word boundaries (in the word and phrase conditions). These findings were supported for five subjects. However, the sixth subject (RM) shows a categorical pattern of pharyngealisation in the word boundary condition. This finding in (RM)'s data indicates that the planned domain of anticipatory pharyngealisation effects is larger than the word. However, for (RM), across phrase boundaries the magnitude of pharyngealisation gradually increases as the trigger is approached, which is true for the other five subjects. The results also show that, for all speakers, there is no pharyngealisation effect across the intonation phrase boundary (followed by a potential pause). This finding might suggest that, unlike lexical pharyngealisation, post-lexical pharyngealisation is determined by how temporally far the measurement point is from the pharyngealised trigger. The lack of pharyngealisation might well be due to the pause following the intonation phrase boundary.

To my knowledge, this is the first formal investigation that presents a clear distinction between lexical (categorical) and post-lexical (gradient) pharyngealisation in Arabic. Some but not all previous data suggest that pharyngealisation is categorical (Younes 1982). Although Younes did not consider the duration in (ms) of the derived pharyngealised vowels, his F2 measurements show that pharyngealisation magnitude is equally distributed throughout the vowel interval (i.e., at the onset, mid and offset measurement points). In contrast, other previous data from the different dialects provide evidence that pharyngealisation might be gradual and is, therefore, a phonetic process of coarticulation (Ghazeli 1977, Card 1983, Bukshaisha 1985). Although no duration measurements were presented in these investigations, their F2 values suggest that pharyngealisation decreases in magnitude with the temporal distance from the pharyngealised trigger. In general, previous findings on pharyngealisation have primarily received phonological interpretations. This is true in the phonetic literature on coarticulatory and spreading phenomena in general. As was discussed in Chapter 2, the early onset of coarticulatory or spreading effect does not necessarily indicate a feature spreading mechanism. However, the key diagnostic of categorical feature spreading is that the magnitude of the effects does not decrease as a function of the temporal distance from the trigger. The present study quantified the magnitude of pharyngealisation over the measured duration of the affected vowel segment(s) in an attempt to tease apart phonological from phonetic characterisations of anticipatory pharyngealisation.

Current models of speech production postulate two fundamentally distinct assumptions regarding coarticulation extent and magnitude, i.e. categorical vs. gradient. Firstly, categorical feature-spreading models assume that input to the speech mechanism is a sequence of discrete phonemes that are characterised in terms of distinctive features. A feature is assumed to spread categorically as a result of phonological rule application. Once pharyngealisation occurs, it extends in an equally distributed magnitude regardless of the duration of the affected sound(s). Under some assumptions about how phonological representations are mapped to phonetics, phonemes have no duration encoded, and spreading is either present or absent. Thus, whatever the duration of a segment, the presence or absence of the phonetic characteristic of the feature [pharyngealisation] is expected to be time-independent and categorical.

Second, models that assume phonetic coarticulation (Henke 1966, Keating 1990) posit that input to the speech mechanism is a sequence of discrete phonemes. A 'look-ahead" planning operator scans the next specified target in the sequence and assigns this target to all preceding unspecified phoneme(s). Within this model's assumptions, an articulatory target is the ideal articulatory position of a sound segment, which might not be fully achieved because of contextual effects. The upcoming articulatory target is realised in space and time via implementation rules. Movement towards the target starts as soon as that target is realised. The model predicts that pharyngealisation magnitude will gradually increase with the approach to the pharyngealised trigger. However, an alternative view regarding gradual coarticulation comes in articulatory phonology. Articulatory phonology assumes an overlap of neighbouring gestures that results in a gradual increase in pharyngealisation magnitude as the trigger is approached.

As discussed above, the window model assigns a range of possible articulatory targets 'window' to all segments for each articulatory parameter (Keating 1990). In the window model, the segment's window size represents all possible coarticulatory effects. The result is that specified segments are associated with narrow window sizes and unspecified segments with wide window sizes. A narrow window will allow for little coarticulatory effect during a specified segment. The observation that pharyngealisation magnitude in /i/ is less that that in /a/ seems compatible with the window model predictions. For example, /i/ is assigned a narrower window size that the /a/. However, a wide window will allow for much coarticulatory effect during unspecified segments.

In the present study, a key diagnostic to see whether pharyngealisation is categorical or gradient was to assess how the magnitude of pharyngealisation might vary as a function of the duration of the affected phoneme(s). More clearly, it was undertaken to see if the increase in the duration of the affected phoneme(s) preceding the trigger contributes to decreasing the magnitude of pharyngealisation effects.

A major issue in models of speech production is the articulatory strategy speakers have access to in spoken utterance. For example, feature-spreading models assume that anticipatory effects extend categorically in whatever portion of utterance is affected, i.e. phoneme, syllable, word etc. The duration of the affected portion of utterance does not affect the magnitude of the spreading. More specifically, the magnitude of pharyngealisation effects does not increase as the trigger is approached but the effects are equally distributed. In contrast, models of phonetic coarticulation assume that coarticulatory effects extend in a gradient fashion, where the magnitude of pharyngealisation increases as the trigger is approached.

The results reported here suggest that both articulatory strategies (categorical and gradient) coexist in Libyan Arabic. More specifically, both categorical feature spreading and gradient coarticulation appear to be available to speakers but each is triggered at a different prosodic levels. The present findings are consistent with the view that coarticulation within words is qualitatively different from that between them (Krakow 1989, Zsiga 1995).

These findings suggest that within words phonemes are targeted as pharyngealised in a word containing a pharyngealised trigger. However, across word boundaries, phonemes are targeted as plain, where any effects might be due to the fact that the articulator cannot instantaneously move from one articulatory position to another.

In the light of the present data, it might be reasonable to assume that a lexical item enters into the lexicon as either plain or pharyngealised. This may imply that words are stored with a given sound shape corresponding to abstract features e.g., [pharyngealised] vs [non-pharyngealised]. These observations are consistent with the findings reported in Zsiga (1995) on palatalisation in American English. Zsiga found a clear-cut distinction between lexical (e.g. *confession*) as opposed to post-lexical (e.g. *confess you*) palatalisation patterns. Zsiga reported that lexical palatalisation involves a categorical effect which is best accounted for in terms of phonological feature spreading. However, post-lexical palatalisation involves gradient and variable changes in magnitude, which is best accounted for in terms of gradient gestural overlap. Thus, Zsiga concluded that featural and gestural representations are both needed to account for her findings regarding palatalisation in American English. Similarly, the findings reported here on anticipatory pharyngealisation suggest that lexical pharyngealisation is best captured by featural descriptions, where pharyngealisation spreads categorically from the trigger regardless of the duration of the affected sounds. In contrast, a model that assumes a gradient process of coarticulation, where the effects gradually increase as the trigger is approached, can readily account for post-lexical pharyngealisation.

6.2 Pharyngealisation domain

The present study examined pharyngealisation effects across a hierarchy of prosodic boundary types, i.e. the syllable, word, phrase and intonation phrase in search for the planned domain of pharyngealisation. The planned domain of pharyngealisation is the linguistic unit to which speakers intend to confine pharyngealisation effects. The results outlined above support the selection of the word as the planned domain unit of pharyngealisation in Libyan Arabic because it was found that the magnitude of pharyngealisation is relatively stable within words as compared to that between words for five speakers. In contrast, for speaker (RM), the magnitude of pharyngealisation is categorical in the syllable and the word conditions. This finding for speaker (RM) indicates that the planned domain of pharyngealisation is larger than the word. Although many previous studies claim that the word is the domain of pharyngealisation, the present study, to my knowledge, is the first formal account that provides evidence the word as the planned domain of pharyngealisation in Libyan Arabic. It was found in the present study that the word serves as the planned pharyngealisation domain, where pharyngealisation spreads as a result of phonological rule application. Marginal effects were found across word boundaries.

Such effects are considered marginal because the magnitude is smaller than that observed within words.

In previous research the domain of pharyngealisation is controversial. Different domain units have been proposed, i.e., syllable, word and phrase. As was discussed above, the disagreement regarding the domain of pharyngealisation might be due to different experimental techniques including data items, segmental composition etc. In addition, the discrepancy might also be due to different domain definitions. As was discussed in Chapter 3, there are two different approaches for the syllable as the domain of pharyngealisation. The first approach, which is held in Lehn (1963) and Broselow (1976), does not strictly posit that pharyngealisation is only contained within the syllable in which the trigger occurs. These investigators assume that the minimum span of pharyngealisation is the CV sequence. In this regard, Lehn (1963: 38) states, “An utterance of more than one syllable may have no syllable, or all syllables, or any one or more of its syllables with emphasis”. According to Broselow (1979: 34, as cited in Younes 1982: 154),

> “But even when emphasis is spread beyond the syllable containing the emphatic phoneme, it is spread through the entire neighbouring syllable; the domain of emphasis is always a complete syllable. The additional rules of emphasis spread beyond the core syllable are to some extent optional and dependent on speed and style of speech”.

This implies that the spreading of pharyngealisation from one syllable to other syllables is done via the application of phonological rules. These authors do not discuss which sounds can and which cannot be pharyngealised. Therefore, any sound can be pharyngealised as a result of a phonological rule of feature spreading. This approach does not contradict the definition of the word as the domain of pharyngealisation.

The second view of the syllable as the domain of pharyngealisation comes in Ali & Daniloff (1972). In this approach, pharyngealisation effects extend over a number of open syllables. Pharyngealisation never extends throughout an entire monosyllabic word in the CVC form. As was reviewed in Chapter 3 above, in the word [Tabaʃiir] “chalk” pharyngealisation extends from the word-initial trigger to cover the first two open syllables. No effects were observed by Ali & Daniloff to extend to the third syllable. One problem with data items such as the word [Tabaʃiir] is that the segmental composition is not tightly controlled. For example, /ʃ/ is [+high], which is not theoretically compatible with a pharyngealised vocal tract configuration. Thus, it is not clear whether the blocking of the effect is due to the syllable boundary, the onset of the third syllable /ʃ/, or to both.

Claims that the word is the domain of pharyngealisation do exist in previous research (Ghazeli 1977, Card 1983, Zawaydeh 1999, Hassan & Esling 2011). For example, Ghazeli notes that although high vowels are not articulatorily compatible with pharyngealisaton, they do not totally block it from spreading over the entire word.

However, Bukshaisha (1985) reported that in Qatari Arabic pharyngealisation might extend across word boundaries in a phrase like, for example, [beet # iTTahir] “Al-Tahir’s home”. Card referred to the possibility that pharyngealisation might extend from a word-initial word to the preceding word, without presenting data on this. These observations corroborate the findings presented in the present study in that the word is planned as the domain of pharyngealisation, but that the surface domain might be larger than what is actually planned by the speaker.

Younes claims that the phoneme is the domain of pharyngealisation. He agues that neither the syllable nor the word can serve as the domain of pharyngealisation. Younes’ main argument against the syllable and the word views of the domain is that not all elements inside the syllable and the word are equally pharyngealised (Younes 1982: 159). Although Younes rejects Ghazeli’s claim that word boundaries block pharyngealisation, he acknowledges the role word boundaries have in weakening the effects of pharyngealisation. In this regard, Younes discusses minimum and maximum domains of pharyngealisation. The maximum domain in Younes’ definition is larger than the word. Younes’ argument was based on the observation that pharyngealisation is a gradient phenomenon that extends across word boundaries in a gradient fashion. Thus, to Younes, the maximum domain of pharyngealisation is larger than the word.

The results of the present acoustic study show that the word is the planned domain of pharyngealisation spread. It was found that the magnitude of pharyngealisation is relatively stable compared to pharyngealisation effects across word boundaries. More specifically, the magnitude of pharyngealisation within word boundaries does not decrease as a function of the duration of the affected phoneme(s). These findings imply that speakers intend to mould pharyngealisation effects within word boundaries. The finding that there are gradient pharyngealisation effects across word boundaries might be due to the fact that articulators cannot move instantaneously from one articulatory position to another.

The results of the present experiment seem to be consistent with two different approaches in the literature[1]. More specifically, in the first approach pharyngealisation is an inherent feature of the underlying pharyngealised triggers. This was based on the observation that, in the presence of opaque phonemes, pharyngealisation might not extend beyond the pharyngealised phoneme. The second phonological approach interprets pharyngealisation as a prosodic feature of the syllable or word (Harrel 1967; Lehn 1963). More specifically, pharyngealisation is a feature of whatever prosodic unit that serves as the domain of pharyngealisation, regardless of whether that unit is the syllable or the word. The results reported in the present study seem consistent with the position of the phonological representation where pharyngealisation is a feature of the phonological word.

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[1] I thank Barry Heselwood for calling my attention to the fact that these findings seem to be consistent with the prosodic approach as well as the segmental one.

Chapter 7. Conclusion

7.1 General conclusion

The present dissertation investigated anticipatory pharyngealisation across a hierarchy of prosodic boundary strengths (Syllable vs. Word vs. Phrase vs. IP). Minimal pairs (emphatic vs. plain) included a constant phonetic test sequence [VbV+Emphatic trigger] in four vowel contexts, i.e., [aba#Emphatic; abi#Emphatic; iba#Emphatic; ibi#Emphatic]. F2 value was measured at onset, mid and offset of both test vowels. The duration of the final vowel and that of the entire test sequence were considered to assess the influence of the temporal proximity to the emphatic trigger. This analysis was crucial to determine a clear-cut distinction between phonological spreading vs. phonetic coarticulation.

The results reported above demonstrate a clear distinction between lexical pharyngealisation within word boundaries and post-lexical pharyngealisation across word boundaries. The present results generally provide evidence that pharyngealisation spreads across the syllable, word and phrase boundary conditions. The magnitude of pharyngealisation effects does not vary with the duration factor in the syllable condition, i.e., within words. More specifically, the increase of vowel duration does not seem to contribute to a decrease in the magnitude of pharyngealisation in the syllable boundary condition. Though, this pattern was found in three out of four vowel contexts. However, across the word and phrase boundaries pharyngealisation effects are found only on the pre-trigger vowel, where the spread of pharyngealisation is predictable from the duration of the affected vowel. More specifically, pharyngealisation magnitude increases as the trigger is approached. These findings suggest that anticipatory pharyngealisation spreads phonologically within words, whereas across word and phrase boundaries pharyngealisation results from phonetic coarticulation.

The findings outlined in the present study pose a challenge to speech production models. Some of these models assume a phonological spread of distinctive features. Others assume that coarticulation is a phonetic process. However, the results reported herein provide support that both strategies are available to speakers, but each strategy is triggered by different prosodic boundary level. The results outlined above reveal that the word is the planned domain of pharyngealisation.

7.2 Recommendation for future research

The present study has shown that a combination of prosodic, segmental and durational factors can effectively provide insightful conclusions regarding the magnitude and the planned domain of coarticulation.

The present study was based on acoustic measurements of pharyngealisation manifested in F2 lowering. It would be interesting and insightful to replicate such data for an articulatory investigation using e.g., MRI. In addition, a replication of the present data on another Arabic dialect will shed some light on cross dialect coarticulatory variation, which will have implications for the phonology-phonetic interface discussions.

The present study was, in part, inspired by the data presented in (Krakow 1989) on nasalisation in terms of segmental composition and boundary manipulation. Thus, it would be interesting for future research on pharyngealisation to manipulate the location of word boundaries across matched phonetic sequences. For example, data in (Krakow 1989) for nasalisation included data items such as /see # more/ vs. /seem # ore/. The rationale underlying this design, for Krakow, was to introduce comparable coarticulatory contexts and sequential positions for initial vs. final nasals (Krakow 1999: 26). Therefore, a similar design for pharyngealised triggers would contribute more to our understanding the notion of the syllable and its role in speech production. For example, Krakow (1989) provided evidence for larger magnitude of nasalisation on vowels preceding nasals than on vowels following them. Thus, it will be interesting to investigate if pharyngealisation magnitude varies as a function of the position of the pharyngealised trigger within the syllable.

Appendices

Appendix A Syllable boundary condition

Transcription	Gloss
ʕabiidi	my slaves
ʕabiiTa	idiot
bibaDaʕ	will make shopping
bibadil	will change
bibaSaT	will simplify
bibassim	will make someone smile
bibaTal	will quit
bibiidu	they will wear out
bibiiDu	the will lay eggs
bifaDal	will prefer
bifadid	will get on someone's nerves
bifaSaʕ	will bend
bifaSal	will fit
bifassaħ	will take someone around
bifassir	will interpret
bifattaħ	will open
bifaTTar	will make someone a breakfast
bifiidu	they will benefit
bifiiDu	they will overflow

bimaatil	will exeplify
bimaaTil	will delay
bimasis	will touch
bimaSiS	will make someone suck
habaTu	they landed
ħafiida	granddaughter
ħafiiDa	keeper
ħamaDit	it got sour
irtibaaT	connection
mabaadiʃ	did not wear out
mabaaDiʃ	did not become white
mabatalliʃ	did not get wet
mafaadiʃ	did not benefit
mafaaDiʃ	did not overflow
mafaSaliʃ	did not fit
mafasariʃ	did not interpret
mafataħiʃ	did not open
mafaTarʃ	did not have breakfast
manafaDiʃ	did not move the dust
marafadiʃ	did not support
nabatit	it grew
qamiiSi	my shirt
xamiis	Thursday
jabat	addressing: hey

	transmission!
jabaT	addressing: hey ducks!

Appendix B Word boundary condition

Transcription	Gloss
ʕarabi daafi	warm Arab
ʕarabi saahil	simple Arab
ʕarabi taajib	repentant Arab
dabaaba daafja	warm tank
dabaaba saahla	simple tank
dabaaba taajba	repentant tank
ɣariiba daafja	warm stranger
ɣariiba saahla	simple stranger
ɣariiba taajba	epentant stranger
ħabiiba daafja	warm lover
ħabiiba saahla	simple lover
ħabiiba taajba	repentant lover
ħabiibi daayib	my melted love
ħabiibi saahil	my simple love
ħabiibi taajib	my repentant love
ħalaba daajba	melted ring
ħalaba saahla	simple ring
ħalaba taajba	repentant ring
iʒaaba daafja	warm answer

iʒaaba sahla	simple answer
iʒaaba taayba	rependent answer
kitaaba daafja	ward writing
kitaaba saahla	simple writing
kitaaba taajba	repentant writing
libi daafi	warm Libyan
liibi saahil	simple Libyan
liibi taayib	repentant Libyan
nisiiba daayba	melted son in law
nisiiba saahla	simple mother in law
nisiiba taayba	repentant mother in law
nisiibi daayib	melted brother in law
nisiibi saahil	simple brother in law
nisiibi taayib	repentant brother in law
rabaaba daafya	warm fiddle
rabaaba saahla	simple fiddle
rabaaba taayba	repentant fiddle
rabiiba daafja	warm daughter in law
rabiiba saahla	simple daughter in alw
rabiiba taayba	repentant daughter in law
sabaaba daajba	melted forefinger
sabaaba saahla	simple forefinger
sabaaba taayba	repentant forefinger
saħaaba daafja	warm umbrella

saħaaba saahla	simple umbrella
saħaaba taayba	repentant umbrella
saħaabi daayib	my repentant clouds
saħaabi saahil	my simple clouds
saħaabi taayib	my repentant clouds
taʒriibi daafi	warm experimental
taʒriibi saahil	simple experimental
taʒriibi taayib	repentant experimental
turaabi daayib	melted + name
turaabi saahil	simple + name
turaabi taayib	repented + name
zabiiba daafya	warm + name
zabiiba saahla	simple + name
zabiiba taayba	repentant + name
ʕarabi Daayaʕ	lost Arab
ʕarabi Saafi	pure Arab
ʕarabi Taayib	repentant Arab
dabaaba Daayʕa	lost tank
dabaaba Saafya	pure tank
dabaaba Taajba	cooked tank
ɣariiba Daayʕa	lost stranger
ɣariiba Saafya	pure stranger
ɣariiba Taayba	cooked stranger
ħabiiba Daayʕa	lost love

ħabiiba Saafya	pure love
ħabiiba Taayba	cooked love
ħabiibi Daayaʕ	my lost love
ħabiibi Saafi	my pure love
ħabiibi Taayib	my cooked love
ħalaba Dayʕa	lost ring
ħalaba Saafya	pure ring
ħalaba Taayba	cooked ring
iʒaaba Daayʕa	lost answer
iʒaaba Saafya	pure answer
iʒaaba Taayba	cooked answer
kitaaba Daayʕa	lost writing
kitaaba Saafya	pure writing
kitaaba Taayba	cooked writing
liibi Daayaʕ	lost Libyan
liibi Saafi	pure Libyan
libii Taayib	cooked Libyan
nisiiba Daayʕa	lost mother in law
nisiiba Saafya	pure mother in law
nisiiba Taayba	cooked mother in law
nisiibi Daayaʕ	lost brother in law
nisiibi Saafi	pure brother in law
nisiibi Taayib	cooked brother in law
rabaaba Daayʕa	lost fiddle

rabaaba Saafya	pure fiddle
rabaaba Taayba	cooked fiddle
rabiiba Daayʕa	lost daughter in law
rabiiba Saafja	pure daughter in law
rabiiba Taajba	cooked daughter in law
sabaaba Daayʕa	lost forefinger
sabaaba Saafya	pure forefinger
sabaaba Taayba	cooked forefinger
saħaaba Daayʕa	lost umbrella
saħaaba Saafya	pure umbrella
saħaaba Taayba	cooked umbrella
saħaabi Daayaʕ	my lost clouds
saħaabi Saafi	my pure clouds
saħaabi Taayib	my cooked clouds
taʒriibi Daayaʕ	lost experimental
taʒriibi Saafi	pure experimental
taʒriibi Taayib	cooked experimental
turaabi Daayaʕ	lost + Name
turaabi Saafi	pure + Name
turaabi Taayib	cooked + Name
zabiiba Daayʕa	lost + Name
zabiiba Saafya	pure + Name
zabiiba Taayba	cooked + Name

Appendix C Phrase boundary condition

Transcription	Gloss
gariibi-Daaʕ	my relative lost
gariibi-Saam	my relative fasted
gariibi-Taab	my relative cooked
ħabiibi-Daaʕ	my beloved lost
ħabiibi-Saam	my beloved fasted
ħabiibi-Taab	my beloved cooked
iddabaaba-Daaʕ	the tank lost
iddabaaba-Saam	the tank fasted
iddabaaba-Tabaʕ	the tank typed
ilʕarabi-Daaʕ	the arab lost
ilʕarabi-Saam	the Arab fasted
ilʕarabi-Taab	the Arab cooked
ilgariiba-Daaʕ	the relative lost
ilgariiba-Saam	the relative fasted
ilgariiba-Taab	the relative fasted
ilɣariiba-Daaʕ	the stranger lost
ilɣariiba-Saam	the ftranger fasted
ilɣariiba-Taab	the stranger cooked
ilħabiiba-Daaʕ	the beloved lost
ilħabiiba-Saam	the beloved fasted
ilħabiiba-Taab	the beloved cooked
ilħalaba-Dall	the ring lost the way

ilħalaba-Saam	the ring fasted
ilħalaba-Taab	the ring cooked
iliʒaaba-Daaʕ	the answer lost
iliʒaaba-Saam	the answer fasted
iliʒaaba-Taab	the answer cooked
ilkitaaba-Daaʕ	the writing lost
ilkitaaba-Saam	the writing fasted
ilkitaaba-Taab	the writing cooked
illiibi-Daaʕ	the Libyan lost
illiibi-Saam	the Libyan fasted
illiibi-Taab	the Libyan cooked
innasiiba-Daaʕ	the mother-in-law lost
innasiiba-Saam	the mother-in-law fasted
innasiiba-Taab	the mother-in-law cooked
irrabiiba-Daaʕ	the daughter-in-law lost
irrabiiba-Saam	the daughter-in-law fasted
irrabiiba-Taab	the daughter-in-law cooked
iʃalabi-Daaʕ	ishalabi lost
iʃalabi-Saam	ishalabi fasted
iʃalabi-Taab	ishalabi cooked
issabaaba-Daaʕ	the forefinger lost
issabaaba-Saam	the forefinger fasted
issabaaba-Taab	the forefinger cooked
issaħaaba-Daaʕ	the unbrella lost

issaħaaba-Saam	the umbrella fasted
issaħaaba-Taar	the umbrella flew
issaħaabi-Daaʕ	my clouds lost
issaħaabi-Saam	my clouds fasted
issaħaabi-Taab	my clouds cooked
itturaabi-Daaʕ	itturaabi lost
itturaabi-Saam	itturaabi fasted
itturaabi-Taab	itturaabi cooked
izzabiiba-Daaʕ	izzabiiba lost
izzabiiba-Saam	izzabiiba fasted
izzabiiba-Taab	izzabiiba cooked
kitaabi-Daaʕ	my book lost
kitaabi-Saam	my book fasted
kitaabi-Taab	my book cooked
nasiibi-Daaʕ	my brother-in-law lost
nasiibi-Saam	my brother-in-law fasted
nasiibi-Taab	my brother-in-law cooked
taʒriibi-Daaʕ	experimental lost
taʒriibi-Saam	experimental fasted
taʒriibi-Taab	experimental cooked
gariibi-daab	my relative melted
gariibi-sabb	my relative poured
gariibi-taab	my relative repented
ħabiibi-daab	my beloved melted

ħabiibi-sabb	my beloved poured
ħabiibi-taab	my beloved repented
iddabaaba-daab	the tank melted
iddabaaba-sabb	the tank poured
iddabaaba-taab	the tank repented
ilʕarabi-daab	the Arab melted
ilʕarabi-sabb	the Arab swared
ilʕarabi-taab	the arab repented
ilgariiba-daab	the stranger melted
ilgariiba-saal	the stranger liquefied
ilgariiba-taab	the stranger repented
ilħabiiba-daab	the beloved melted
ilħabiiba-sabb	the beloved swared
ilħabiiba-taab	the beloved repented
ilħalaba-dall	the ring lost
ilħalaba-sabb	the ring swore
ilħalaba-taab	the ring repented
iliʒaaba-daab	the answer melted
iliʒaaba-sabb	the answer swore
iliʒaaba-taab	the answer cooked
ilkitaaba-daab	the writing melted
ilkitaaba-sabb	the writing swore
ilkitaaba-taab	the writing repented
illiibi-daab	the Libyan melted

illiibi-sabb	the Libyan swore
illiibi-taab	the Libyan repented
innasiiba-daab	the mother-in-law melted
innasiiba-sabb	the mother-in-law swore
innasiiba-taab	the mother-in-law repented
irrabiiba-daab	the daughter-in-law melted
irrabiiba-sabb	the daughter-in-law swore
irrabiiba-taab	the daughter-in-law repented
iʃalabi-daab	ishalabi melted
iʃalabi-sabb	ishalabi swore
iʃalabi-taab	ishalabi repented
issabaaba-daab	the forefinger melted
issabaaba-sabb	the forefinger swore
issabaaba-taab	the forefinger repented
issaħaaba-daab	the umbrella melted
issaħaaba-sabb	the umbrella swore
issaħaaba-taab	the umbrella repented
issaħaabi-daab	ishalabi melted
issaħaabi-sabb	ishalabi swore
issaħaabi-taab	ishalabi repented
itturaabi-daab	itturaabi melted
itturaabi-sabb	itturaabi swore
itturaabi-taab	itturaabi cooked
izzabiiba-daab	izzabiiba melted

izzabiiba-sabb	izzabiiba swore
izzabiiba-taab	izzabiiba repented
kitaabi-daab	my book melted
kitaabi-sabb	my book swore
kitaabi-taab	my book repented
nasiibi-daab	my brother-in-law melted
nisiibi-sabb	my brother-in-law swore
nisiibi-taab	my brother-in-law repented
taʒriibi-daab	experimental melted
taʒriibi-sabb	experimental swore
taʒriibi-taab	experimental repented

Appendix D Intonation phrase boundary condition

The intonation phrase condition is as follows: [Hasb kalaam gariibi # Diyaa jaab il bint] “according to my relative, Diyaa brought the girl”. This table lists only the pre-trigger word containing the test sequence, and the post-trigger word containing the word-initial pharyngealised trigger.

Transcription	Gloss
gariibi, Diyaa	my relative, Diyaa
ghariibi, Salaaħ	my relative, Salaaħ
gariibi, Taahir	my relative, Taahir
ħabiibi, Diyaa	my beloved, Diyaa
ħabiibi, Salaaħ	my beloved, Salaaħ
ħabiibi, Taahir	my beloved, Taahir

idabaaba, Diyaa	the tank, Diyaa
idabaaba, Salaaħ	the tank, salaaħ
idabaaba, Taahir	the tank, Taahir
ilʕarabi, Diyaa	the Arab, Diyaa
ilʕarabi, Salaaħ	the Arab, Salaaħ
ilʕarabi, Taaher	the Arab, Taahir
ilgariiba, Diyaa	the relative, Diyaa
ilgariiba, Salaaħ	the relative, Salaaħ
ilgariiba, Taahir	the relative, Taahir
ilɣariiba, Diyaa	the stranger, Diyaa
ilɣariiba, Salaaħ	the stranger, Salaaħ
ilɣariiba, Taahir	the stranger, Taahir
ilħabiiba, Diyaa	the beloved, Diyaa
ilħabiiba, Salaaħ	the beloved, Salaaħ
ilħabiiba, Taahir	the beloved, Taahir
ilħalaba, Diyaa	the ring, Diyaa
ilħalaba, Salaaħ	the ring, Salaaħ
ilħalaba, Taahir	the ring, Taahir
ilijaaba, Diyaa	the answer, Diyaa
ilijaaba, Salaaħ	the answer, Salaaħ
ilijaaba, Taahir	the answer, Taahir
ilkitaaba, Diyaa	the writing, Diyaa
ilkitaaba, Salaaħ	the writing, Salaaħ
ilkitaaba, Taahir	the writing, Taahir

illiibi, Diyaa	the Libyan, Diyaa
illiibi, SalaaH	the Libyan, Salaaħ
illiibi, Taahir	the Libyan, Taahir
innasiiba, Diyaa	the mother-in-law, Diyaa
innasiiba, Salaaħ	the mother-in-law, Salaaħ
innasiiba, Taahir	the mother-in-law, Taahir
irrabiiba, Diyaa	the daughter-in-law, Diyaa
irrabiiba, Salaaħ	the daughter-in-law, Salaaħ
irrabiiba, Taahir	the daughter-in-law, Taahir
iʃalabi, Diyaa	ishalabi, Diyaa
iʃalabi, Salaaħ	ishalabi, Salaaħ
iʃalabi, Taahir	ishalabi, Taahir
issabaaba, Diyaa	the forefinger, Diyaa
issabaaba, Salaaħ	the forefinger, Salaaħ
issabaaba, Taahir	the forefinger, Taahir
issaħaaba, Diyaa	the umbrella, Diyaa
issaħaaba, Salaaħ	the umbrella, Salaaħ
issaħaaba, Taahir	the umbrella, Taahir
issaħaabi, Diyaa	my clouds, Diyaa
issaħaabi, Salaaħ	my clouds, Salaaħ
issaħaabi, Taahir	my clouds, Salaaħ
itturaabi, Diyaa	itturaabi, Diyaa
itturaabi, Salaaħ	itturaabi, Salaaħ
itturaabi, Taahir	itturaabi, Taahir

izzabiiba, Diyaa	izzabiiba, Diyaa
izzabiiba, Salaaħ	izzabiiba, Salaaħ
izzabiiba, Taahir	izzabiiba, Taahir
kitaabi, Diyaa	my book, diyaa
kitaabi, Salaaħ	my book, Salaaħ
kitaabi, Taahir	my book, Taahir
nasiibi, Diyaa	my brother-in-law, Diyaa
nasiibi, Salaaħ	my brother-in-law, Salaaħ
nasiibi, Taahir	my brother-in-law, Taahir
taʒriibi, Diyaa	experimental, Diyaa
taʒriibi, Salaaħ	experimental, Salaaħ
taʒriibi, Taahir	experimental, Taahir
gariibi, diyaab	my relative, diyaab
gariibi, samiir	my relative, samiir
gariibi, taamir	my relative, taamir
ħabiibi, diyaab	my beloved, diyaab
ħabiibi, saamir	my beloved, samiir
ħabiibi, taamir	my beloved, taamir
idabaaba, diyaab	the tank, diyaab
idabaaba, samiir	the tank, samiir
idabaaba, taamir	the tank, taamir
ilʕarabi, dyiaab	the Arab, diyaab
ilʕarabi, samiir	the Arab, samiir
ilʕarabi, taamir	the Araab, taamir

ilgariiba, dalaal	the relative, dalaal
ilgariiba, saami	the relative, saami
ilgariiba, taamir	the relative, taamir
ilɣariiba, dalaal	the stranger, dalaal
ilɣariiba, saami	the stranger, saami
ilɣariiba, taamir	the stranger, taamir
ilħabiiba, diyaab	the beloved, diyaab
ilħabiiba, saami	the beloved, saami
ilħabiiba, taamir	the beloved, taamir
ilħalaba, dalaal	the beloved, dalaal
ilħalaba, saami	the ring, saami
ilħalaba, taamir	the ring, taamir
iliʒaaba, dalaal	the answer, dalaal
iliʒaaba, saami	the answer, saami
iliʒaaba, taamir	the answer, taamir
ilkitaaba, diyaab	the writing, diyaab
ilkitaaba, saamir	the answer, saamir
ilkitaaba, taamir	the answer, taamir
illiibi, diyaab	the Libyan, diyaab
illiibi, sammir	the Libyan, saamir
illiibi, taamir	the Libyan, taamir
innasiiba, dalaal	the mother-in-law, dalaal
innasiiba, saamir	the mother-in-law, saamir
innasiiba, taamir	the mother-in-law, taamir

irrabiiba, diyaab	the daughter-in-law, diyaab
irrabiiba, saami	the daughter-in-law, saami
irrabiiba, taamir	the daughter-in-law, taamir
iʃalabi, diyaab	Ishalabi, diyaab
iʃalabi, saami	Ishalabi, saami
iʃalabi, taamir	Ishalabi, taamir
issabaaba, diyaab	the forefinger, diyaab
issabaaba, saami	the forefinger, saami
issabaaba, taamir	the forefinger, taamir
issaħaaba, diyaab	the umbrella, diyaab
issaħaaba, saami	the umbrella, saami
issaħaaba, taamir	the umbrella, taamir
issaħaabi, diyaab	my clouds, diyaab
issaħaabi, saamir	my clouds, saamir
issaħaabi, taamir	my clouds, taamir
itturaabi, diyaab	itturaabi, diyaab
itturaabi, saamir	itturaabi, saamir
itturaabi, taamir	itturaabi, taamir
izzabiiba, diyaab	izzabiiba, diyaab
izzabiiba, saami	izzabiiba, saami
izzabiiba, taamir	izzabiiba, taamir
kitaabi, diyaab	my book, diyaab
kitaabi, saami	my book, saami
kitaabi, taamir	my book, taamir

nasiibi, diyaab	my brother-in-law, diyaab
nasiibi, saami	my brother-in-law, saami
nasiibi, taamir	my brother-in-law, taamir
taʒriibi, diyaab	experimental, diyaab
taʒriibi, saami	experimental, saami
taʒriibi, taamir	experimental, taamir

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