Emphasis in Zilfaawi Arabic

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Abstract of the Dissertation

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This dissertation enhances our understanding of the nature of emphatics and their effects on neighboring vowels through a large-scale acoustic study of emphasis in Zilfaawi Arabic. Based on data from 15 male speakers of Zilfaawi, the acoustic correlates of emphasis are shown to be F2 drop and F1 increase, which can extend across entire disyllabic words when emphatics appear in word-initial and word-final positions. Because of lowering the second formant and raising the first one, I argue that emphasis is expressed as a pharyngealization process produced by backing the tongue root towards the pharynx. Furthermore, I show that the effect of emphasis on neighboring segments is *phonetic* (using the criteria proposed by Zawaydeh 1999), as evidenced by the effect's gradient decline with distance, the lack of blocking by high vowels and consonants, and the lack of blocking by

morpheme boundaries. I also show that emphatics affect stressed and unstressed vowels equally. Finally, I offer a constraint-based analysis of emphatic effect as it applies to /a/, /i/, and /u/, adopting the framework developed by Flemming (2001) which uses universal weighted constraints and implements phonetic representations associated with phonetic dimensions such as F2. I demonstrate how such a system can handle the complex interaction of phonological and phonetic goals when vowels and emphatics interact. The amount of emphatic effect exerted on vowels differs from one vowel quality to another. The high vowels /i/ and /u/ are the least affected vowels while the low vowel /a/ is the most affected one; I attribute the smaller effect on /i/ to the conflict between the acoustic requirements of /i/, low F1 and high F2, and the opposite requirements of the emphatics. With regard to the smaller effect on /u/, I attribute this to the vowel's inherently low F2, which is already in agreement with the requirements of the emphatics. Finally, /a/ is most affected because it does not have an opposing (high F2) goal, nor does it already have a low F2 target.

It is my hope that this analysis of Zilfaawi Arabic will be one step towards comparisons between this dialect and other dialects of Arabic, on the one hand, and between Arabic and other languages, on the other, all working toward the goal of better understanding of how knowledge of speech sounds is represented and used in human language.

Dedication

I dedicate this dissertation to my parents, Sharifa and Ahmed.

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Chapter One

1 Introduction

Semitic languages such as Arabic and Aramaic are characterized by a distinctive feature known as "emphasis" (Lehn, 1963). Thus, in addition to the primary articulation in the dental/alveolar region, emphatic consonants have a secondary articulation in the back of the vocal tract (Lehn 1963, Al-Ani 1970, Ghazeli 1977, Card 1983, Watson 2002, Bin Muqbil 2006). Classical and Modern Standard Arabic have the following emphatic segments (/tˤ/ /ðˤ/ /sˤ/ /dˤ/), although there has been less consensus on the nature of the emphatic sound /dˤ/ based on Sibawayh's description (Ghazali, 1977). However, the present dialects of Arabic have the two segments /tˤ/ and /sˤ/ in addition to either /dˤ/~ /zˤ/ or /ðˤ/[1]. The set of emphatic consonants and their plain counterparts that contrast in minimal pairs in Zilfaawi Arabic are (/tˤ/ /ðˤ/ /sˤ/) as shown in (1):

(1)

/tˤa:b/ "he cured"	/ta:b/ "he repented"
/ðˤil/ "shade"	/ðil/ "humiliation"
/sˤab/ "he poured sth"	/sab/ "he cursed"

Emphasis effects have been observed to have a strong influence on neighboring vowels. This effect on neighboring vowels is often referred to as

[1] The pharyngealized alveolar stop /dˤ/ and pharyngealized interdental fricative /ðˤ/ in Zilfaawi Arabic, and in Najdi Arabic in general, as mentioned by Ingham (1994), merged into the interdental fricative /ðˤ/. So, it would be interesting to answer the question of whether speakers of Zilfaawi Arabic would produce neutralization or a subtle difference between Modern Standard Arabic items that should have /dˤ/ and /ðˤ/, e.g., /ħaðˤ/ "luck" vs. /ħadˤ/ "he urged", when they seem to say all with the pharyngealized interdental fricative /ðˤ/, especially when they read these words.

“emphasis spread”. In many analyses, emphasis effect has traditionally been analyzed as a characteristic of the emphatic sounds that affect the neighboring vowels (Ghazali, 1977; Card, 1982; Watson, 1999; Zawaydeh, 1999; among others). However, other researchers have analyzed emphasis as syllable prosody (Harrell, 1957; Lehn, 1963; Broselow, 1979). In their lexical representations, the syllables that have the emphatic sounds are labeled “emphatic”. Therefore, emphasis is not a property of the emphatic sound, but it is a property of the syllable. However, this analysis has been rejected by many later researchers based on articulatory and acoustic studies (for example, Ghazali, 1977; Card, 1982).

It has been claimed that the exact nature of this secondary articulation of emphatics varies across the dialects of Arabic, from a constriction in the upper pharynx with a retraction of the tongue dorsum, known as uvularization, (Ali and Daniloff; 1972, Ghazeli, 1977), to a constriction in the lower pharynx with a retraction of the tongue root, known as pharyngealization (Al-Ani, 1970; Giannini and Pettorino, 1982; Khattab et al., 2006).

Some researchers have related emphasis to pharyngealization based on articulatory studies of some dialects of Arabic. Based on the results of articulatory study, MarCais (1948), Jakobson (1957) and Harrell (1962) associated emphasis with a constriction in the back of the oral cavity by retracting the tongue root towards the pharynx. In addition, based on his articulatory study of Arabic sounds, Al-Ani (1970) argued that to produce the stop emphatic /$t^{ʕ}$/, the root of the tongue is retracted towards the upper oropharynx. Therefore, he concluded that the secondary articulation in Arabic is a pharyngealization, rather than a velarization, process. The x-ray tracing in the figure in Figure 1 shows the configuration of the vocal tract during the production of the emphatic /tˤ/ and the plain /t/ as reported by Al-Ani (1970).

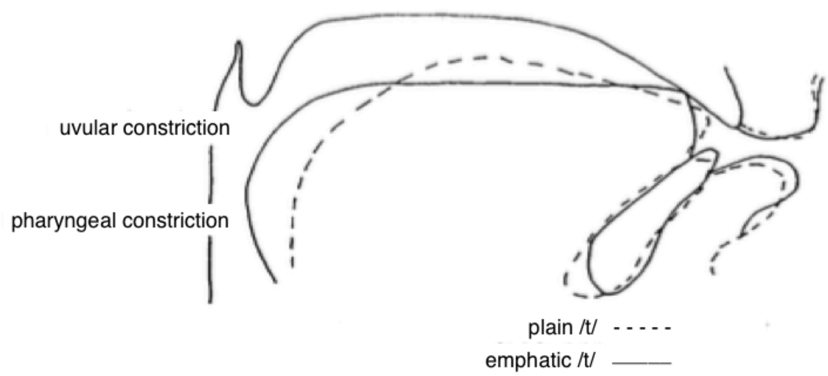


Figure 1: X-ray tracing of the plain and emphatic /t/ after Al-Ani (1970: Tracing 11)

Another group of researchers (McCarthy 1994; Shahin 1997; Zawaydeh 1999; al-Khairy (2005) proposed that this co-production or secondary articulation is a uvularization process. They found that the secondary articulation occurs in the uppermost part of the oropharynx. Because the oropharynx is close to the uvula, where the uvular sounds are produced, these sounds might be better called uvularized (Watson, 2002).

Velarization has also been used by many researchers to refer to emphasis because they claimed that the back of the tongue is retracted towards the soft palate (Gairdner, 1925; Obrecht, 1968; NaSr, 1959a; Ferguson, 1956a; Catford, 1977). This description originated when Sibawayh described emphasis as elevation of the back of the tongue towards the upper palate. In their articulatory study, Ali and Daniloff (1982) rejected the term "velarization" based on the results of their study that showed the velum played no role in the production of the Arabic emphatics. In addition, Norlin (1987) was not in favor of calling the emphatic sounds velarized because the acoustic features of velarized sounds are different, based on the acoustic results of his analysis. Despite the different specific depiction of this back articulation, there is a general consensus on the retraction of the back of the tongue in all dialects of Arabic.

In some studies, formants of neighboring vowels have been used to characterize the emphatic consonants as pharyngealized (Al-Ani, 1979; Davis, 1995), uvularized (Zawaydeh, 1999; Shahin, 2002; McCarthy, 1994), or velarized (Obrecht, 1968), although the latter is least commonly reported. It is argued that each of these articulations is accompanied by different changes for F1 and F2 of the neighboring vowels: F2 drop and unchanged F1 is uvularization, F2 drop and F1 increase is pharyngealization, and F2 and F1 drop is velarization (Zawaydeh, 1999; Shar, 2012).

Lowering of vowels' F2 values is the most common emphatic effect on neighboring vowels reported by many authors (Al-Ani, 1970; Ghazali, 1977; Card, 1983; Zawaydeh, 1999; among others). Consistent raising of the F1 of the vowels has also been reported by some authors, (Ghazali, 1977; Al-Masri, 2009; among others), although it is not as common as the second formant decrease. These reported acoustic cues of emphasis, F2 drop and F1 increase, can prevail throughout the syllable (Lehn, 1963; Obrecht, 1968; Ali and Daniloff, 1972b, Broselow, 1976), the entire word (Ghazali, 1977; Card, 1982; Watson, 1999; Zawaydeh, 1999), or the vowel immediately to the right (Younes, 1993).

Some earlier studies have considered emphasis spread, which is also called emphatic effect in this study, in Arabic as a phonological phenomenon controlled via phonological mechanisms, such as phonological feature spreading, (Broselow 1979; Ali and Daniloff, 1972; Alghazo, 1987; Watson, 1999). However, some other authors have argued that emphasis spread is a phonetic process (Bukhshaisha, 1985; Zawaydeh, 1999; among others). Zawaydeh (1999) proposed some factors that might indicate whether emphasis spread is phonetic or phonological. Firstly, based on acoustic cues, if emphasis spread is gradient, then we may consider it phonetic. If it is categorical, however, it is then considered to be phonological. The implementation of gradiency as an indicator of phonological status was also proposed by Cohn (1993) when she investigated phonetic nasalization in English and phonemic nasalization French. In English VN sequences, the nasalization effect is transitional and it strengthens gradually as the nasal consonant is approached. In French, however, the effect has a plateau phase with rapid transition from the preceding non-nasal segment, and that phonetic transitional effect is not present (Cohn 1993). Bessel (1998) in his analysis of two languages of Salish, also used gradiency as a tool to differentiate phonetic from phonological faucal harmony in these languages. Secondly, Zawaydeh (1999) also used blocking by high consonants and vowels as evidence of phonological emphasis. Thus, if emphasis spread is never blocked by any segments, then it can be considered phonetic; otherwise, it is phonological. In the Arabic literature, the high segments have been reported to resist the emphatic effect and they would block the effect affecting the non-adjacent syllable. The segments that have been reported to be blockers and opaque and are the high vowel /i/, (Ghazali, 1977; Card, 1983; Heath, 1987; Younes, 1993; Davis, 1995; among others), and /j/ and /ʃ/, (Card, 1983; Heath, 1987; Younes, 1993; Davis, 1995; Shahin, 1997a, b; among others). The affricates /ʧ/ and /ʤ/ have also been reported by Shahin (1997a, b) as being opaque in the Arabic dialect of Abu Shusha Palestinian Arabic. In addition, Heath (1987) reported that the fricative /ʒ/ is an opaque segment in the Arabic dialects that have this consonant in their consonantal systems. Moreover, emphasis has been argued to spread rightward and leftward differently; some authors have reported that leftward emphasis spread is more prominent and is never blocked (Zawaydeh, 1999; Davis, 1995; Al-Masri, 2011).

By contrast, rightward spread has been reported to be blocked by the high segments /i/ (Davis, 1995), (/i/, /i:/, /e:/) (Card, 1983), and /u/ (Al-Masri, 2011).

In addition to the segmental blocking proposed above, blocking by morpheme boundaries can be also implemented to indicate whether a specific phenomenon is controlled via phonological or phonetic mechanisms. It has been reported in some languages that, in phonological phenomena such as nasalization and RTR harmony, affixes do not always undergo these processes along with the roots (Rose & Walker, 2011). Bessel (1998) reported that the vowels of the prefixes in the sub-dialect of Salish, Snchitsuʕumshtsn, do not usually retract when they are followed by post-velar consonants when compared to those of the stems that retract. Having reported that, only a few studies have investigated emphasis spread across morpheme boundaries in Arabic. Emphasis might spread into prefixes and suffixes across morpheme boundaries differently from one dialect to another. Younes (1993), in an impressionistic study, stated that, in Palestinian Arabic, emphasis spreads into prefixes optionally, but spreads obligatorily into suffixes. Zawaydeh (1998), using herself as an informant, stated that, in Ammani-Jordanian Arabic, emphasis spreads obligatorily into prefixes and spreads optionally into suffixes. However, emphasis spreads into suffixes obligatorily in the dialect only if the stem ends with one of the emphatics. Schulte (1985) reported the same findings in Cairene Arabic.

There is much evidence in the literature that stress may affect the magnitude and timing of vowel and consonant gestures, and that stressed vowel qualities become more peripheral than do their unstressed counterparts (Ortega & Prieto, 2010; Fry, 1965; Cho & Keating, 2009). Some studies (Farnetani, 1990; Fowler, 1981; Agwuele, 2004) have claimed that prosodic features, such as stress, affect the degree and extent of coarticulation among neighboring segments within the same word, such as VCV. Therefore, stress is an important factor that should be taken into consideration when studying the formants of vowels because it might affect the degree and extent of emphasis. Contrary to what has usually been reported in the literature, Alammar (2015) reported that, in the vicinity of initial target emphatics, vowels show significantly higher F1 and lower F2 values compared to the vowels in the vicinity of final target emphatics. In his study, because of how stress works in Arabic, all words have initial stress when target emphatics are used word-initially, while they have varying stress, initial and final, when target emphatics are used word-finally. Therefore, he stated that vowels in initial syllables might be affected more by initial emphatics because they are all stressed.

Before discussing the aims and questions of the dissertation, I will review some of the relevant literature in the following subsection.

1.1 Medieval and Modern Studies of Emphasis

In his book *Al-Kitaab*, the prominent linguist Sibawayh (who lived between 760 and 796 AD) wrote about the pharyngealized segments specifically, and about the speech sounds of Arabic in general. Sibawayh classified the Arabic sounds based on the place of articulation, manner of articulation, and voicing. In his classification of the sounds of the Arabic language, he made a distinction between the /mustaʕlijah/ "elevated" and /mustafilah/ "non-elevated". The sounds that have the feature "ʔistiʕla:ʔ" are the pharyngealized consonants above (/tˤ/, /ðˤ/, /sˤ/, /dˤ/), in addition to the voiceless uvular fricative /χ/, the voiced uvular fricative /ʁ/, and the uvular stop /q/. These sounds - which are called "guttural" in modern linguistics (see McCarthy, 1991) - are articulated at the back of the oral cavity. They are produced by raising the tongue to either the uvular or the velar region, while the rest of the sounds are articulated in the other parts of the oral cavity between the lips and soft palate (Alsurf, 2012; Al-Nassir, 1993). In addition, Sibawayh categorized the speech sounds as either /mutˤbaqah/ (semi-closed) or "munfatiħa" (open). According to Sibawayh, the pharyngealized sounds have the /ʔitˤba:q/ feature, which "involves a double articulation accompanied by simultaneously positioning the blade of the tongue in the anterior part of the mouth – primary articulation - and applying the back of the tongue to the 'upper palate'" (Ghazali, 1977, p. 6). Therefore, according to Sibawayh, the emphatics have a secondary articulation at the back of the oral cavity in addition to their primary articulation in another part of the mouth. These sounds are the sounds (/tˤ/, /ðˤ/, /sˤ/, /dˤ/).

One distinctive acoustic feature was used by Sibawayh in his description of the sounds in Arabic. The feature "tafχi:m" (translated by Bellem, 2007, as "aggrandizement", "puffing up", or "making portentous", and by Alsurf, 2012, as "thickening") has been introduced and has been widely used by modern linguists (Jakobson, 1957; Ali & Daniloff, 1972; among others). The English term "emphasis" has been used to refer to the same phenomenon, and the secondarily articulated sounds are traditionally called the Arabic "emphatic consonants". Other terms have been used to refer to this phenomenon, such as "velarization", "uvularization", and "pharyngealization", as mentioned above.

Al-Ani (1970) investigated emphatics in one of the most prominent recent acoustic studies of Arabic consonants and vowels. While Al-Ani (1970) did not report anything about F1, he concluded that F2 drops in the onsets of vowels following emphatic consonants as opposed to non-emphatic ones. The vowel found to be most affected was /a/. With regard to the high vowel /i/, only the onset of the vowel is affected. However, the vowel /u/ showed the least effect in terms of the onset and steady state of the vowel.

Ghazeli (1977) investigated Tunisian Arabic along with other Arabic dialects. The domain of the emphasis was the entire word and not only the syllable, as reported by some researchers. He reported that F2 drops at the onset of the vowel /i/. Moreover, Ghazeli (1977) found that F2 lowering affects and extends throughout /a/. Having said this, however, he concluded that the vowel /i:/ neither acquires nor transmits emphasis. Ghazeli (1977) revealed that anticipatory emphasis spread is less restricted than is carryover emphasis spread. His results showed that the anticipatory emphasis spread can be weakened but not blocked by /i/, while the carryover emphasis spread is strongly weakened or blocked by /i/.

Giannini and Pettorino (1982) investigated the acoustic correlates of emphasis in Iraqi Arabic using data from one speaker. They revealed that the F1 and F2 of vowels move towards each other due to the acoustic influence of emphatics. Although both the F1 and F2 of vowels are affected, F1 raising is not as consistent and significant as F2 depression when the vowels are adjacent to emphatics. However, the F3 exhibited no change in plain or emphatic contexts. Based on their study, they claimed that the first and second formants of the vowels change as a result of a pharyngealization process that takes place in the Iraqi dialect under study. However, Giannini and Pettorino (1982) did not perform any statistical analyses of their results.

Card (1983) examined the acoustic correlates of emphasis in Palestinian Arabic using 82 words. The participants were four male speakers of Palestinian Arabic, with two speaking Rural Palestinian Arabic and two speaking Urban Palestinian Arabic. The major acoustic effect reported by Card was the lowering of the F2 of the vowels adjacent to the emphatic consonants. This acoustic property was identical, regardless of whether the target consonant was word-initial or word-final. While Card (1983) failed to mention the position at which she took the measurements, the more affected vowels were the low and back vowels: (/a/, /a:/, /u/, /u:/, /o:/), but not (/i/, /i:/, /e:/) for some speakers. This acoustic effect of emphatic consonants was blocked when the adjacent vowel was (/i:/, /i/, /e:/). However, the high consonants, such as /ʃ/ and /ʤ/, were not properly considered by her to test blocking in the dialects in her study. Card (1983) measured F1 and F3, finding no significant effects on these two formants. Based on F2 lowering in monosyllables, Card (1983) mentioned that leftward emphasis spread is more attested than is rightward emphasis.

Heath (1987) investigated the acoustic correlates of emphasis in Moroccan Arabic using data from one speaker. He was interested in the second formant of the low vowel /a/. Heath found consistent and significant F2 depression when vowels were adjacent to the emphatics in Moroccan Arabic. He also reported that high segments block the emphatic effect when they are available in the word, as in the only relevant word presented, /ʕtˤʃan/ "thirsty". However, Heath (1987) did not reveal the data used for testing emphasis in the Moroccan dialect.

Using monosyllabic and disyllabic word pairs, Wahba (1993) examined the acoustic correlates of emphasis in Alexandrian Egyptian Arabic. The first and second formants were measured at the onset and midpoint of the eight vowels in the dialect. In the emphatic environments, F2 was significantly lowered at the onset and middle of the vowels. Of the eight vowels, the low vowels (/æ, æ:/) were the most affected. However, Wahba (1993) reported no significant change for F1 in the emphatic environments.

Davis (1995) conducted an impressionistic phonological study on only one speaker of Southern Palestinian Arabic to study the extent of emphasis spread. He found that that anticipatory emphasis spread was unbounded, while the carryover emphasis spread was blocked by the non-back high segments such as /i/.

Zawaydeh (1999) and Zawaydeh and De Jong (2002) investigated emphasis spread in Ammani-Jordanian Arabic using real words. The use of real words was at the expense of having words with no identical phonetic environments. The subjects of their study were three male and three female speakers. The only vowel used for the acoustic experiment was the low vowel /a/. By measuring the midpoint of the vowel, Zawaydeh (1999) claimed that the vowels following or preceding emphatics have a raised F1 and a depressed F2. She found that carryover emphasis spread is a gradient, while the anticipatory emphasis spread is categorical. As such, for the leftward emphasis spread, the F2 values of the target and preceding vowels in the word are equally low. However, for the rightward emphasis spread, this acoustic effect of emphasis diminishes when we get further from the target emphatic consonant. Zawaydeh (1999) also found that emphasis spread is never blocked by either of the high segments (/i/, /u/, /ʃ/, /j/), regardless of the direction.

In her book *The Phonology and Morphology of Arabic*, Watson (2002) devoted the study to two dialects of Arabic. One was the dialect spoken in Cairo, and the other was the one spoken in the capital of Yemen, San'a. She claimed that F2 depression constitutes the more significant acoustic correlates of emphatics, compared to F1 raising. In her analysis of Cairene Arabic, Watson (2002) argued that regressive emphasis affects the entire stem, whereas progressive emphasis is blocked by the non-tautosyllabic segments, /i/ and /j/. Watson (2002) claimed that emphasis spread in Arabic words is optional, particularly when the neighboring vowel is a short one.

Khattab et al. (2006) investigated the acoustic correlates of /$t^ʕ$/ used by male and female speakers of Jordanian Arabic. They were interested only in the high vowel /i/ and the low vowel /æ/ following the initial emphatic /$t^ʕ$/. The measurements were taken at the onset of the vowels, with findings revealing significant F1 raising and F2 lowering. However, the effect exerted by the emphatic consonant was stronger on the following low vowel /a/ than it was on the high vowel /i/.

Al-Masri (2009) assessed the acoustic correlates of emphasis in urban Jordanian Arabic. He examined word pairs that have the target emphatic and plain consonants word-initially, word-medially, and word-finally. Formant frequencies were measured at the onset, middle, and offset of the vowels. The vowels used in this study included /a/ and /i/, and their long counterparts /a:/ and /i:/. Al-Masri (2009) reported significant F1 and F3 raising, together with F2 lowering in emphatic environments. The vowels found to be most affected were the low and high front vowels. For disyllabic words with final target consonants, the findings showed that F1 was significantly raised at all measurement positions of the target vowel, as well as in the vowel in the preceding syllable, with the exception of the midpoint position. However, the F1 was not significantly raised at all measurement positions when the target consonants were word-initial. Based on these findings, Al-Masri (2009) argued that the F1 anticipatory emphasis spread is more prominent than is the carryover spread, since it barely goes beyond the target syllable. With regard to F2, the same results were obtained, supporting his claim concerning the asymmetrical emphasis spread. In terms of F3, the results showed that, in disyllabic words with initial and final target consonants, F3 was significantly raised at most of the measurement positions of the target vowel, as well as in the vowel before or after the target syllable. Al-Masri also found that, although the high back vowel /u/ blocked emphasis spread, the two vowels /a/ and /i/ did not. As an effect of F1, the vowel /a/ underwent more F1 raising than did the vowel /i/.

1.2 Aims of the Dissertation

Despite the good number of previous studies, several of them suffer from some limitations. One is that they are either impressionistic, or the number of participants is small. Moreover, with the exception of Al- Masri's study (2009), the sound sequences of interest were not all in identical phonetic environments, which resulted in not controlling for segmental context effects. Other limitations are considering only the F2, or measuring the vowel at only one point such as the midpoint of the vowel, which does not give accurate measurements, since the midpoint of a long vowel is further away from the target consonant compared to the midpoint of a short one, which is closer, for example. Another limitation is that the possible stress effect has not been taken into consideration when studying emphasis in the dialects of Arabic.

Using a more controlled set of data produced by a bigger number of subjects speaking Zilfaawi Arabic, this dissertation investigates the acoustic correlates of pharyngealization in Zilfaawi Arabic (ZA), and it has many aims to be achieved. First, as a general goal, this dissertation aims to fill the gap in the literature on Arabic emphatics and other languages by investigating the effect of emphatics on the neighboring vowel values of F1 and F2 in ZA to enhance the understanding of the nature of emphatics and their effects on the vowels near them. The focus is on F1 and F2 because the height of F1 is associated with tongue lowering, and the depression of F2 is associated with tongue retraction (Ladefoged, 1972). F3 is not considered in this research because it is not a significant and consistent correlate of pharyngealization. El-Dalee (1984) found inconsistent F3 change of vowels adjacent to emphatics. Bin Muqbil (2006) reported that, when measuring F3 values of neighboring vowels, no coarticulation effect was shown. Giannini &Pettorino (1982) found no F3 change in the vowels adjacent to emphatics.

Second, because the presence of emphatics lowers the values of F2 and may raise the values of F1, this dissertation aims to investigate whether the set of emphatics are articulated by retracting the tongue root or dorsum towards the upper part of the pharynx. If they are produced by retracting the tongue root, the emphasis effect in ZA is a pharyngealization process, contrary to other dialects such as Palestinian Arabic (Zawaydeh, 1999). However, if the consonants are produced by retracting the tongue dorsum, the emphasis effect is a uvularization process. This is based on the assumption that articulatory mechanisms can be inferred from acoustic data (Fant, 1960; Recasens, 1985; Bin Muqbil, 2006).

Third, this study aims to investigate the extent of pharyngealization looking for any gradiency, non-blocked effect of emphatics and any extending of the effect across the morpheme boundaries. If the extent is gradient, affecting affixes, and never blocked by middle consonants with opposing phonological in the word, then pharyngealization in Zilfaawi Arabic could be a phonetic phenomenon.

Fourth, this research aims to investigate the possible influence of stress on the duration and magnitude of the emphatic effect on the vowels. Some studies (Farnetani, 1990; Fowler, 1981) have claimed that prosodic features, such as stress, affect the neighboring vowels. To test whether stress has any direct influence on the extent of emphatics on the neighboring vowels, words with identical phonetic contexts contrasting in the stress position are investigated.

Fifth, on the basis of the acoustic results, this study aims to capture the emphatic effect in Zilfaawi Arabic by adopting a model that can account for the emphatic effect on neighboring vowels. This model should be able to derive the emphatic effect on the neighboring vowels, whether this effect is controlled via phonetic or phonological mechanisms, such as feature spreading. Some studies that proposed that the emphatic effect was phonetic failed to provide a model to derive that effect (Bukhshaisha, 1985; Zawaydeh, 1999; among others).

1.3 Questions of the Study

To achieve the aims of this study and to avoid the limitations of the previous ones, the dissertation will answer the following questions:

1. What are the acoustic effects of emphatics on neighboring vowels in Zilfaawi

Arabic that could distinguish them from their plain counterparts?

2. Is emphasis a pharyngealization process (F2 drop and F1 increase), or is it a uvularization process (F2 drop and unchanged F1)?

3. Do these acoustic effects vary based on the quality of the vowel?

4. Do changes in stress produce varying patterns of emphatic effect?

5. Is there phonetic evidence of phonological emphatic effect in Zilfaawi Arabic?

If the emphatic effect is shown to take place in Zilfaawi Arabic, the claim that emphasis is phonological needs to be tested by answering the following sub-questions:

A. How does the emphatic effect behave over time?

By measuring the vowel formants at different points of the vowels, one can test the emphatic effect over time to see if it is gradient or if it is categorical. If the effect is gradient, this would indicate that the emphatic effect is not phonological.

B. Do intervening segments with opposing phonological qualities, (/j, ʃ, dʒ, u:, i:/), block pharyngealization?

On one hand, if these high segments block the emphatic effect, we could say that the emphatic effect is phonological, assuming that blockers could be specified with a feature value, such as [FRONT], which cannot be combined with the pharyngealization feature, such as [DORSAL] and [RTR] (Shahin 1997) . On the other hand, if these high segments do not block, we could say that the emphatic effect is phonetic.

C. Do morpheme boundaries block emphatic effects on vowels?

It has been reported in some languages that, while roots undergo processes such as phonological nasalization and [ATR] harmony, affixes do not always do so (Rose & Walker, 2011). Thus, if emphasis does not spread across morpheme boundaries in Zilfaawi, this might be a strong indication that the emphatic effect is sensitive to morpheme boundaries and is hence phonological. However, if emphasis does spread into the affixes, this might indicate that it is phonetic.

1.4 Zilfaawi Arabic

Zilfaawi Arabic is a sub-dialect of Najdi Arabic. It is the dialect spoken by the people of the town of Az-Zilfi town in the central region of Saudi Arabia. It is part of Najd region in which the capital of Saudi Arabia is situated as can be seen on the map below. Al Zilfi is approximately 180 miles from the capital, Riyadh. The population of this town is around 90,000 people.

Figure 1: Map of Saudi Arabia showing Az Zilfi town in the center part of the country.

Zilfaawi Arabic is distinct from Modern Standard Arabic (MSA) and from Classical Arabic (CA). MSA is the language of mass media, and CA is the language of the Quran and of old Arabic poetry. Although no study has described Zilfaawi Arabic previously, there are some other studies that have described the phonology and morphology of other Saudi Arabic dialects (Johnston, 1967; Al-Sweel, 1992; among others). In addition, there are some studies that investigated the phonology of Najdi Arabic, such as the work done by Ingham (1994), who reported some variations among the sub-dialects of Najdi Arabic. This dialect was chosen because it is not documented in any of the mentioned works, although it shows some differences. For example, Al-Sweel (1992) reported that there are three basic perfective patterns for Najdi Arabic: *faʕal, fiʕal,* and *fiʕil*. However, Zilfaawi shows only one pattern, which is fʕal. On the phonological level, after deletion of the first vowel in the input triliteral word /ʕanab/, stress falls on the syllable CCVC syllable, as in /ʕnab/ "grapes", in contrast to other Najdi dialects in which no deletion takes place.

The surface segmental inventory of Zilfaawi consists of twenty-seven consonants and eight vowels. In addition to these consonants, the uvular stop /q/ is only found in loan words from Modern Standard Arabic. The full inventory of ZA consonant system is presented in **Table 1**, which shows the place and manner of articulation using the IPA symbols:

Table 1: The Consonantal Inventory of Zilfaawi Arabic

	Bilabial	Labio-dental	Inter-dental	Dental	Alveolar	Alveo-palatal	Palatal	velar	Uvular	Pharyngeal	glottal
stop	b			t d				k g			ʔ
Emphatic stop				tˁ							
fricative		f	θ ð		s z	ʃ			χ ʁ	ħ ʕ	h
Emphatic fricative			ðˁ		sˁ						
Affricate						dʒ					
nasal	m				n						
liquid				l	r						
glide	w						j				

Maintaining the three-vowel system of Classical Arabic, ZA has only three short phonemic vowels: /i/, /a/, and /u/. The following examples illustrate these short vowels in ZA:

(2)

[madd]	"he extended"
[simm]	"shade"
[umm]	"a mother"

In addition, it possesses the five long vowels: /i:/, /a:/, /u:/, /e:/, and /o:/ as shown in the following:

(3)

[fi:l]	"an elephant"
[fa:l]	"omen"
[fu:l]	"beans"
[ʕe:n]	"an eye"
[ʕo:n]	"help"

Many authors have reported that Arabic long vowels are more peripheral while short vowels are more centralized (Saadah, 2011; Alghamdi, 1998; among others). Therefore, length is not the only difference between short and long vowels in ZA. Moreover, allophonic realizations of these phonemic short and long vowels vary from one context to another; for example, when they are adjacent to emphatics or when they appear word-finally. These vowels' phonetic realizations are somewhat variable, but their phonemic values are the same. Throughout this dissertation, the phonemic transcriptions will be used.

Stress in ZA falls on one of the last three syllables of the prosodic word.

Stress in ZA is thus a three-syllable window stress, where it does not fall on any syllable beyond the antepenult, as in Jordanian Arabic (Abu Abbas, 2003), Syrian Arabic (Adra, 1999), and in some other languages. If we have more than one heavy syllable, stress falls on the rightmost heavy syllable. The final syllable is stressed only if it has the syllable structure CVVC or CVCC since the last consonant is extrametrical in ZA, as in most Arabic dialects. If all three final syllables are light, then stress then falls on the penultimate position respecting the iambic stress system of the language. The antepenultimate syllable might attract stress if it is the only heavy syllable in the word (Al-Ammar, 2013).

1.5 Organization of the Dissertation

This dissertation consists of four chapters. The current chapter provides the necessary background and reviews the literature relevant to Arabic emphasis and its effect on neighboring vowels across the different dialects of Arabic. Moreover, this chapter presents the aims of the current study, as well as the questions that will be answered in order to achieve these aims. Chapter Two describes the acoustic study and presents the results thereof. Chapter Three proposes a weighted-constraint model to account for phonetic pharyngealization in Zilfaawi Arabic. Chapter Four concludes the dissertation and suggests possible topics for future research.

Chapter Two

2 The Acoustic Study

2.1 Methods

2.1.1 Materials

The target sounds examined in this study are a set of Arabic emphatics (/tˤ/, /sˤ/, /ðˤ/) and their plain counterparts, (/t/, /s/, /ð/). To investigate the acoustic effects of emphatics on neighboring vowels, the production stimuli used in the present experiment consisted of a list of disyllabic minimal pairs contrasted in terms of whether the initial or final consonant was emphatic or plain; for example, /**ðˤ**abbad/ versus /ðabbad/ (see Appendix A for the full set of stimuli). The target sounds are pronounced initially, followed immediately by one of the following vowels, (/i/, /u/, /a/, /iː/, /uː/, /aː/), or are pronounced finally, preceded by one of the same sets of vowels. This experiment investigated six emphatics and plain sounds in initial and final positions, followed or preceded by six vowels and produced by fifteen subjects three times. This yielded 3,240 tokens for measurement (3 [consonants] x 2 [plain-emphatic] x 2 [initial-final] x 6 [vowels] x 15 [subjects] x 3[repetitions]). The set of stimuli for this experiment consists of non-words that are phonetically acceptable in Zilfaawi Arabic. The use of nonsense words means that it is possible to represent all sound sequences of interest in identical phonetic environments. The word list consists of 72 CVb.bVC words, in which the consonant in the middle is always a geminate /b/ and the non-target consonant is always /d/. The geminate /b/, rather than the single /b/, is selected to have a closed first syllable because, in Zilfaawi Arabic, the low vowel /a/ does not appear in non-final open syllables. Thus, the use of geminates ensures having a closed syllable with any type of vowel in the dialect. The non-target syllable is always either *–bad* if the target consonant is in the first syllable, or *dab-* if the target consonant is in the second syllable. If the target consonant is word-initial, the stress is always on the first syllable. However, if the target consonant is word-final, the stress is on the initial syllable in 50% of the words, whereas vowels are short, but it is on the final syllable in the other 50%.

To test whether vowels with opposing phonological qualities (high F2 and low F1 /i:/ and low F1 /u:/) block pharyngealization or not, part of the above stimuli in which the vowels in the target syllables are these vowels is used. The vowel /a/ in the non-target syllable, preceding or following, is measured and compared to its plain counterpart, for example /ðˤibb**a**d/ versus /ðibb**a**d/. However, to test whether consonants with opposing phonological qualities, high F2, (/j, ʃ, dʒ/), block pharyngealization or not, another set of data is used (see Appendix B). The target emphatic sounds and their plain counterparts are pronounced initially or finally. The word list consisted of 36 CVC.CVC words, in which the consonant in the middle is one of the high segments (/j, ʃ, dʒ/), the non-target consonant is always /d/, and the vowel in both syllables is always the low vowel /a/; for example, /ðˤaʃʃ**a**d/ versus /ðaʃʃ**a**d/. The low vowel is used in both syllables because it is the vowel most affected by emphasis; therefore, it enables us to see the blocking effect, if there is any, more clearly. The list was produced by fifteen subjects three times.

To test the possible effect of stress on carryover emphasis, another set of data is used (Appendix C). The target emphatic sounds and their plain counterparts are pronounced initially only. The word list consisted of 6 Cab.bVd-words, in which the consonant in the middle is always /b/, the non-target consonant is always /d/, and the vowel in the first syllable is the low vowel /a/. The second vowel is the short /a/ in the first three words and the long /a:/ in the other three; for example, /ðˤ**á**bbad/ versus /ðˤ**a**bbá:d/. The purpose of varying the length of the vowel in the second syllable is to shift the stress. The words with /a/ in the second syllable have word-initial stress, while words with /a:/ have word-final stress.

To test the possible effect of stress on anticipatory emphasis, a new set of stimuli is used in which stress effects are controlled, as shown in Appendix D. The target emphatic sounds and their plain counterparts are pronounced word-medially. The word list consists of six baC.CVd words, in which the consonant in the middle is the target consonant, the initial non-target consonant is always /b/, the final non-target consonant is always /d/, and the vowel in the first syllable is the low vowel /a/. The second vowel is the short /a/ in the first three words, and is the long /a:/ in the other three for the same reason above, to shift the stress. As in the above data lists, the words are produced by fifteen subjects three times.

To investigate the emphatic effect on affix vowels, a set of real words was used. In these words, we have the emphatic consonant stem-initially or stem-finally and the possible affix as a prefix or suffix. The affix vowel is always /a/ because it has been the most reported vowel to be affected by emphatics (Al-Ani, 1970; Ghazeli, 1977; Card, 1983; among others). The formants of affix vowels adjacent to emphatic consonants are measured and compared to the vowels in the words in which they have the emphatic consonant's counterpart and to words with no morpheme boundaries, as in the following tables:

Table 2: plain and emphatic first person prefix a- compared to the stems in (b)

No.	Plain	Gloss	Emphatic	Gloss
a.	**a-s**idlih	I block for him	**a**-**s**ˤidlih	I look away for him
b.	**as**i:lih	A proper name	**as**ˤi:lih	genuine, fem.

These words are used in the following sentence to ensure they have the same number of syllables before the target words:

(4)

kin-t _____ 'I was ____for him' (for the (a) words in **Table 2**)

kin-t ____ 'I was ____' (for the (b) words in **Table 2**)

Table 3: Plain and emphatic perfective third person feminine plural suffix –at in (a) compared to the stems in (b)

No.	Plain	Gloss	Emphatic	Gloss
a.	xass-**at**	She lost weight.	ˈxa**sˤsˤ-at**	she singled out sb or sth.
b.	fass**a**d	he ruined sth.	ˈfa**sˤsˤa**d	he extracted fresh blood out.

These words are used in the following sentences to ensure having the same number of syllables before the target words:

(5)

Hind ____‘Hind____’ (for the (a) words in **Table 3**)

Hu _____ ‘He _____’ (for the (b) words in **Table 3**)

2.1.2 Participants

Fifteen male native speakers of Zilfaawi Arabic, as spoken in Az Zilfi town, participated in the production experiment. The age range of the subjects was between 20 and 35 years. All subjects were native speakers of the Zilfaawi Arabic dialect. None of the subjects suffered from any visual or hearing difficulties. All subjects were unpaid volunteers, and consent was obtained according to standard procedures.

2.1.3 Procedures

The recordings were performed in a private anechoic chamber in which the participants were recorded using a microphone (BadAax CM40 Studio Mic) attached directly to an Apple Macintosh desktop computer. The data were stored as .wav files digitized at a 22-kHz sampling rate and 16-bit quantization. Each participant was recorded individually. The words were presented to participants in the Arabic language orthography and were supplemented with diacritical markings. Except when testing emphasis across morpheme boundaries, the target word pairs were recorded in the carrier phrase /ʔiktibi ____ sit marra:t/ [write (fem.) ____ six times!]. To test the emphatic effect across morpheme boundaries, the sentences in (4) and (5) above were used. The phrases were displayed in front of the participants as individual Microsoft PowerPoint (Microsoft Corp. 2011) slides. Each participant was asked to read a differently randomized list of minimal pairs at a normal rate. The list of words was repeated three times by each participant, and none of the target words occurred at the beginning or end of the list.

2.1.4 Acoustic measurements

The Praat speech analysis software (Boersma and Weenink, 2015) was used to perform the acoustic measurements in this study. The boundaries of the vowels of interest were marked by visually consulting waveforms and wide-band spectrograms. Vowel onset was defined as the first waveform's minimum that accompanied the clear emergence of vowel formants on the wideband spectrogram. Vowel offset, on the other hand, was defined as the final waveform minimum that accompanied the disappearance or weakening of F2 (Wright and Nicholas, 2014). Boundaries that were difficult to distinguish were verified by looking for visual cues from the waveform and the spectrogram of the vowel of interest. The identified boundaries for the sound of the vowels were saved as a TextGrid file. Following this, a script was used to carry out automatic measurements of the duration and the vowel formants at the following three time points: the onset (point 25%), midpoint (point 50%), and offset (point 75%) of the vowel durations. These measurements were calculated using a 25 ms window and 5000 Hz as the maximum formant. The results were then saved as a text file before being analyzed using the R statistical analysis software.

To assess the reliability of the results obtained via the automatic measurements of the first three formants and duration of the target vowels, 100 pairs of sound and TextGrid files were selected randomly and reanalyzed following the same procedures stated above. The results were similar to those obtained by the first calculations. Moreover, another set of pairs of sound and TextGrid files was randomly selected and measured manually. The results were also similar, or very close, to those calculated automatically; thus, the automatic measurements were judged to be reliable.

2.2 Analysis

I compiled descriptive statistics and carried out linear mixed-effects analyses. Since F1 and F2 have been reported in the literature as exhibiting differing effects, I will report on each of them in separate sections. Linear mixed-effects analyses were carried out to test the statistical significance of several independent variables that may have influenced the dependent variables F1 and F2 values, using R (R Core Team, 2012) and *lme4* (Bates, Maechler and Bolker, 2012). The fixed-effect predictors chosen for investigation are summarized in **Table 4** below.

Table 4: List of fixed-effect predictors.

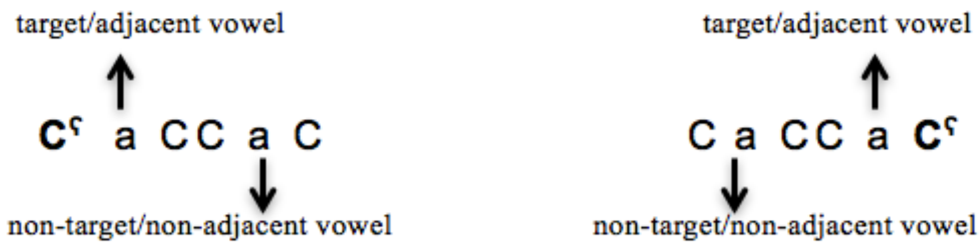
Predictor	Type
initial consonant-type	A binary predictor with two levels for both consonants: (plain vs. emphatic)
final consonant-type	A binary predictor with two levels for both consonants: (plain vs. emphatic)
vowel quality	Two predictors with two levels: (a vs. i) and (a vs. u)
distance	A scalar predictor that encodes the distance of measurement from the beginning of the word, where one unit of distance is the distance from the onset to the offset of the vowel
target vowel length	A binary predictor with two levels: short vs. long
middle consonant-type	A binary predictor with two levels for the consonant: high vs. non-high
c.affix vs. stem	A binary predictor with two levels for vowels: affix vowel vs. stem vowel
non-target-vowel-type	A binary predictor with two levels: short vs. long

Stress falls on the first syllable unless the second syllable is a long vowel. Therefore, to test the possible statistical significance of stress on the dependent variables F1 and F2 values, the independent variable *non-target-vowel-type*, as shown in **Table 4**, was used. The levels of all predictors were coded and centered using Helmert coding. Interactions between some of these independent variables were also investigated. The independent variables were entered into the model as fixed effects. Random effects for both subjects, coded as *speakers*, and items, coded as *files*, were also added to the model. P-values were obtained by conducting normal approximation.

2.3 Results of F2

In the following sections, almost all words used for investigation are bi-syllabic ones. Some of these words have the emphatic consonants word-initially, while others have the emphatic consonants word-finally. As shown in (6) below, in words with word-initial emphatic consonants, such as /**tˤ**abbad/, the closest vowels to the emphatic consonants in the first syllable, or the adjacent syllable, will be referred to as "target" or "adjacent" vowels, and those in the second syllable will be referred to as "non-target" or "non-adjacent" ones. On the other hand, in words with word-final emphatic consonants, such as /dabba**tˤ**/, the "target" or "adjacent" vowels are those closest to the emphatic consonants in the second, or adjacent, syllable, while the vowels in the first, or non-adjacent, syllable will be referred to as the "non-target" or "non-adjacent" ones.

(6)



As a reminder, each vowel was tested by measuring formants at the following three points: point 25 (p25), which is the onset of the vowel, point 50 (p50), which is the midpoint of the vowel, and point 75 (p75), which is the offset of the vowel.

When reporting F2 of the vowels in Section 2.3 below, the results of the lowering effect will be divided into two parts: One is when emphatics are word-initial, Section 2.3.1, and the other is when emphatics are word-final, Section 2.3.5. When presenting the results of word-initial emphatic effect, I will show the results for the emphatic effect on all vowels combined, followed by the results for the short and long vowels separately. The results of the vowels immediately adjacent to the emphatic will be presented first. Then, the results for the non-adjacent vowels will be presented later. The results of the interaction between the lowering effect and vowel quality in the target syllable and non-target syllable, which is called the long-distance effect, will be presented for each type of emphatics, word-initial in Section 2.3.4 and word-final in section 2.3.8.

The results for the vowels' F1 values will be presented in Section 2.4 in the same order as for F2 above. Next, the results of the possible role of stress on the vowels' F2 values are presented in Section 2.52.6. The results for blocking are presented in Section 2.7, starting with the word-initial emphatic effect on the F2 of the vowels and followed by the word-final emphatic effect. The blocking of the emphatic effect on the vowel's F1 values will be presented in Section 2.8 in the same order. The results for investigating the blocking high segments (/j, ʃ, dʒ/) will be reported first. Then, the results of the long high vowels (/i:, u:/) as possible blockers will be reported later. In Section 2.9, the emphatic lowering effect across morpheme boundaries is presented. I will start by reporting the results for the vowels in prefixes, followed by the vowel in suffixes. Thereafter, the emphatic raising effect, F1, across morpheme boundaries is also reported in the same order. Finally, all reported results will be discussed in Section 2.10.

2.3.1 Rightward Lowering Effect (F2)

In this section, I will present the results of investigating the acoustic effects of emphatics on neighboring vowels by reporting the F2s of the vowels in both syllables of the bi-syllabic words when emphatics appear word-initially. I will also present the results of the emphatic effect on vowels over time to see whether the effect is gradient or categorical to provide a partial answer to the question of whether the emphatic effect on neighboring vowels on which it is detected is phonetic or phonological.

The F2 of both target and non-target vowels in both syllables was consistently lowered as a result of the presence of emphatic consonants word-initially. **Figure 2** illustrates the effect of emphatics on the target and non-target vowels in the first and second syllables, respectively, in terms of the second formant. Overall, the presence of the word-initial emphatic consonant lowered the F2 of the adjacent target vowel by an average difference of 300 Hz (1550 Hz vs. 1250 Hz). In addition, the effect on the non-target vowel in the non-adjacent syllable was also indicated by a depressed F2, with an average of 35 Hz drop (1600 Hz vs. 1565 Hz.).

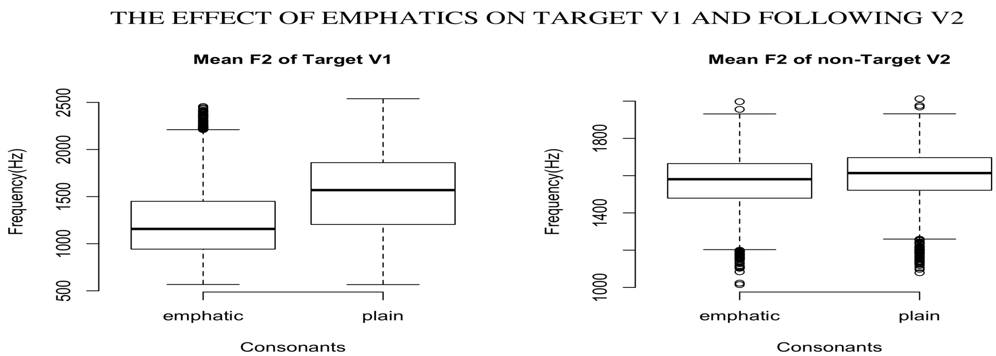


Figure 2: Box plots illustrating the effect of emphatics on the target vowel (V1) and the non-target one (V2) in terms of F2

As shown in **Figure 3**, the effect of the emphatic consonant on the target vowel in the word decreased with distance: Closest to the emphatic consonant, F2 was lowered by 410 Hz (1630 Hz vs. 1220 Hz) and the effect decreased gradually by going through the midpoint with a difference of 280 Hz (1550 Hz vs. 1270 Hz), and down to 200 Hz (1470 Hz vs. 1270 Hz) at the farthest point of measurement.

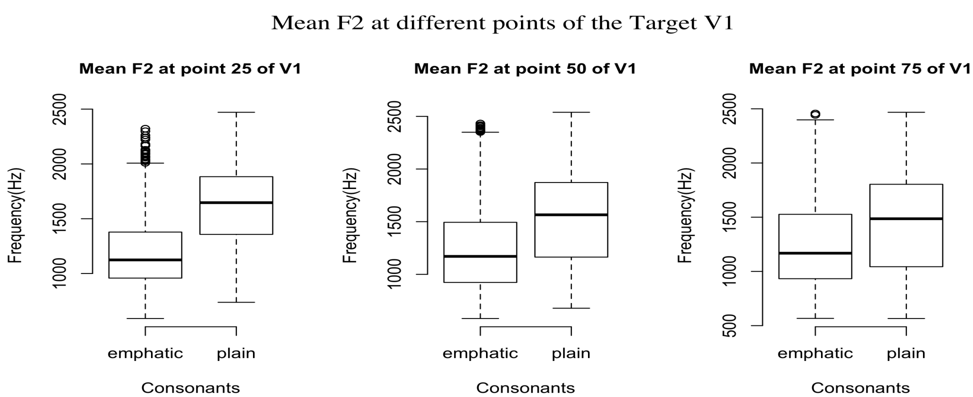


Figure 3: Box plots of mean F2 at different points of the target vowel (V1) when adjacent to word-initial emphatics

The effect on the non-target vowel in the non-adjacent syllable was indicated by a depressed F2, with an average of 35 Hz drop, as shown in **Figure 2** above. By considering the following non-target vowel, it can be seen that the effect of the emphatic consonant also diminished with distance. **Figure 4** shows that, closest to the emphatic consonant, F2 of the vowel was lowered by 45 Hz (1510 Hz-1465 Hz). However, the effect is lowered gradually, with a difference of 35 Hz (1605 Hz vs. 1570 Hz) at the midpoint and down to a difference of 30 Hz (1685 Hz vs. 1655 Hz) at the farthest point of measurement.

Mean F2 at different points of non-Target V2

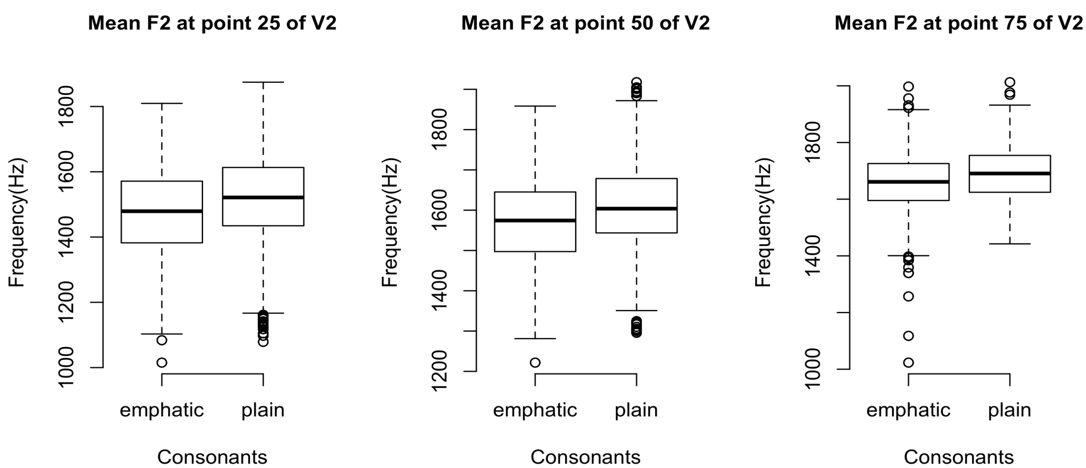


Figure 4: Box plots of mean F2 at different points of the non-target vowel (V2) in the following syllable

The above measurements were taken for all vowels grouped together, short and long. Now, let's consider short and long vowels separately to see whether emphatics lowers the vowels' F2 differently based on their length. Short and long vowels are tested separately to see whether the emphatics affect the non-target vowels differently, based on the type of vowel that is in the target syllable: short or long. Moreover, if it is not clear whether the emphatic effect in the adjacent vowel is gradient or not due to the shortness of the vowel, long vowels with their extended duration could be used better as an indicator whether emphatic effect is phonetic or phonological.

2.3.2 Rightward Lowering Effect on Short Vowels

As can be seen from **Figure 5**, overall, the presence of the word-initial emphatic consonant caused F2 of target short vowels in the first syllable to decrease by an average of 390 Hz (1550 Hz vs. 1160 Hz). In addition, F2 of the non-target vowel in the non-adjacent syllable was depressed by an average of 40 Hz (1595 vs. 1555).

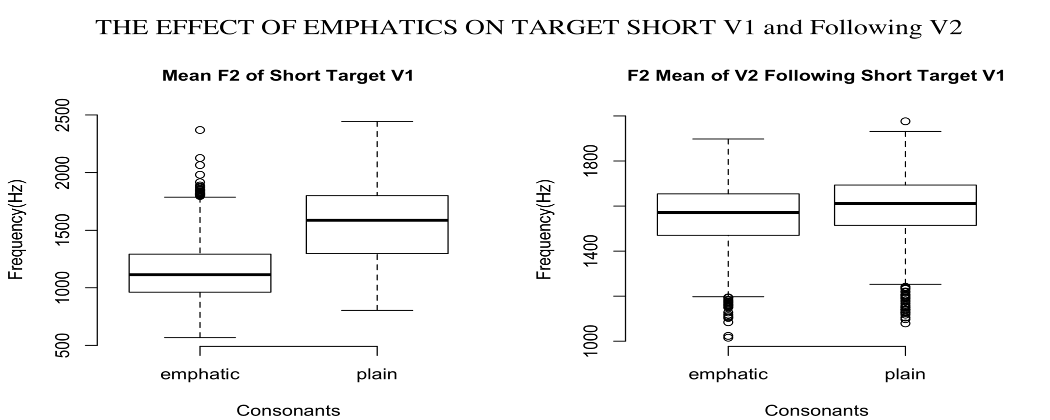


Figure 5: Box plots illustrating effect of emphatics on the target short vowel (V1) and the non-target one (V2) in terms of F2

Figure 6 presents F2 for three measurement points in the short target vowels, allowing us to track F2 lowering effects over time. We can see that the effect of the emphatic consonant on the vowel in the word diminishes gradually. When measuring the closest point to the emphatic consonant, F2 was lowered by 500 Hz (1640 Hz vs. 1140 Hz). The effect decreases gradually with a difference of 380 Hz (1550 Hz vs. 1170 Hz) at the midpoint of the vowel. At the farthest point of measurement, the lowering effect decrease to a difference of 270 Hz (1450 Hz vs. 1180 Hz).

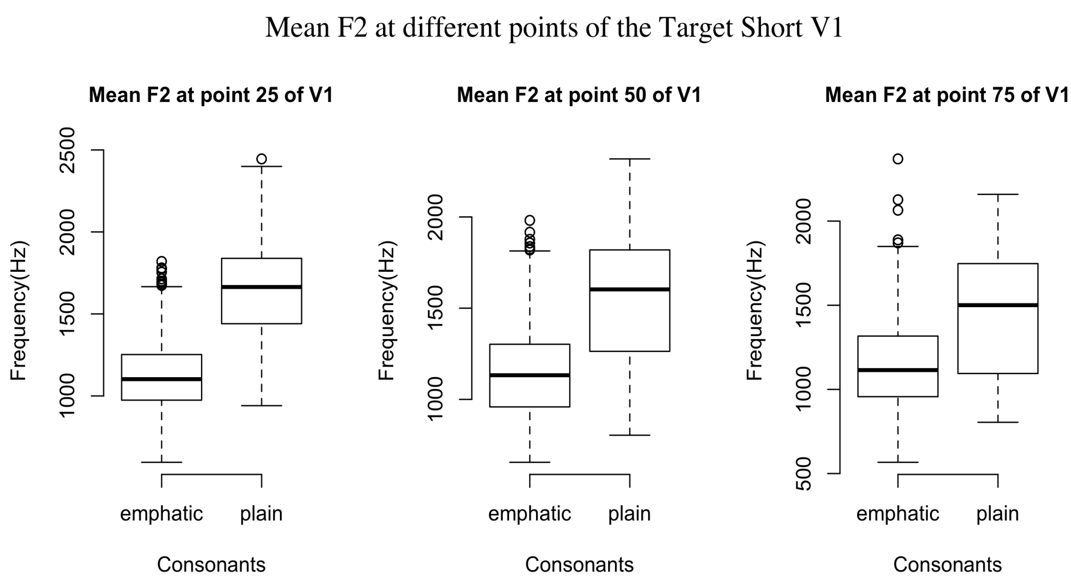


Figure 6: Box plots of mean F2 at different points of the target short vowel (V1) in the syllable adjacent to emphatics

As shown in **Figure 5**, in the syllables following the short target vowel, the overall effect depressed F2 of the non-target vowel by an average of 40 Hz (1595 vs. 1555).

With regard to the non-target vowel, the lowering effect of the emphatic consonant decreased gradually as can be seen in **Figure 7**. F2 was lowered by 50 Hz (1505 Hz-1455 Hz) closest to the emphatic consonant and the effect diminished gradually through the midpoint with a difference of 35 Hz (1600 Hz vs. 1565 Hz) and down to a difference of 30 Hz (1680 Hz vs. 1650 Hz) at the farthest point of measurement.

Mean F2 at different points of the Following V2

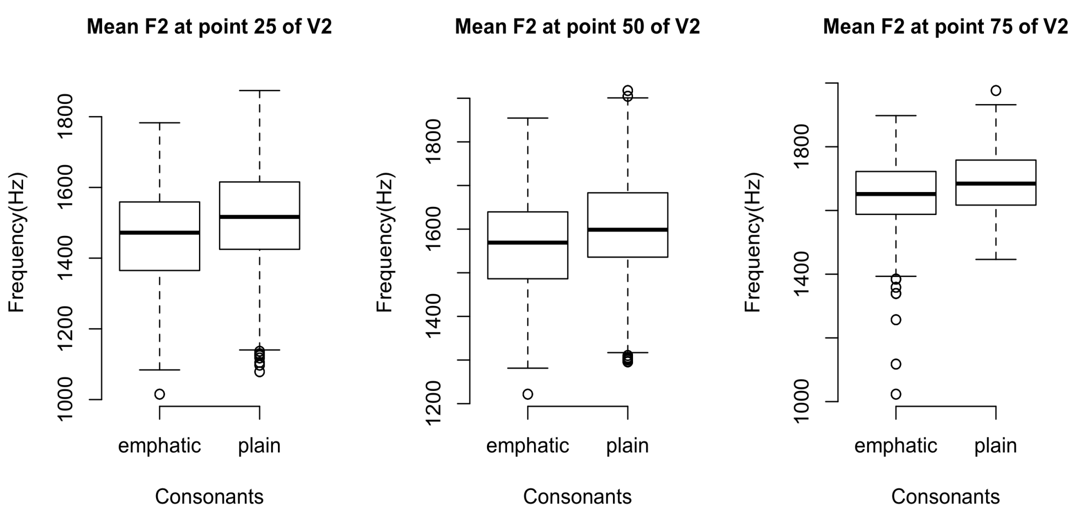


Figure 7: Box plots of mean F2 at different points of the non-target vowel (V2) in the following syllable, which is always /a/

2.3.3 Rightward Lowering Effect on Long Vowels

After considering the short vowels, it is now time to test the emphatic lowering effect on the long vowels. **Figure 8** shows that, overall, the word-initial emphatic consonant lowered F2 of adjacent long target vowels in the first syllable by an average of 220 Hz (1560 Hz vs. 1340 Hz). In addition, the effect on the non-target vowel in the non-adjacent syllable was also indicated by a depressed F2, with an average difference of 30 Hz (1605 vs. 1576)

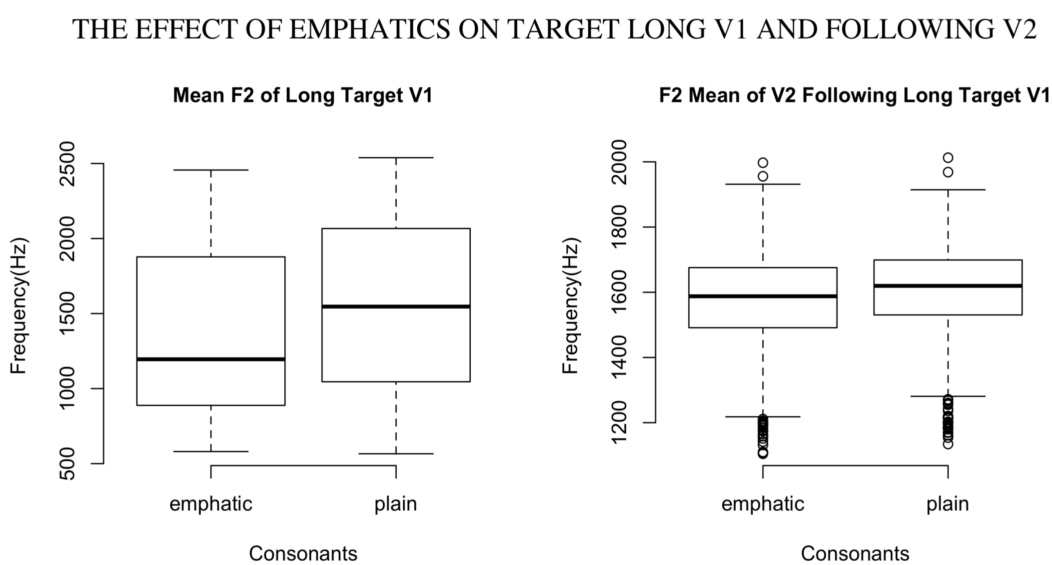


Figure 8: Box plots illustrating emphatic effect on the target long vowel (V1) and the non-target short one (V2) in terms of F2

As shown in **Figure 9**, the word-initial emphatic consonant exerted lowering effect on each point of measurement of the vowel. However, this lowering effect on the target long vowel in the word decreased with distance. F2 was lowered by 340 Hz (1630 Hz vs. 1290 Hz) at the closest point to the emphatic consonant. The effect decreased gradually with a difference of 190 Hz (1560 Hz vs. 1370 Hz) at midpoint of the vowel and a difference of 130 Hz (1500 Hz vs. 1370 Hz) at the farthest point of measurement.

Mean F2 at different points of the Target Long V1

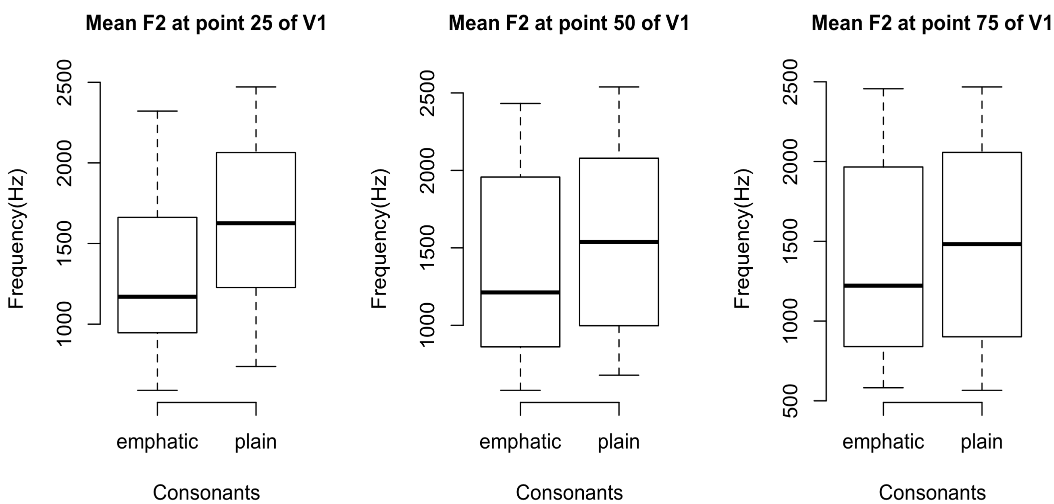


Figure 9: Box plots illustrating mean F2 at different points of the target long vowel (V1) in the syllable adjacent to emphatics

The lowering effect on non-target vowel in the following non-adjacent syllable showed less F2 depression by an average of 30 Hz (1605 vs. 1576), as shown in **Figure 8** above. The exerted lowering effect of the emphatic consonant on the following non-target vowel in the word became weaker gradually. **Figure 10** shows that F2 of the closest point to the emphatic consonant was lowered by 35 Hz (1515 Hz-1480 Hz). However, this effect diminished gradually with a difference of 30 Hz (1610 Hz vs. 1580 Hz) and 25 Hz (1690 Hz vs. 1665 Hz) at the midpoint and at the farthest point of measurement, respectively.

Mean F2 at different points of the Following V2

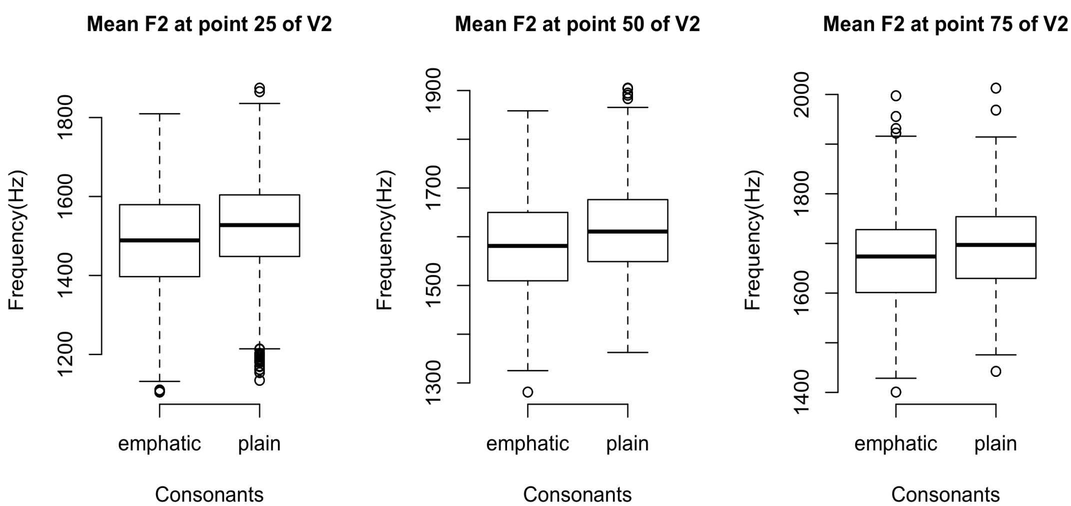


Figure 10: Box plots illustrating mean F2 at different points of the non-target vowel (V2) in the non-adjacent syllable

It appears that the initial emphatic consonants affect both the target and non-target vowels in the word. However, their effect on the target short vowel is stronger than is the effect on the target long one. In addition, the effect on the non-target vowel is stronger when short vowels occur in the target syllable. The effect exerted by these emphatic consonants is gradient in both syllables of the word: adjacent and non-adjacent. In other words, the effect increased, showing greater F2 lowering, closer to the emphatic consonant.

2.3.4 Lowering Effect and Vowel Quality

The above results are derived from the averages of the measurements of all vowels regardless of their quality. However, the emphatic effect might vary from one vowel to another based on their qualities as reported in previous studies on Arabic emphasis (Card, 1983; Hassan & Esling, 2011; among others). Therefore, let us obtain the values of all vowels based on their qualities. **Table 5** shows the vowels and the F2 values in plain and emphatic environments.

Table 5: Different vowels and their averaged F2 values across all three points, p25, p50, and p75, in plain and emphatic environments when emphatics are initial

Vowel type	Type of consonant		Difference in Hz
	plain	emphatic	
a	1590	1120	470
i	1870	1440	430
a:	1560	1190	370
u	1180	920	260
i:	2180	1990	190
u:	950	840	110

As can be seen from Table 5 and **Figure 11**, the lowering effect of the emphatic consonants when they are word-initial was strongest on the adjacent short low vowel /a/ with a difference of 470 Hz (1590 Hz vs. 1120 Hz), followed by the vowel /i/ with a difference of 430 Hz (1870 Hz vs. 1440 Hz), and then the long vowel /a:/ with a difference of 370 Hz (1560 Hz vs. 1190 Hz). This was followed by short /u/, with a difference of 260 Hz (1180 Hz vs. 920 Hz), and long

/i:/ and /u:/, with a difference of 190 Hz (2180 Hz vs. 1990 Hz) and 110 Hz (950 Hz vs. 840 Hz), respectively.

It appears that the emphatic lowering effect was stronger on the short vowels /a/ and /i/ and weaker on the long vowels /i:/ and /u:/. By considering all vowels of the different quality and length across all points of the vowel, the low vowel is the most affected while the long high vowels are the least affected ones.

Mean F2 of Different V1 Qualities in the Target Syllable

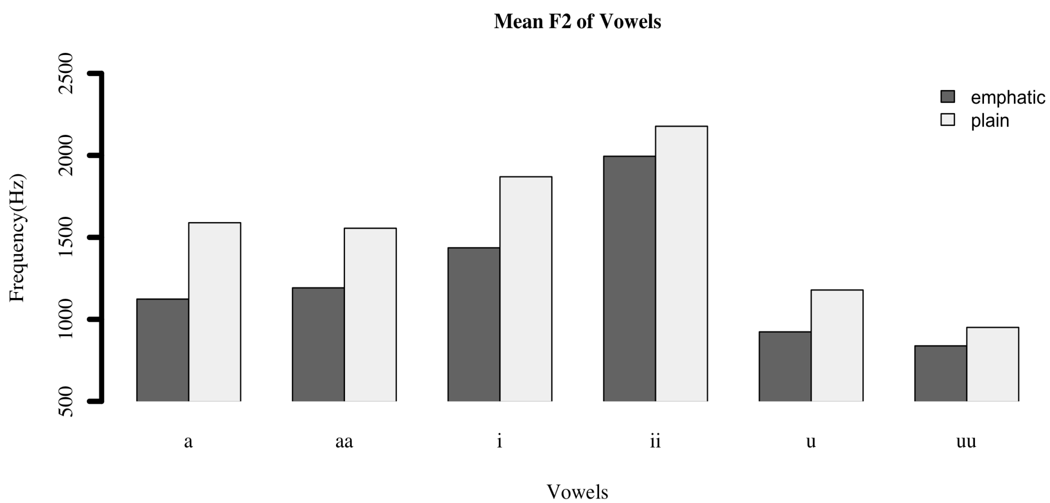


Figure 11: Bar plot illustrating different emphatic effect on vowels based on their qualities

2.3.4.1 Lowering Effect and Vowel Quality over Time

When considering the effect of vowel quality over time, the same results for the overall vowel quality effects were obtained, except in one case. This case was when the short high /i/ was more affected at point 25 than was /a/. However, this difference is very subtle, namely 10 Hz. The results that will be reported are presented in **Figure 12**, **Figure 13**, and **Figure 14**. At p25, the effect of the initial emphatic consonants was strongest on the adjacent short vowel /i/ with a difference of 550 Hz, followed by the vowel /a/ with a difference of 540 Hz, and the long vowel /a:/ with a difference of 480 Hz. These were followed by the short /u/, with a difference of 400 Hz, and the long /i:/, with a difference of 340 Hz, and the long /u:/ with a difference of 220 Hz. At p50, the initial emphatic consonants' lowering effect was strongest on the adjacent short vowel /a/ with a difference of 470 Hz, followed by the vowel /i/ with a difference of 420 Hz, and the long vowel /a:/ with a difference of 340 Hz This was followed by the short /u/, with a difference of 260 Hz, then the long high /i:/, with a difference of 130 Hz, and the long back /u:/ with a difference of 90 Hz. At the furthest point of the vowel, p75, the adjacent short low vowel /a/ was the most affected vowel with a difference of 390 Hz, followed by the high short vowel /i/ with a difference of 320 Hz, and the long low vowel /a:/ with a difference of 280 Hz. The short back vowel /u/ came forth with a difference of 100 Hz, followed by the long high /i:/, with a difference of 80 Hz. With a difference of 30 Hz, the long back /u:/ was the least affect vowel.

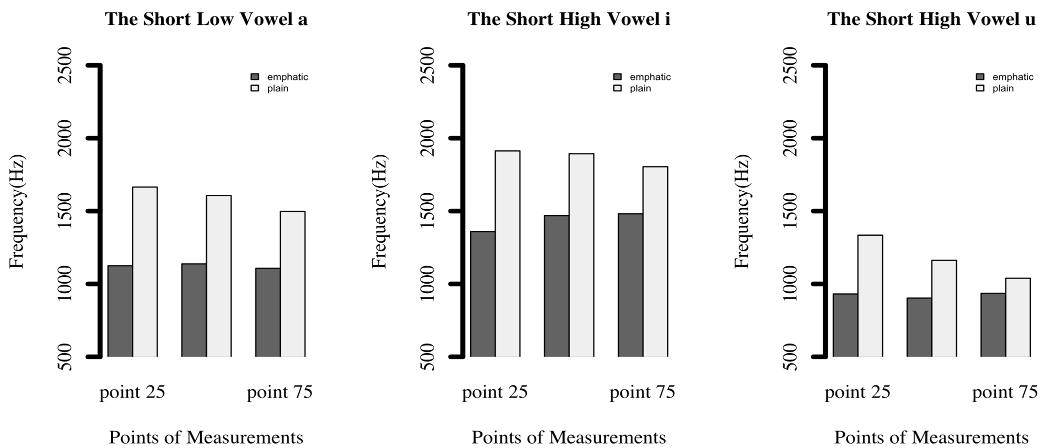


Figure 12: Bar Plots illustrating different emphatic effect on short vowels based on their qualities at different vowel points of measurements

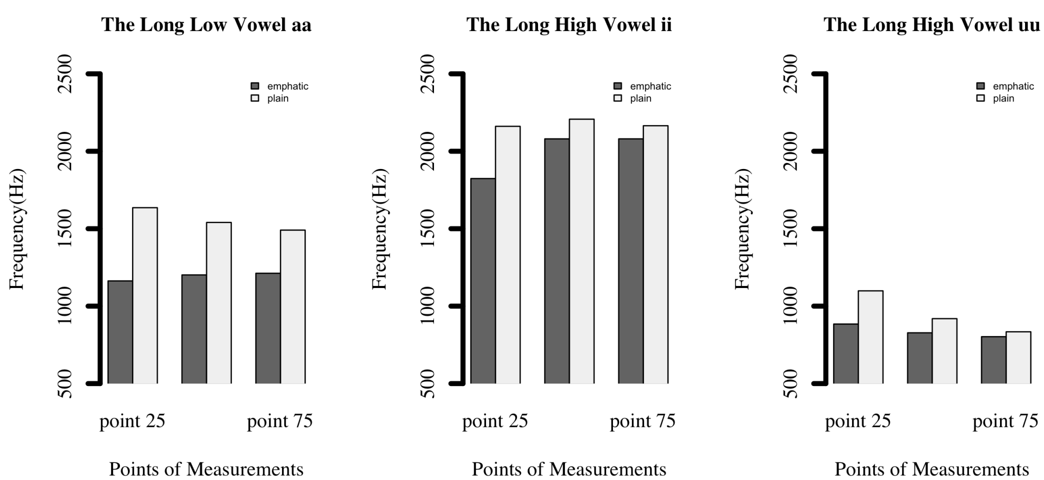


Figure 13: Bar plots illustrating different emphatic effect on long vowels based on their qualities at different vowel points of measurements

Figure 14 shows all vowels combined at different points of measurements in plain and emphatic environments.

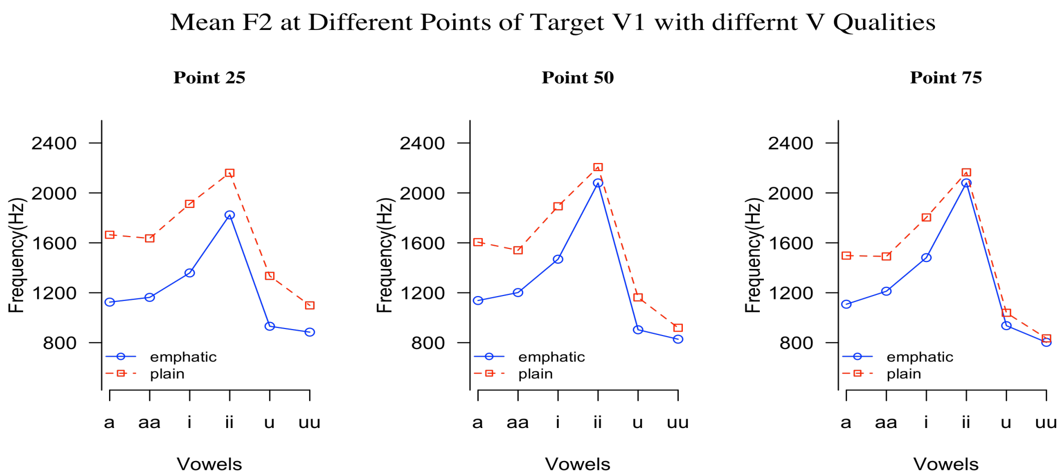


Figure 14: Line charts illustrating different emphatic effect on vowels based on their qualities at different vowel points of measurements

The high vowels /i:/ and /u:/ followed by geminates are not observed within stems in ZA. The non-existance of these specific long vowels in this specific context in the ZA phonology could be either accidental gaps or systematic gaps. However, since long low vowels followed by geminates do exist and are completely acceptable, such as /ʕa:mmah/ 'public', I consider this absence of long high vowels followed by geminates to be an accidental gap.

However, the sequence of long high vowels followed by geminates is observed across morpheme boundaries when the stem ends with the same initial consonant of the following morpheme as in the shown below:

(7)

a. hum ðˤ a:lmi:n-na
They unfair-us
'They have been unfair to us'

b. gi:l-l-ih
Has been told-to-him
'He has been told'

c. y-ħa:ʤʤ-u:n-na
they-argue-plural-us
'they have been arguing with us'

Moreover, the sequence of the non-low vowel /e:/ followed by geminates is observed in diminutive forms within the stem such as /dwe:bb-ih/ 'a small animal' and /ħwe:rr-ih/ 'little hot, adj'.

In addition, when considering all long vowels when they are adjacent to emphatics, it seems that they show the same behavior. The effect of emphatics on adjacent long vowels weakens when they are further away from the target consonants with different amount of effect depending on the quality of the vowel as seen with short ones as see in the combined plots below:

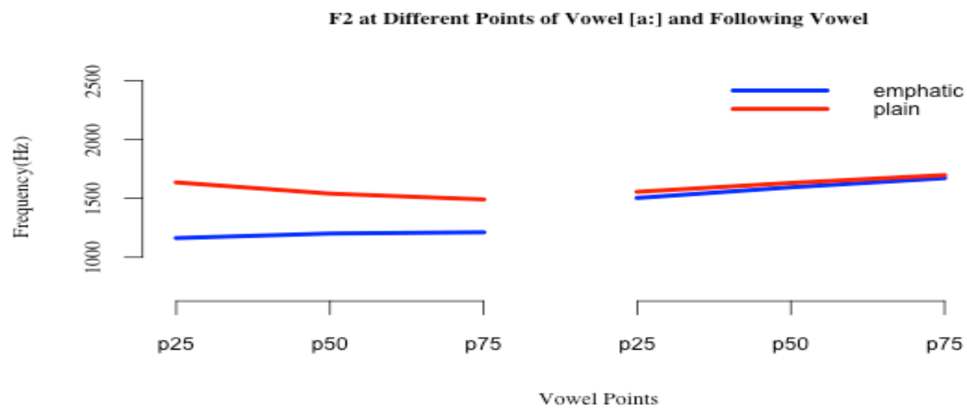


Figure 15: Line chart illustrating the emphatic effect on low vowels at different vowel points of measurements

The following plot shows the long high vowel /i:/:

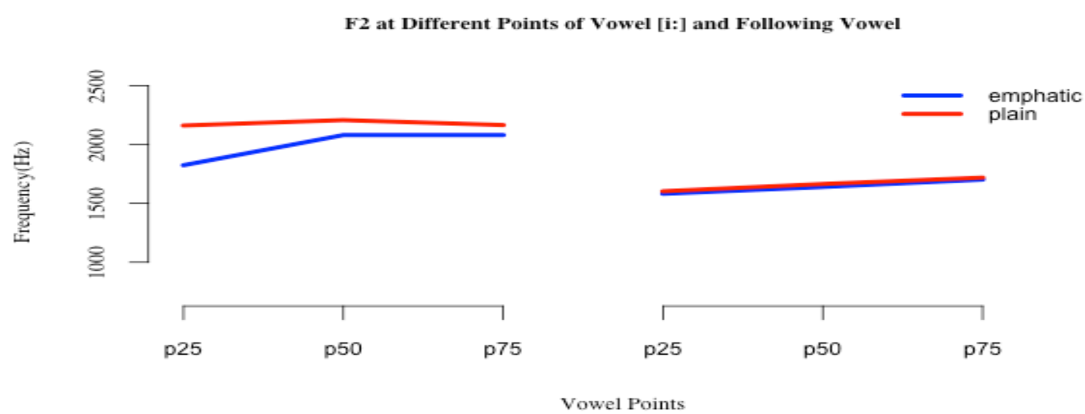


Figure 16: Line chart illustrating the emphatic effect on high vowels at different vowel points of measurements showing the same behavior of low vowels

And the long back vowel /u:/:

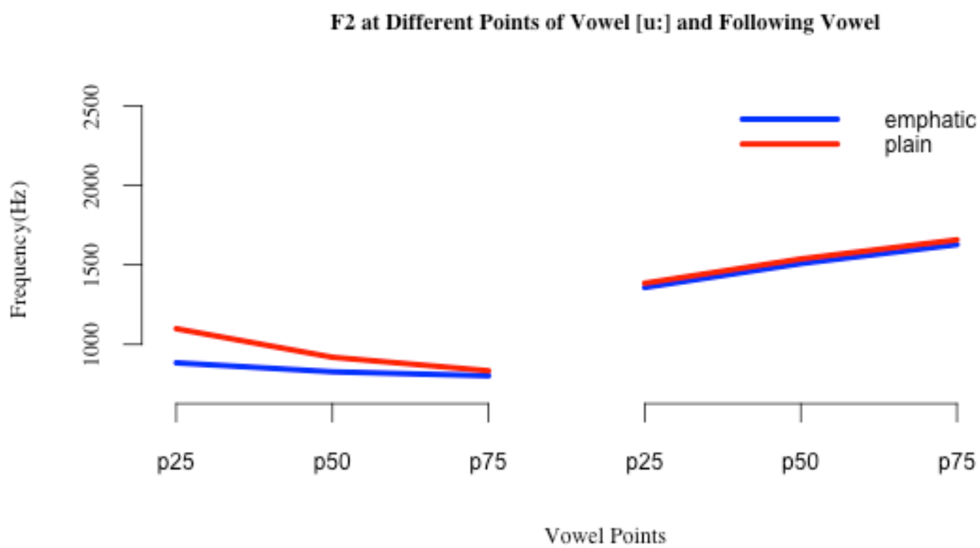


Figure 17: Line chart illustrating the emphatic effect on high back vowels at different vowel points of measurements showing the same behavior of low vowels with smaller effect

2.3.4.2 Long-Distance Lowering Effect

The emphatic effect on the non-target vowel might also vary based on the quality of the target vowel due to the antagonistic behavior of such vowels such as the high vowel /i/, as mentioned in Section 1. I will now consider the effect of emphatic consonants on the non-target vowel /a/ in the non-adjacent syllable depending on the type of the target vowel in the first syllable. As shown in **Figure**

18, F2 of the non-target vowel was most depressed when the vowels in the initial syllable were the low ones: the short low vowel /a/ with a difference of 65 Hz (1565 vs. 1630) followed by the long low vowel /a:/ with a difference of 40 Hz (1590 vs. 1630). That was followed by the short high vowel /i/ with a difference of 40 Hz (1615 vs. 1655), then the long back vowel /u:/ with a difference of 30 Hz (1495 vs. 1525). The non-target vowels' F2 was lowered the least when the vowel in the initial syllable was /u/ and /i:/ with differences of 25 Hz (1480 vs. 1505) & 20 Hz (1640 vs. 1660), respectively.

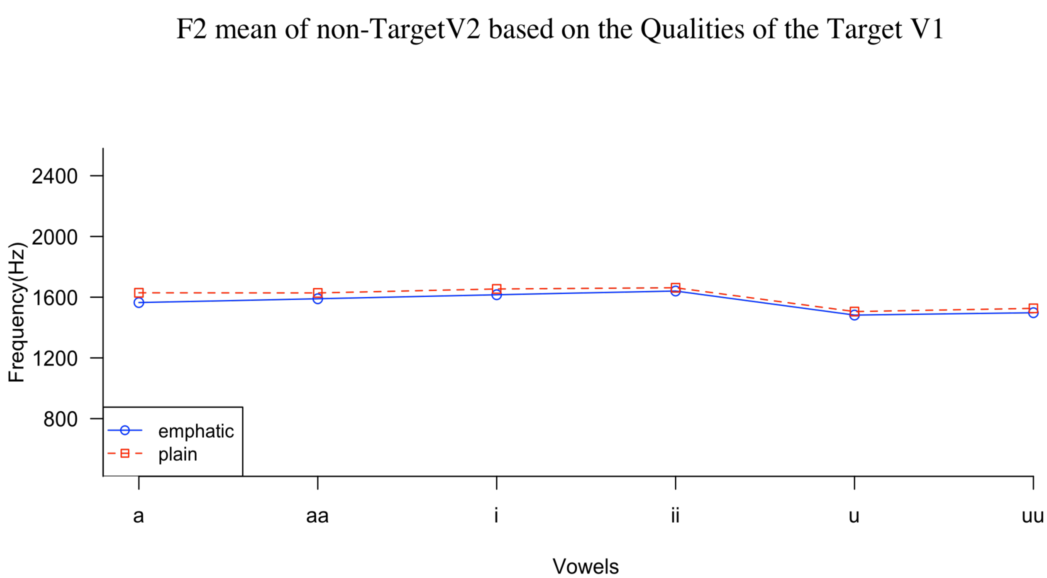


Figure 18: Line chart illustrating F2 of plain and emphatic non-target vowels based on the quality of the vowel in the target syllable

By looking at the above F2 values, it appears that the emphatic lowering effect on the non-target vowel was strongest when the vowel in the first syllable were the low vowels /a/ and /a:/. When the high vowels /i:/ appeared as target vowel, the lowering effect was the weakest on the non-target vowel /a/.

The following figure shows summarizes the effect of emphatics over time, pooled across vowel qualities, for both syllables in words with initial emphatics. It displays how the effect begins strongly and weakens gradually until it reaches the point at which there is almost no difference between emphatic and plain anymore.

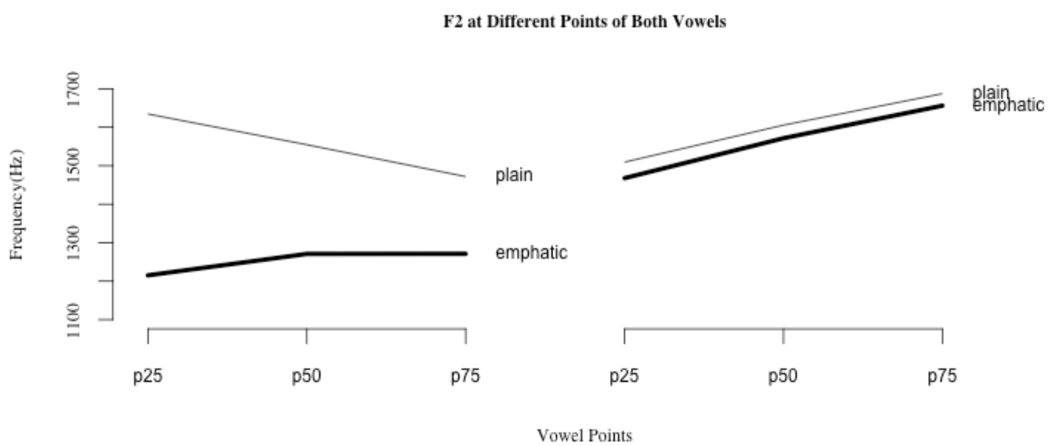


Figure 19: Line chart illustrating degree of F2 depression in both syllables of words with initial emphatics

2.3.4.3 Statistical Analysis

In order to examine the statistical significance of the initial emphatic effect, mixed- effects linear regression models were fitted with F2 as the dependent variable. One model is fitted for testing the effect of emphatics on the target syllable and another one for the non-target syllable. Table 6 shows the results of the fitted model when vowels in first syllables are adjacent to emphatics in initial positions. T-values are rounded off when reporting them in the discussion throughout this dissertation.

As expected, the results of the model in Table 6 shows that F2 was significantly lowered when vowels were immediately preceded by an emphatic consonant (t=–18, p<.0001). In addition, there was a significant interaction between the type of consonant and *distance* (t=23, p<.0001); in other words, the further we move from the emphatic consonant, the weaker the effect on the vowel becomes.

Table 6: Regression model for the F2 of the target vowel in the first syllable

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	1467	18	83	
c.C1	-418	23	-18.32	<.0001
c.V1a.vs.u	-388	23	-17.07	<.0001
c.lengthV1	14	21	0.66	=.5
c.V1a.vs.i	352	23	15.47	<.0001
distance3	-107	5	-19.70	<.0001
c.V1a.vs.u:c.lengthV1	-181	38	-4.77	<.0001
c.C1:c.V1a.vs.u	220	41	5.41	<.0001
c.C1:c.lengthV1	125	38	3.29	<.001
c.lengthV1:c.V1a.vs.i	379	38	10.01	<.0001
c.C1:distance3	223	10	22.95	<.0001
c.C1:c.lengthV1:c.V1a.vs.i	148	68	2.19	<.05

In addition, there was a significant interaction between the type of consonant and the difference between the low vowel /a/ and the high back vowel /u/ (t=5,

$p<.0001$). In other words, there is a significant difference between the low vowel /a/ and the back vowel /u/ in an emphatic environment. Furthermore, there was a significant interaction between the type of consonant and the short and long vowels ($t=3$, $p<.001$). In other words, the presence of an emphatic has a significantly different effect on F2 depending on vowel length. As described in Section 2.3.2 above, the emphatic lowers F2 significantly more in the presence of a short vowel or equivalently, significantly less in the presence of a long vowel. Finally, there was a significant three-way interaction between the type of consonant, the type of length, and the vowel qualities /a/ vs. /i/. There is a significant difference between the F2 of the long low vowel /a/ and the long front vowel /i/ in emphatic environments ($t=2$, $p<.05$).

To test the significance of the emphatic effect on the non-target syllable, we fitted a separate model, as shown in Table 7. This table shows the results of the fitted model when the vowels appear in the second syllables, which are not adjacent to emphatics in initial positions.

Table 7: Regression model for F2 of the non-target vowel in the second syllable

Predictor	β	$SE(\beta)$	t	p
(Intercept)	1605	20	80	
c.C1	-53	5	-11.52	<.0001
c.V1a.vs.u	-111	14	-8.00	<.0001
c.lengthV1	8	3	2.89	<.05
c.V1a.vs.i	33	3	11.23	<.0001
distance3	-180	17	-10.53	<.0001
c.V1a.vs.u:c.lengthV1	14	5	2.91	<.05
c.C1:c.V1a.vs.u	36	5	6.90	<.0001
c.C1:c.lengthV1	21	5	4.39	<.0001
c.lengthV1:c.V1a.vs.i	6	5	1.33	=.18
c.C1:c.V1a.vs.i	25	5	4.72	<.0001
c.C1:distance3	-11	4	-2.55	<.05
c.C1:c.V1a.vs.u:c.lengthV1	-32	9	-3.62	<.001
c.C1:c.lengthV1:c.V1a.vs.i	-9	9	-1.05	=.29

The results of this model show that F2 of the non-target syllable's vowel (V2) was significantly lowered when preceded by an emphatic consonant in the preceding syllable (t=–12, p<.0001). In addition, there was a significant interaction between the type of consonant and *distance*; the effect of the emphatic consonant on the non-target vowel is stronger when it is closer to the emphatic (t=–3, p<.05). Notice that the interaction estimate is negative (indicating a further depression of the F2) because distance was defined as being positive closer to the emphatic consonant. In addition, there was a significant interaction between the type of consonant and the difference between the low vowel /a/ and the high back vowel /u/ in the preceding syllable (t=7, p<.0001). In other words, there is a difference between the emphatic effect on the vowel in the non-target syllable depending on which vowel is in the target syllable: low vowel /a/ or back vowel /u/. Furthermore, there was a significant interaction between the type of consonant and the difference between the low vowel /a/ and the high front vowel /i/ in the preceding syllable ($t=5$, $p<.0001$). Therefore, there is a significant difference between the emphatic effect on the vowel in the non-target syllable depending on which vowel is in the target syllable: low vowel /a/ or high front vowel /i/. Moreover, there was a significant interaction between the type of consonant and the short and long vowels in the preceding syllable ($t=4$, $p<.0001$). Alternatively, the emphatic effect on the vowel in the non-target syllable is significantly different depending on which vowel is in the target syllable: short vowel or long one. Finally, there was a significant three-way interaction between the type of consonant, the type of length and the vowel qualities /a/ vs. /u/ in the preceding syllable. There is a significant effect on the non-target's vowel's F2 depending on the type of the vowel in the preceding syllable: the long low vowel /a/ or the long back vowel /u/ in emphatic environments ($t=4$, $p<.001$).

2.3.5 Leftward Lowering Effect on all Vowels Combined

Some authors have reported that emphatics affect the neighboring vowels differently based on their position in the word. It has been reported that the leftward emphatic effect extends further and is rarely blocked when compared to rightward emphatic lowering. Moreover, the effect of emphatics in some dialects is reportedly non-gradient (Ghazeli, 1977; Watson, 2002; Al-Masri, 2009; among others). Therefore, I will present the results of the word-final emphatic effect on the neighboring vowels to determine how it patterns in Zilfaawi Arabic.

As presented in **Figure 20**, F2 of both vowels in the word was consistently lowered as a result of presence of emphatic consonants at the end of the words. Overall, the presence of the word-final emphatic consonant lowered F2 of the adjacent target vowel by an average difference of 280 Hz (1540 Hz vs. 1260 Hz). In addition, the effect on the non-target vowel in the non-adjacent syllable was also indicated by a decreased F2, with an average of 90 Hz (1640 vs. 1550).

THE EFFECT OF EMPHATICS ON TARGET V2 AND PRECEDING V1

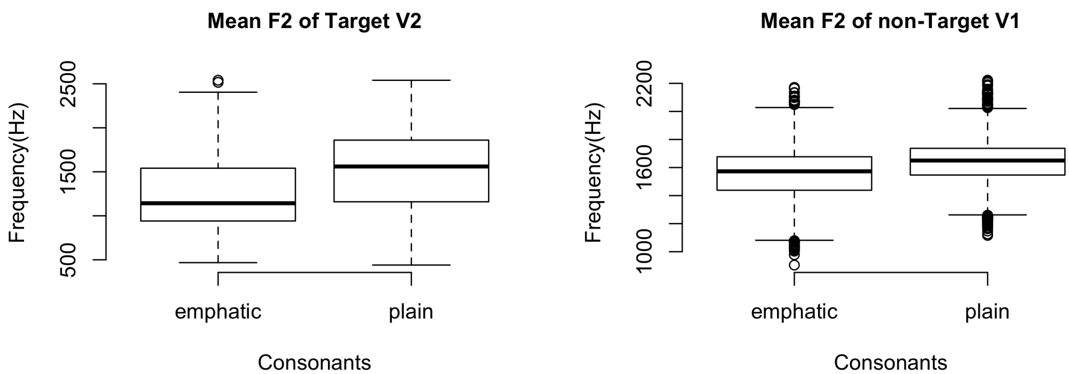


Figure 20: Box plots illustrating effect of emphatics on the target vowel (V2) and the non-target one (V1) in terms of F2

The effect of the emphatic consonant on the target vowel in the word decreased with distance, as can be seen in **Figure 21** below: For those closest to the emphatic consonant, F2 values were lowered by 400 Hz (1610 Hz vs. 1210 Hz) and the effect decreased gradually by going through the midpoint by a difference of 240 Hz (1530 Hz vs. 1290 Hz) and down to a difference of 190 Hz (1480 Hz vs. 1290 Hz) at the farthest point of measurement.

Mean F2 Values at different points of the Target V2

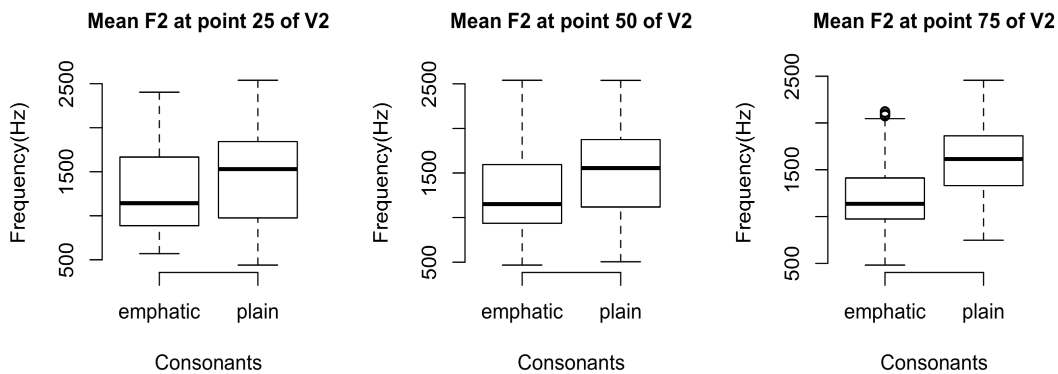


Figure 21: Box plots illustrating mean F2 at different points of the target vowel (V2) adjacent to emphatics at the end of the word

The overall emphatic effect on the non-target vowel in the non-adjacent first syllable was also indicated by a depressed F2 with an average of 90 Hz, as can be seen in **Figure 20** above. **Figure 22** shows that the effect of the emphatic consonant on the preceding non-target vowel in the word diminished with distance. Closest to the emphatic consonant, F2 was lowered by 95 Hz (1500 Hz vs. 1405 Hz). However, the effect decreased gradually with a difference of 90 Hz (1655 Hz vs. 1565 Hz) at the midpoint and goes down to a difference of 70 Hz (1755 Hz vs. 1685 Hz) at the farthest point.

Mean F2 Values at different points of the Non-Target V1

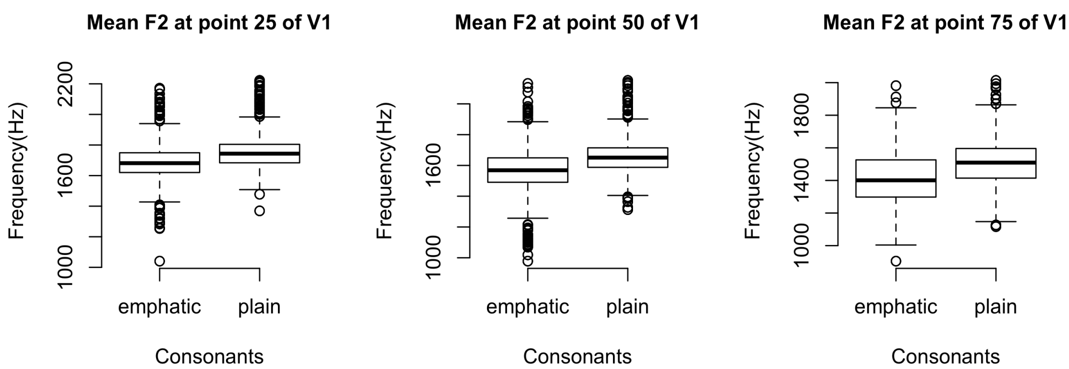


Figure 22: Box plots illustrating mean F2 at different points of the non-target vowel (V1) in the preceding syllable

After measuring all vowels combined, short and long, let us now consider short and long vowels separately to see if the different emphatic effect noticed between short and long vowels preceded by emphatics word-initially can be found when emphatics appear word-finally.

2.3.6 Leftward Lowering Effect on Short Vowels

As can be seen in **Figure 23**, when measuring F2 values of short target vowels only, the presence of the word-final emphatic consonant caused F2 of target short vowels in the second syllable to decrease by an average of 340 Hz (1190 Hz vs. 1530 Hz). In addition, F2 of the non-target vowel in the non-adjacent first syllable was lowered by an average of 100 Hz (1630 vs. 1530).

THE EFFECT OF EMPHATICS ON SHORT TARGET V2 AND PRECEDING V1

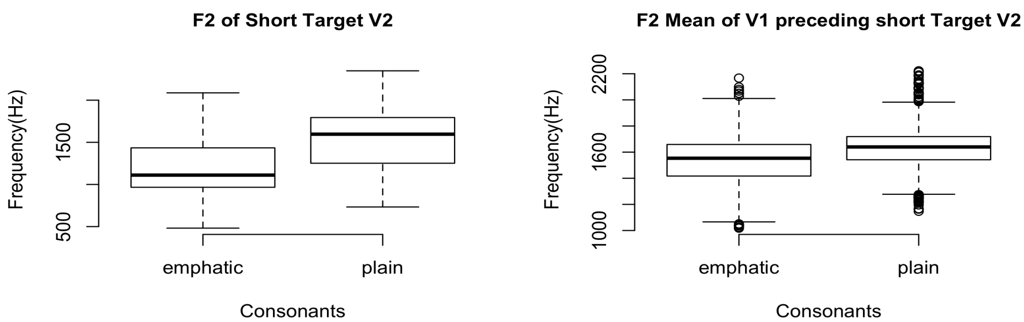


Figure 23: Box plots illustrating effect of emphatics on the target short vowel (V2) and the non-target one (V1) in terms of F2

Mean F2 Values at different points of the Target Short V2

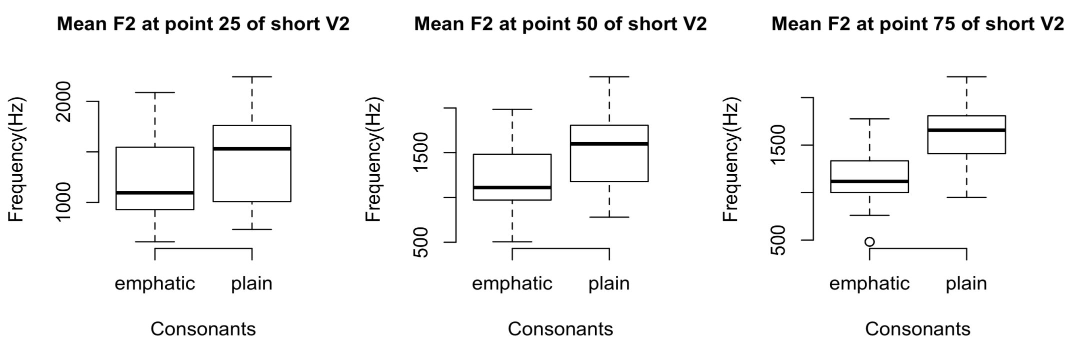


Figure 24 shows that when calculating the F2 values of all three points of the short target vowels, the effect of the emphatic consonant on the vowel in the word diminished gradually. When measuring the closest point to the emphatic consonant, F2 was lowered with a difference of 460 Hz (1620 Hz vs. 1160 Hz) and a difference of 320 Hz (1530 Hz vs. 1210 Hz) at the vowel midpoint. At the farthest point, the effect goes down to a 230 Hz difference (1440 Hz vs. 1210 Hz).

Mean F2 Values at different points of the Target Short V2

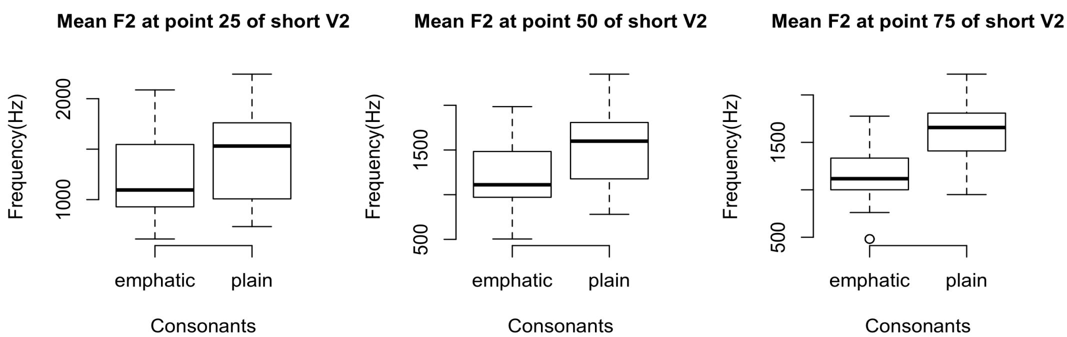


Figure 24: Box plots illustrating mean F2 at different points of the target short vowel (V2) in the syllable adjacent to emphatics

When considering the preceding syllables, the overall effect depressed F2 of the non-target vowel by an average of 100 Hz as shown in **Figure 23** above. **Figure 25** shows that the effect of the emphatic consonant on the non-target vowel decreased with distance: For those closest to the emphatic consonant, F2 was lowered by 105 Hz (1495 Hz vs. 1390 Hz) and by a difference of 95 Hz (1640 Hz vs. 1545 Hz) the midpoint and down to a difference of 75 Hz (1745 Hz vs. 1670 Hz) at the farthest point one.

Mean F2 Values at different points of the Non-Target V1

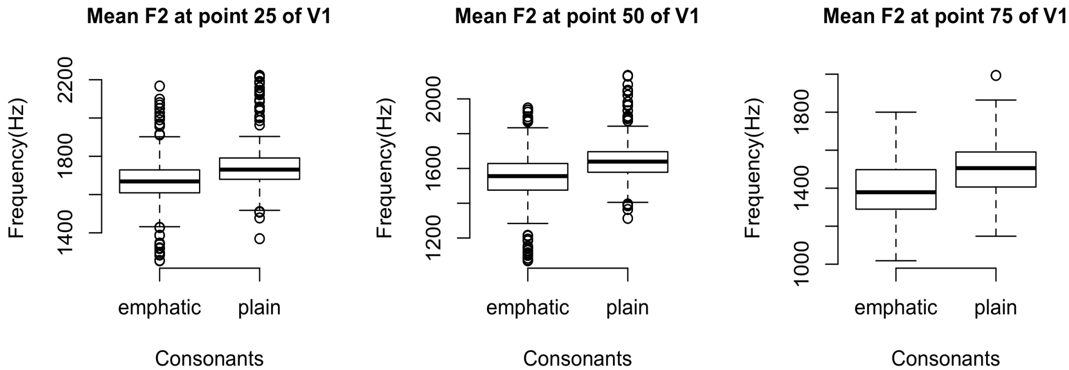


Figure 25: Box plots illustrating mean F2 at different points of the non-target vowel (V1) in the preceding syllable, which is always /a/

The following bar plot shows the effect on both syllables over time in one picture.

Mean F2 Values at different points of the Target V2 and non-Target V1

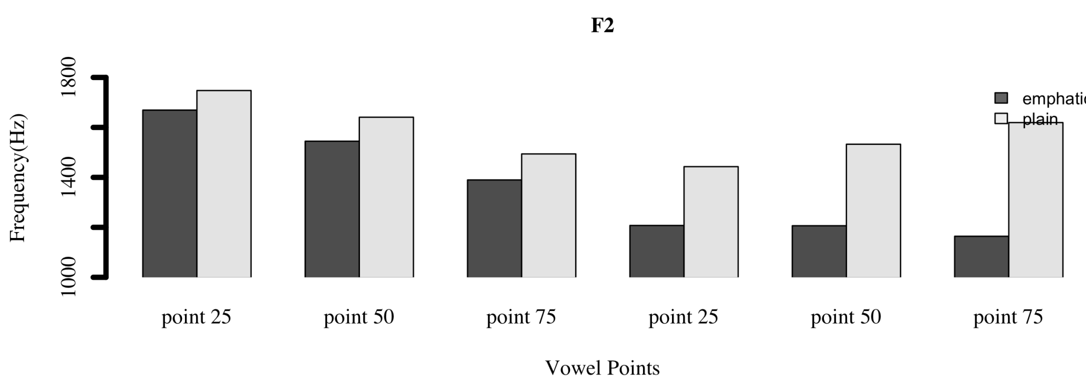


Figure 26: Bar plot illustrating mean F2 at different points non-adjacent (V1) and adjacent (V2)

2.3.7 Leftward Lowering Effect on Long Vowels

It is now time to calculate the emphatic lowering effect on the long vowels, having done so for the short vowels above. **Figure 27** shows that, overall, the word-final emphatic consonant lowered F2 of the adjacent target long vowels in the second syllable by an average of 210 Hz (1540 Hz vs. 1330 Hz). The F2 of the non-target vowel in the first syllable was also depressed by an average difference of 80 Hz (1650 vs. 1570).

THE EFFECT OF EMPHATICS ON LONG TARGET V2 AND PRECEDING V1

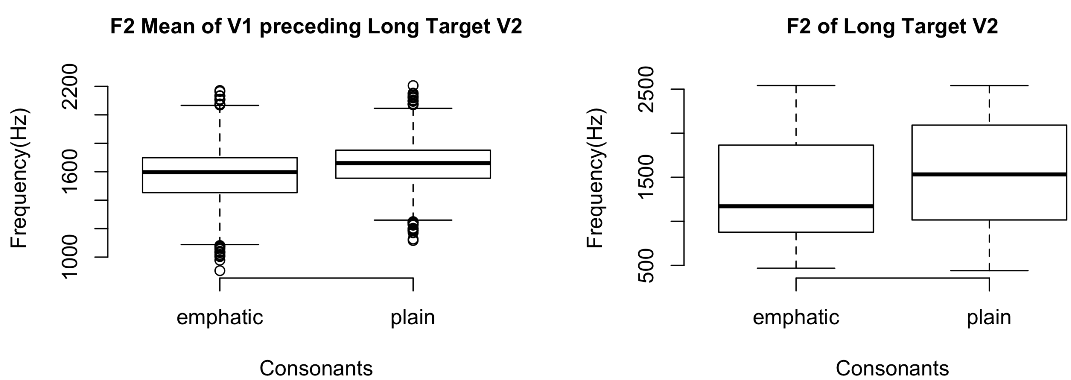


Figure 27: Box plots illustrating effect of emphatics on the target long vowel (V2) and the non-target one (V1) in terms of F2

Figure 28 shows that the word-final emphatic consonant exerted lowering effect on each point of measurement of the vowel. However, this lowering effect on the target long vowel in the word decreased with distance. F2 was lowered by 330 Hz (1590 Hz vs. 1260 Hz) at the closest point to the emphatic consonant. The effect decreased gradually with a difference of 150 Hz (1520 Hz vs. 1370 Hz) at the midpoint of the vowel and with a difference of 140 Hz (1510 Hz vs. 1370 Hz) at the farthest point of measurement.

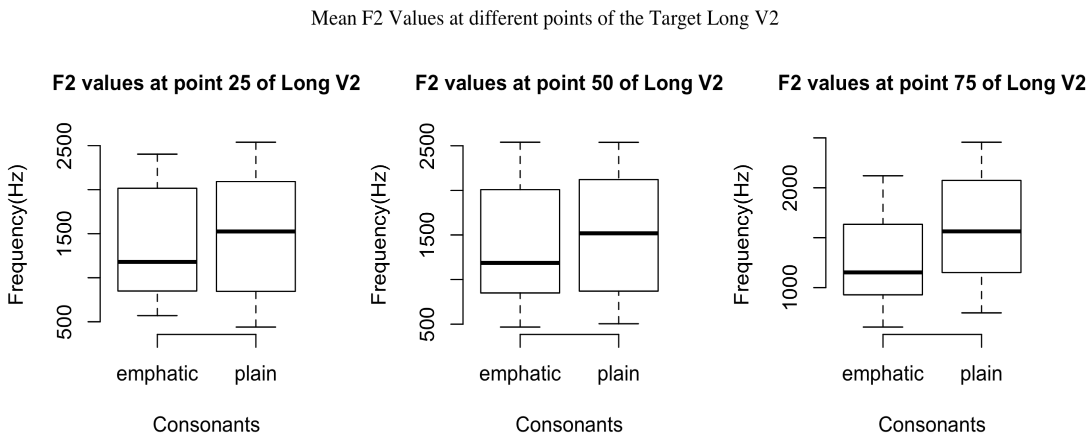


Figure 28: Box plots illustrating mean F2 at different points of the target long vowel (V2) in the syllable adjacent to emphatics

Figure 27 above shows that the emphatic lowering effect on the non-target vowel in the non-adjacent syllable showed F2 depression by an average of 80 Hz. Looking at **Figure 29** below, the exerted lowering effect of the emphatic consonant on the preceding vowel in the word became gradually weaker: For those closest to the emphatic consonant, F2 was lowered by 85 Hz (1510 Hz vs. 1425 Hz) and the effect decreased gradually by going through the midpoint by a difference of 85 Hz (1670 Hz vs. 1585 Hz) and down to a difference of 65 Hz (1765 Hz vs. 1700 Hz) at the farthest point of measurement.

F2 Values at different points of the non-Target V1

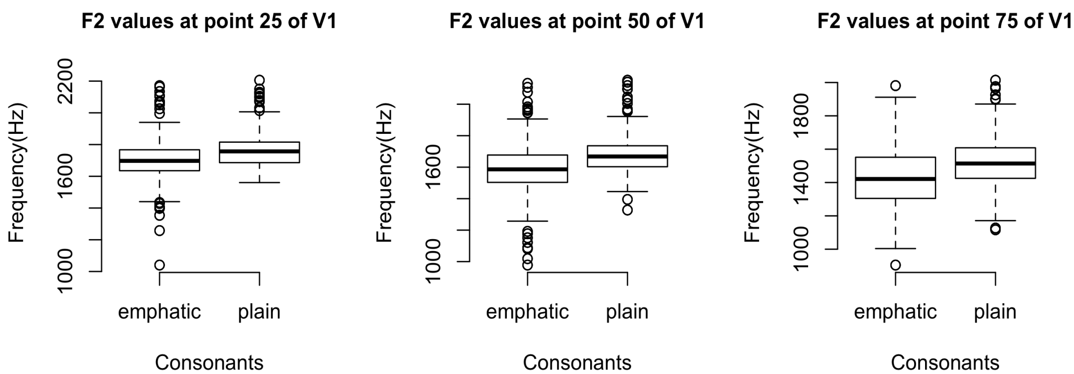


Figure 29: Box plots illustrating mean F2 at different points of the non-target vowel (V1) in the non-adjacent syllable

Compared to the emphatic effect of word-initial emphatics, it appears that the final emphatic consonants exert a lowering effect on the target and non-target vowels in both syllables of the word. The emphatic effect on the target short vowel is stronger than is the effect on the targeted long one. In addition, the effect exerted by these emphatic consonants is gradient. Therefore, the further we move from the emphatic consonant at the end of the word, the weaker the effect on the vowels of both syllables becomes. However, the emphatic lowering effect when emphatics appear word-finally affects the target vowel less, but extends and affects the non-target vowel of the first syllable more. **Figure 30** below shows the effect on both syllables in one picture.

Mean F2 Values at different points of the Vowels in the Target and non-Target Syllables

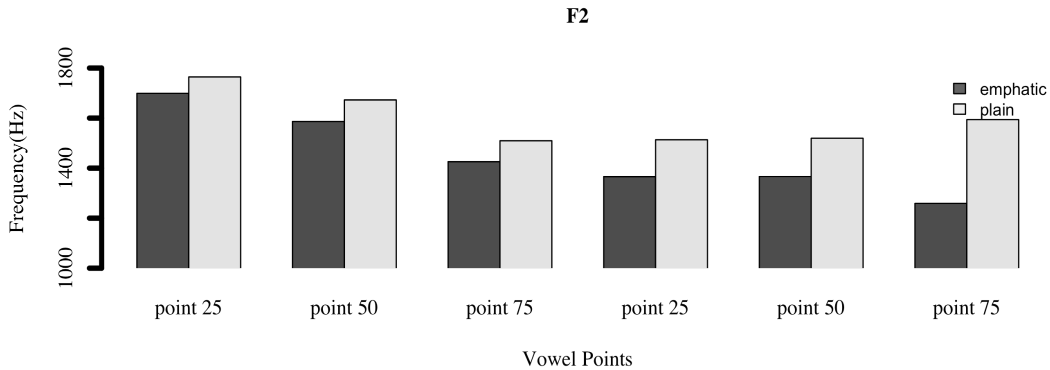


Figure 30: Bar plots illustrating mean F2 at different points of non-adjacent (V1) and adjacent (V2)

2.3.8 Lowering Effect and Vowel Quality

The emphatic effect might vary from one vowel to another based on their qualities as seen in word-initial emphatic effect above. Therefore, it is time to obtain the values of all vowels based on their qualities when emphatics appear word-finally. Table 8 shows the vowels and the F2 values in plain and emphatic environments.

Table 8: Vowel F2 values of adjacent vowels in plain and emphatic environments pooled across three points of measurements when emphatics appear word-finally

Vowel type	Type of consonant		Difference in Hz
	plain	emphatic	
a	1600	1120	480
a:	1540	1170	370
i	1870	1540	330
i:	2180	1970	210
u	1220	920	200
u:	900	840	60

As can been seen in Table 8 and **Figure 31**, when emphatic consonants are word-final, their lowering effect is strongest on the adjacent short vowel /a/ with a difference of 480 Hz (1600 Hz vs. 1120 Hz), followed by the vowel /a:/ with a difference of 370 Hz (1540 Hz vs. 1170 Hz), then by the high vowel /i/ with a difference of 330 Hz (1870 Hz vs. 1540 Hz). This was followed by the long /i:/, with a difference of 210 Hz (2180 Hz vs. 1970 Hz), and the short /u/ and, with a difference of 200 Hz (1120 Hz vs. 920 Hz). The least affected vowel was the long back vowel /u:/ with a difference of 60 Hz (900 Hz vs. 840 Hz).

Mean F2 of Different V2 Qualities in the Target Syllable

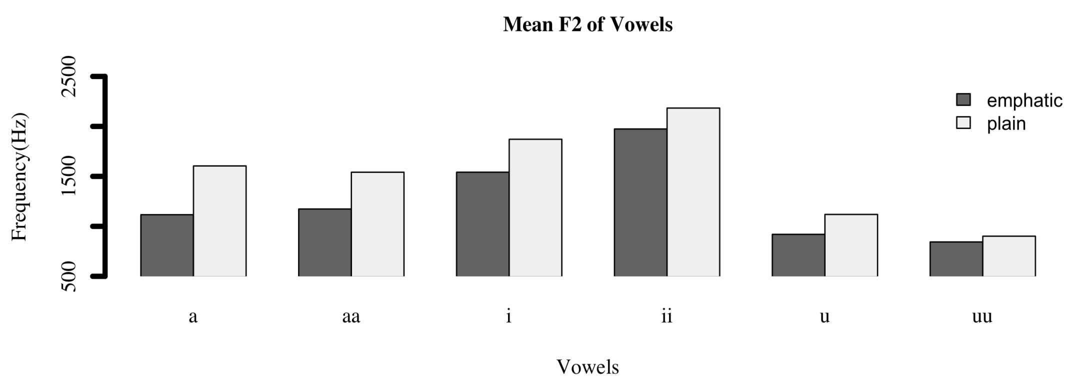


Figure 31: Bar plot illustrating different emphatic effect on vowels when they appear word-finally based on their qualities

It appears that the word-final emphatic lowering effect affects vowels based on their quality. It was stronger on the low vowels /a/ and /a:/ and weaker on the back vowels, /u/ and /u:/.

2.3.8.1 Over Time Measurements:

Non-low vowels have been reported to show sharp transition from the adjacent emphatic the undergoing emphatic effect only at the onset (Bin-Muqbil, 2003). Therefore, all three different points of all vowels of different qualities are to be measured to test how they are affected in ZA. Furthermore, to see if leftward emphatic lowering will show the same effect of rightward effect on vowels. **Figure 32**, **Figure 33**, and Figure 34 show the emphatic effect of vowel quality over time.

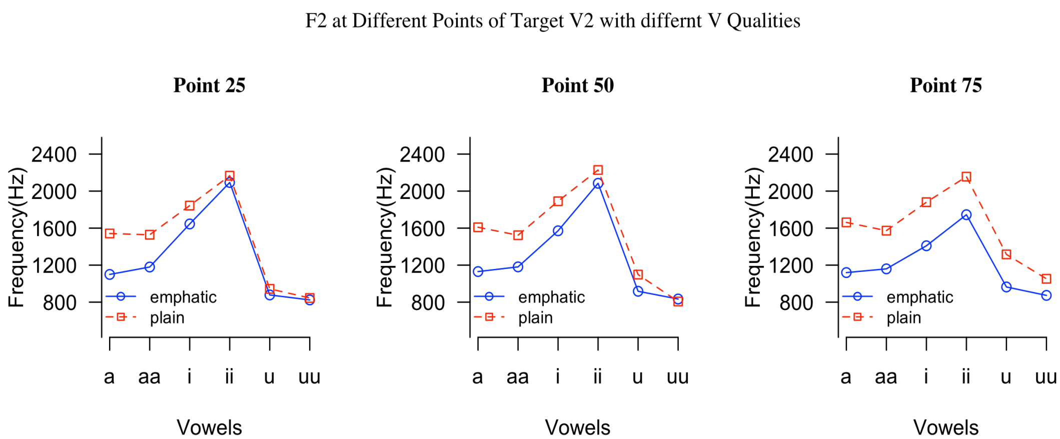


Figure 32: Bar plots illustrating different emphatic effect on vowels based on their qualities at different vowel points of measurements

At p75, the effect of the final emphatic consonants was strongest on the adjacent short low vowel /a/ with a difference of 540 Hz, followed by the short high vowel /i/ with a difference of 470 Hz, then by the long high vowel /i:/ with a difference of 420 Hz. This was followed by the long low vowel /a:/, with a difference of 410 Hz, and the short back vowel /u/, with a difference of 360 Hz and the long back vowel /u:/ with a difference of 180 Hz. At p50, the exerted effect was strongest on the adjacent short low vowel /a/ with a difference of 480 Hz, followed by the long low vowel /a:/ with a difference of 340 Hz, then by the long high vowel /i/ with a difference of 320 Hz. This was followed by the short back vowel /u/, with a difference of 180 Hz, and the long high vowel /i:/, with a difference of 150 Hz and long back vowel /u:/ with a difference of 20 Hz. What is interesting here is that the long /a:/ was affected more than was the short /i/. At p25, the lowering effect was strongest on the adjacent the short low vowel /a/ with a difference of 440 Hz, followed by the long low vowel /a:/ with a difference of 350 Hz, then by the short high vowel /i/ with a difference of 200 Hz. This was followed by the long high vowel /i:/, with a difference of 80 Hz, the short back vowel /u/, with a difference of 60 Hz, while the long back vowel /u:/ was the least affected vowel with a difference of 20 Hz.

In general, it appears that the short low vowel is the one that is most affected when emphatics occur word-finally. However, the high back vowels /u/ and /u:/ are the least affected ones. The long vowel /u:/ shows a stronger effect at p75, which is closer to emphatics, and much less effect at p50 and p25. This is in agreement with the word-initial emphatic effect.

The following figures display each vowel separately showing the greater difference between the plain and empathic environments of the low vowel /a/:

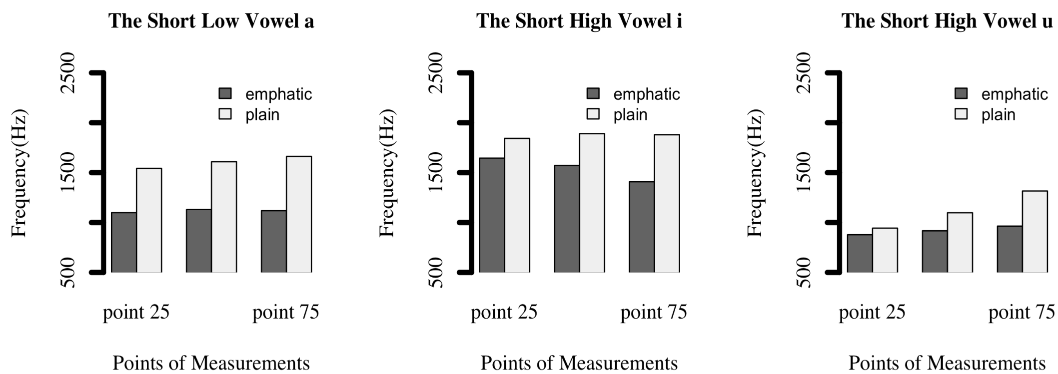


Figure 33: Bar plots illustrating different emphatic effect on short vowels based on their qualities at different vowel points of measurements

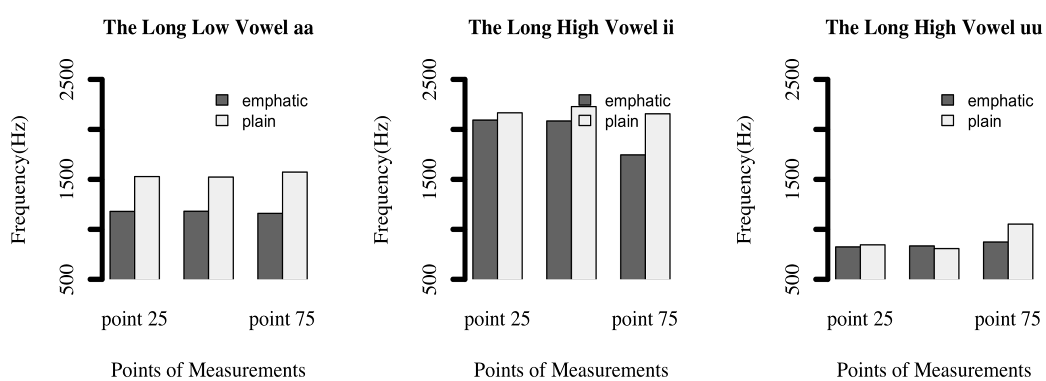


Figure 34: Bar plots illustrating different emphatic effect on long vowels based on their qualities at different vowel points of measurements

2.3.8.2 Long Distance Lowering Effect

The long-distance effect of emphatic consonants on non-target vowels varies based on the quality of the target vowel in the adjacent syllable. I will now consider the effect of emphatic consonants on the non-target vowel in the first syllable, which is always /a/, by calculating its F2 values. As seen in **Figure 35** below, the F2 of the non-target vowel was lowered to the greatest degree when the vowels in the initial syllable were the low vowels: the short low vowel /a/ with a difference of 120 Hz (1535 vs.1655). The short high vowel /i/ follows with a difference of 70 Hz (1620 Hz vs.1690 Hz), then /u/ with a difference of 70 Hz (1470 Hz vs. 1540 Hz) and /u:/ with a difference of 70 Hz (1495 Hz vs. 1565 Hz). The vowel's F2 was least affected when the vowel was /i:/ with differences of 50 Hz (1680 Hz vs.1730 Hz).

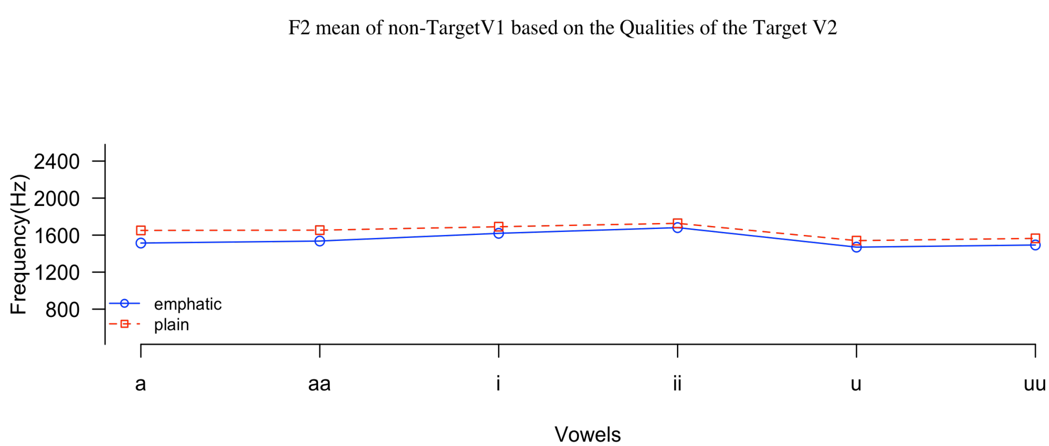


Figure 35: emphatic effect on non-target vowels based on the quality of the vowel in the target's second syllable

As in the cases in which the emphatic consonants are word-initial, the above F2 values show that the word-final emphatic's lowering effect on the non-target vowel was strongest when the vowels in the first syllable were the low vowels /a/ and /a:/. However, the emphatic lowering effect was the weakest on the non-target vowel when the long high vowels /i:/ and /u:/ appeared as target vowels in the first syllable.

Before turning into the statistical analysis, I will summarize the effect on the combined vowels. Figure 36 shows a more comprehensive picture of both syllables in terms of the emphatic effect over time with all vowels combined. It shows how the effect of word-final emphatics is stronger and extends further than does the effect word-initial emphatics.

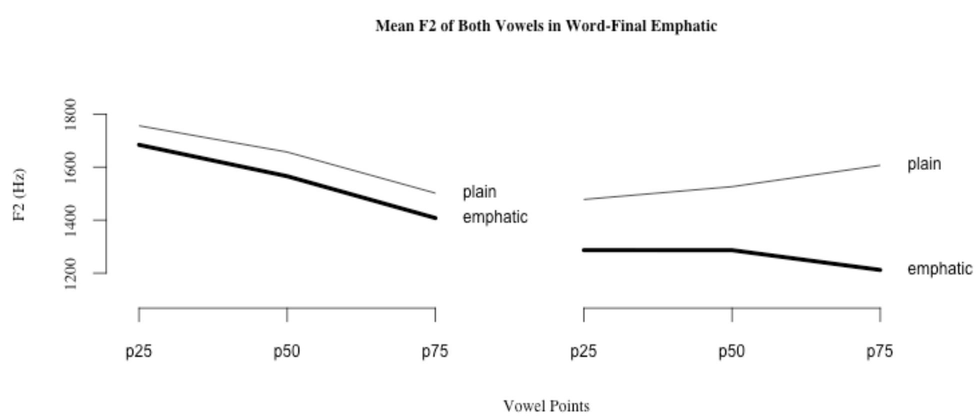


Figure 36: Degree of F2 depression in both syllables of words with final emphatics

2.3.9 Statistical Analysis

To examine the statistical significance of the final emphatic effect, mixed-effects linear regression models were fitted with F2 as the dependent variable. One model is fitted for testing the effect of emphatics on the target syllable, while the other is fitted for the non-target syllable. **Table 9** shows the results of the fitted model when the target vowels in the second syllables were adjacent to the emphatics in final positions.

Table 9: Regression model for F2 of the target the vowel in the second syllable

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	1470	14	101.58	
c.C3	-418	11	-39.62	<.0001
c.V2a.vs.u	-436	11	-41.55	<.0001
c.lengthV2	-7	10	-0.72	=.47
c.V2a.vs.i	369	11	35.17	<.0001
distance3	-77	6	-13.18	<.0001
c.V2a.vs.u:c.lengthV2	-146	17	-8.33	<.0001
c.C3:c.V2a.vs.u	294	19	15.63	<.0001
c.C3:c.lengthV2	121	18	6.91	<.0001
c.lengthV2:c.V2a.vs.i	378	17	21.64	<.0001
c.C3:c.V2a.vs.i	158	19	8.40	<.0001
c.C3:distance3	203	10	19.39	<.0001
c.C3:c.V2a.vs.u:c.lengthV2	15	31	0.48	=.63
c.C3:c.lengthV2:c.V2a.vs.i	-4	31	-0.12	=.90

As expected, as shown in **Table 9** above, the model's results show that the F2 was lowered significantly when vowels were followed by an emphatic consonant (t=–40, p<.0001). In addition, there was a significant interaction between the type of consonant and *distance*; in other words, the further we move from the emphatic consonant, the weaker the effect is on the vowel (t=19, p<.0001). The results of the model in **Table 10** show that the F2 of the vowel in the preceding non-target syllable was significantly lowered when vowels were followed by an emphatic consonant in the following syllable (t=–19, p<.0001). In addition, there was a significant interaction between the type of consonant and *distance*; thus, the further we move towards the emphatic consonant in the target syllable, the stronger the effect on the vowel (t=–22, p<.0001). Furthermore, there was a significant interaction between the type of consonant and the difference between the low vowel /a/ and the high back vowel /u/ in the following syllable (t=6, p<.0001). In other words, there was a difference between the emphatic effect on the vowel in the non-target syllable depending on which vowel was in the target syllable: the low vowel /a/ or the back vowel /u/. Moreover, there was a significant interaction between the type of consonant and the difference between the low vowel /a/ and the high front vowel /i/ in the following syllable (t=6, p<.0001). In other words, there was a difference between the emphatic effect on the vowel in the non-target syllable depending on which vowel was in the target syllable: the low vowel /a/ or the high front vowel /i/.

To see the effect of emphatics on the preceding non-target syllable, I fitted a separate model, as shown in **Table 10** below. This table shows the results of the fitted model when the vowels appear in the first syllables, which are not adjacent to the emphatics in final positions.

Table 10: Regression model for F2 of the non-target vowel in the second syllable

Predictor	β	$SE(\beta)$	t	p
(Intercept)	1615	19	83.54	
c.C3	-119	6	-19.24	<.0001
c.V2a.vs.u	-91	6	-14.77	<.0001
c.lengthV2	13	6	2.31	<.05
c.V2a.vs.i	62	6	10.06	<.0001
distance3	-260	4	-72.49	<.0001
c.V2a.vs.u:c.lengthV2	-17	10	1.62	=.10
c.C3:c.V2a.vs.u	63	11	5.72	<.0001
c.C3:c.lengthV2	18	10	1.71	=.08
c.lengthV2:c.V2a.vs.i	35	10	3.45	<.001
c.C3:c.V2a.vs.i	66	11	6.02	<.0001
c.C3:distance3	-22	6	-3.42	<.001
c.C3:c.V2a.vs.u:c.lengthV2	-21	18	-1.12	=.26
c.C3:c.lengthV2:c.V2a.vs.i	6	18	0.31	=.76

The results of the model in **Table 10** show that the F2 of the vowel in the preceding non-target syllable was significantly lowered when vowels were followed by an emphatic consonant in the following syllable ($t=-19$, $p<.0001$). In addition, there was a significant interaction between the type of consonant and *distance*; thus, the further we move towards the emphatic consonant in the target syllable, the stronger the effect on the vowel ($t=-22$, $p<.0001$). Furthermore, there was a significant interaction between the type of consonant and the difference between the low vowel /a/ and the high back vowel /u/ in the following syllable (t=6, p<.0001). In other words, there was a difference between the emphatic effect on the vowel in the non-target syllable depending on which vowel was in the target syllable: the low vowel /a/ or the back vowel /u/. Moreover, there was a significant interaction between the type of consonant and the difference between the low vowel /a/ and the high front vowel /i/ in the following syllable (t=6, p<.0001). In other words, there was a difference between the emphatic effect on the vowel in the non-target syllable depending on which vowel was in the target syllable: the low vowel /a/ or the high front vowel /i/.

2.4 Results for F1

After investigating the effect of emphatics on the target and non-target vowels in the word by measuring the F2 values of vowels at three points of each vowel, now it is time to measure the second most reported acoustic effect of emphatics on the neighboring vowels of the word, F1 raising. The same questions raised when presenting the results of vowels' F2 above will be raised again here in this section. One question is of whether emphatic effect is a pharyngealization process, F2 drop and F1 increase, or uvularization process, F2 drop unchanged F1. Another question is whether this F1 raising effect, if detected, is gradient or categorical.

Let us now start with the effect of the word-initial emphatics on the following vowels. The results of F1 in this section will be presented in the same order used to present F2 above.

2.4.1 Rightward Raising Effect (F1) on all Vowels Combined

As shown in **Figure 37**, overall, the presence of the word-initial emphatic consonant raised F1 of the adjacent target vowel by an average difference of 50 Hz (490 Hz vs. 440 Hz). Also, the effect on the non-target vowel in the second syllable was also indicated by a slightly raised F1, with an average of 10 Hz (520 Hz vs. 510 Hz).

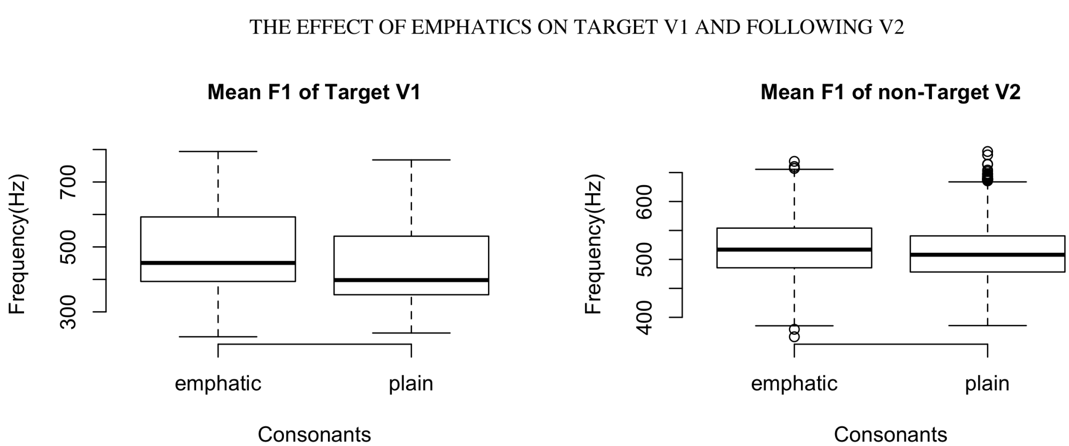


Figure 37: Box plots illustrating effect of emphatics on the target vowel (V1) and the non-target one (V2) in terms of F1

Figure 38 below shows that the effect of the emphatic consonant on the target vowel in the word decreased with distance: Closest to the emphatic consonant, F1 was raised by 60 Hz (490 Hz vs. 430 Hz) and the effect decreased gradually by going through the midpoint by a difference of 45 Hz (500 Hz vs. 455 Hz) and down to a difference of 30 Hz (475 Hz vs. 445 Hz) at the farthest point of measurement.

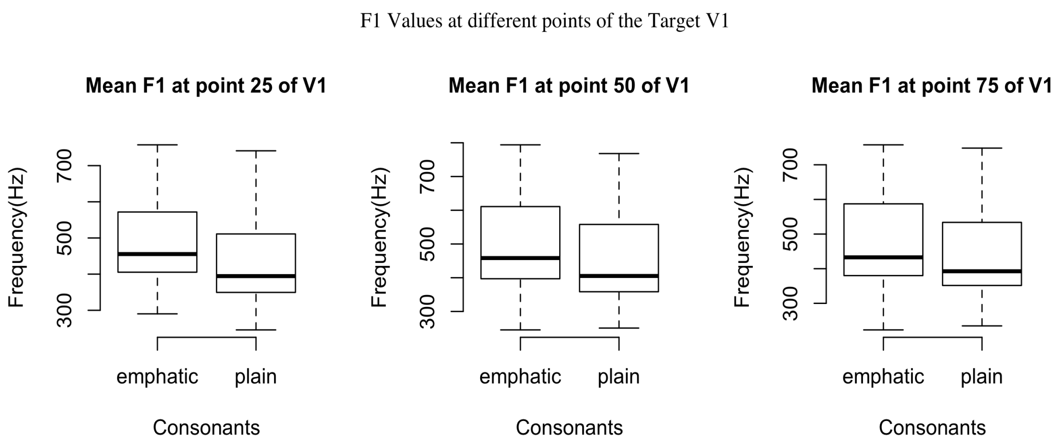


Figure 38: Box plots illustrating mean F1 at different points of (V1) adjacent to emphatics

By considering the non-target vowel in the second syllable, the effect was also present by raising F1 of the vowel slightly by an average of 10 Hz, as can be seen from **Figure 37**. Although the effect is minimal compared to the lowering effect, **Figure 39** shows that the effect of the emphatic consonant on the following non-target minimized with distance. Closest to the emphatic consonant, F1 was increased by 10 Hz (540 Hz-528Hz). However, the effect decreased gradually with a difference of 5 Hz at the midpoint (540 Hz vs. 535 Hz) and (480 Hz vs. 475 Hz) at the farthest point of measurement.

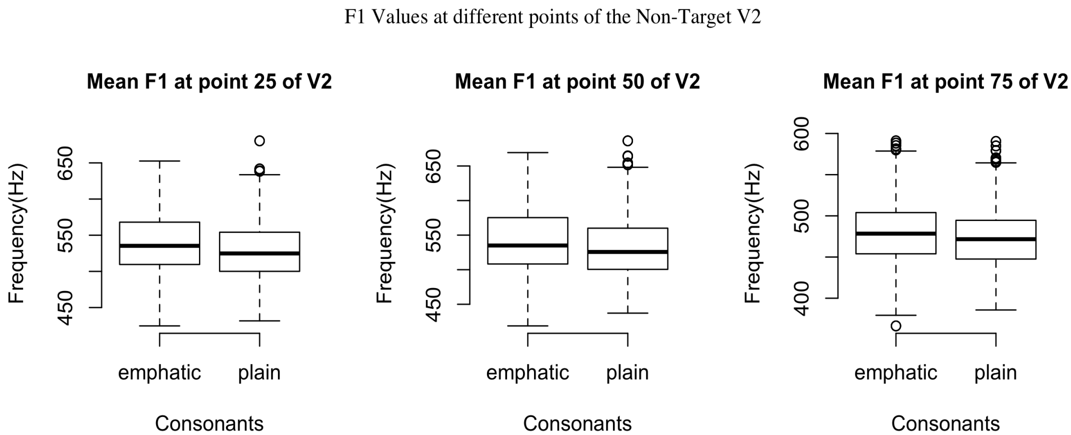


Figure 39: Box plots illustrating mean F1 at different points of the non-target vowel (V2) in the following syllable

One reason for this small F1 increase of the target and non-target vowels might be the fact that the measurements were averaged across all short and long vowels, as shown in the results of emphatic effect on F2 of vowels. Therefore, let us consider short and long vowels separately in the following sections to see if the different effect on short and long vowels is also available by measuring F1 of the vowels.

2.4.2 Rightward Raising Effect on Short Vowels

Figure 40 shows that by testing short target vowels only, the presence of the word-initial emphatic consonant caused F1 of target short vowels to go up by an average of 55 Hz (480 Hz vs. 425 Hz) as can be seen in below. In addition, the non-target vowel's F1 was slightly raised by an average of 10 Hz (520 Hz vs. 510 Hz).

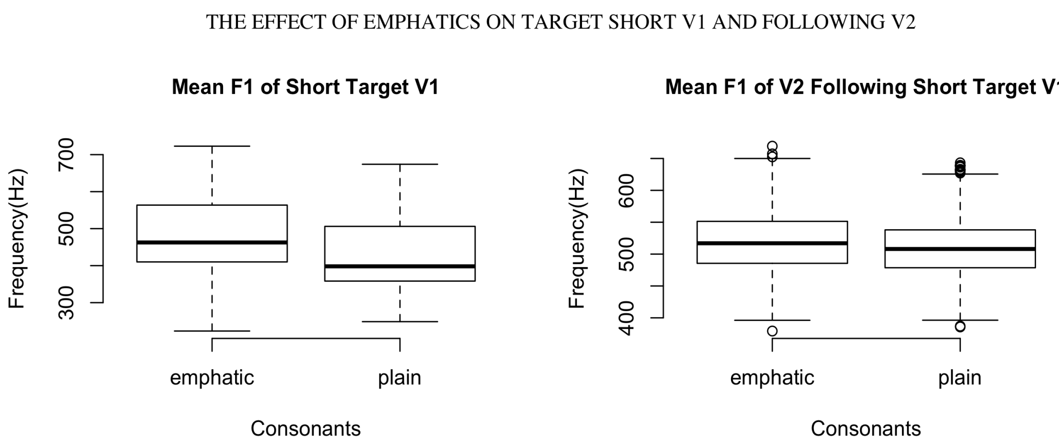


Figure 40: Box plots illustrating effect of emphatics on the target short vowel (V1) and the non-target one (V2) in terms of F1

By measuring three points of the short target vowels, it appears that the effect of the emphatic consonant on the vowel in the word diminished gradually. As shown in **Figure 41**, when measuring the closest point to the emphatic consonant, F1 was raised by 65 Hz (485 Hz vs. 420 Hz). The effect gradually decreased with a difference of 55 Hz (495 Hz vs. 440 Hz) at the midpoint of the vowel and down to a difference of 50 Hz (470 Hz vs. 420 Hz) at the farthest point of measurement.

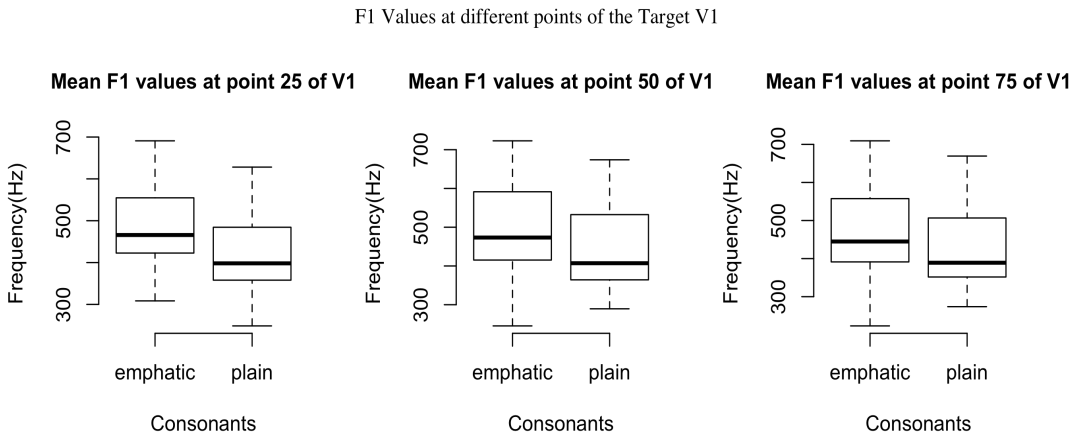


Figure 41: Box plots illustrating mean F1 at different points of the target short vowel (V1) in the syllable adjacent to emphatics

In the non-adjacent syllables following the target short vowel, the overall effect of initial emphatics raised F1 of the non-target vowel slightly by an average of 10 Hz as shown in **Figure 40** above. **Figure 42** shows that the effect of the emphatic consonant on the non-target vowel in the word diminished with distance: Closest to the emphatic consonant, F1 was raised by 15 Hz (540 Hz-525 Hz) and the effect decreased gradually by going through the midpoint by a difference of 10 Hz (540 Hz vs. 430 Hz) and down to a difference of 7 Hz (480 Hz vs. 473 Hz) at the farthest point of measurement.

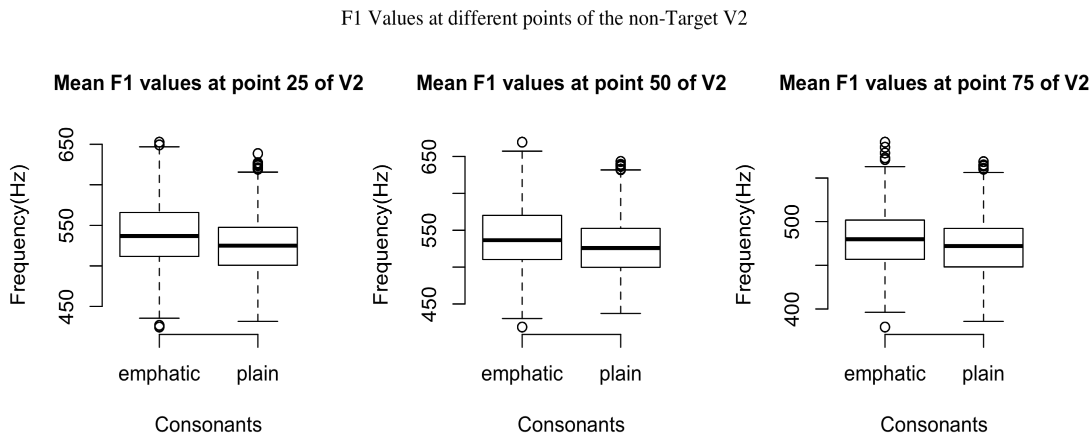


Figure 42: Box plots illustrating mean F1 at different points of the non-target vowel (V2) in the following syllable, which is always /a/

2.4.3 Rightward Raising Effect on Long Vowels

It is now time to test the emphatic lowering effect on the long vowels. Overall, the word-initial emphatic consonant raised F1 of adjacent target long vowels by an average of 30 Hz (490 Hz vs. 460 Hz) as can be seen from **Figure 43** below. However, The effect on the non-target vowel in the non-adjacent syllable barely raised F1, with an average difference of 5 Hz (520 Hz vs. 515 Hz).

THE EFFECT OF EMPHATICS ON TARGET LONG V1 and FOLLOWING V2

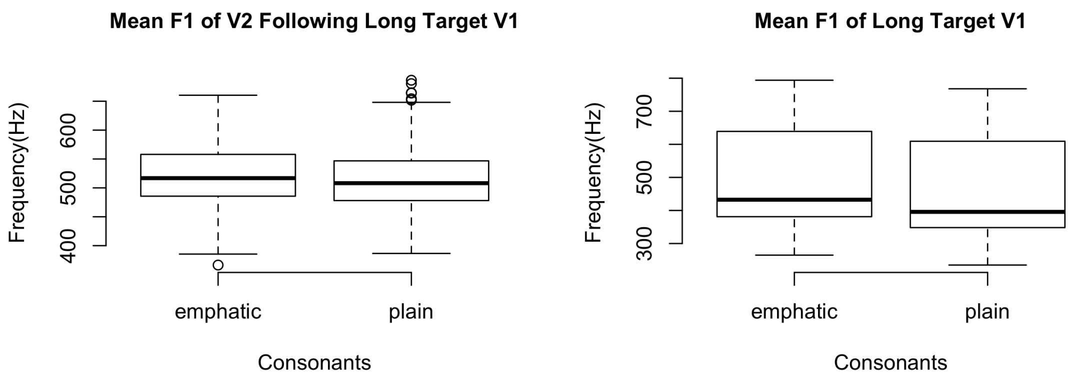


Figure 43: Box plots illustrating effect of emphatics on the target long vowel (V1) and the non-target short one (V2) in terms of F1

The word-initial emphatic consonant exerted raising effect on each point of measurement of the vowel. However, **Figure 44** shows that that raising effect on the target long vowel in the word decreased gradually. F1 was raised by 50 Hz (490 Hz vs. 440 Hz) at the closest point to the emphatic consonant. The effect became weaker gradually with a difference of 30 Hz (500 Hz vs. 470 Hz) at midpoint of the vowel and a difference of 10 Hz (480 Hz vs. 470 Hz) at the farthest point of measurement.

Mean F1 Values at different points of the Target V1

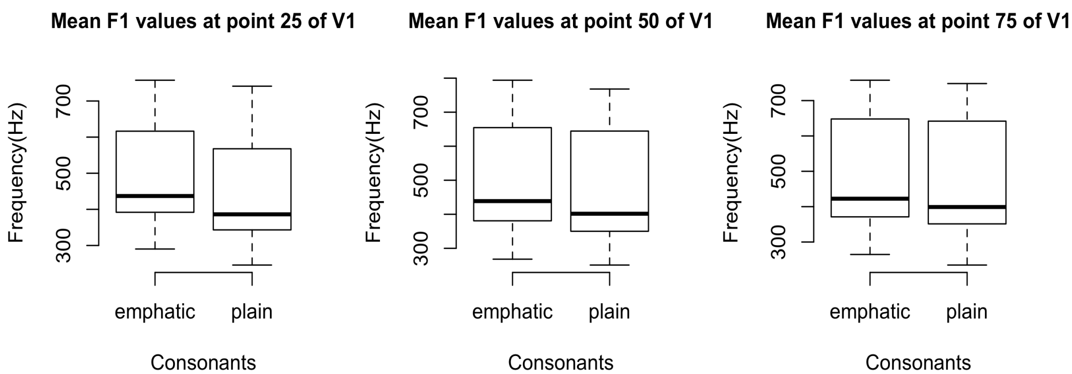


Figure 44: Box plots illustrating mean F1 at different points of the target long vowel (V1) in the syllable adjacent to emphatics

By looking at **Figure 43** above, it appears that the non-adjacent following syllables showed a slight F1 increase by an average of 5 Hz. The exerted raising effect of the emphatic consonant on the following non-target vowel in the word became gradually weaker. As can be seen in **Figure 45**, F1 of the closest point to the emphatic consonant was higher with a difference of 10 Hz (540 Hz-530 Hz). However, that effect diminished gradually with a difference of 7 Hz (545 Hz vs. 538 Hz) and 5 Hz (480 Hz vs. 475 Hz) at the midpoint and the farthest point of measurement, respectively.

Mean F1 Values at different points of the Non-Target V2

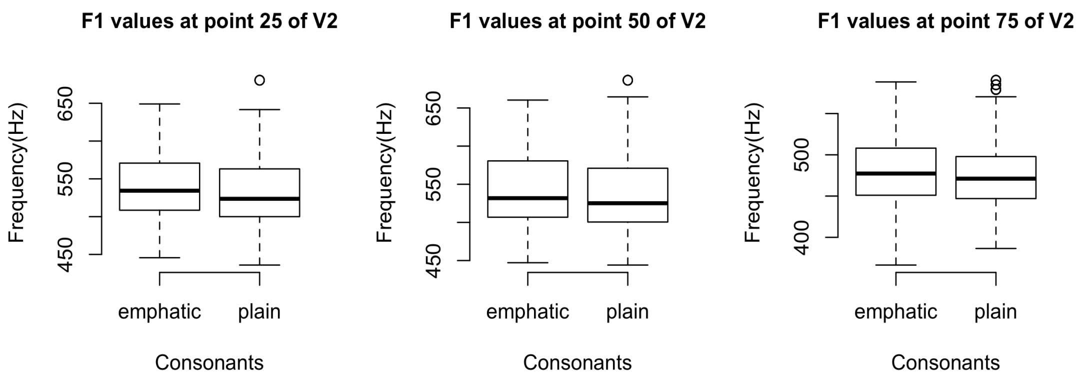


Figure 45: Box plots illustrating mean F1 at different points of the non-target vowel (V2) in the non-adjacent syllable

By measuring F1 values, it appears that the initial emphatic consonants affect the target and non-target vowels in the word. However, their effect on the target long vowel is weaker than the effect on the target short one. In addition, this emphatic raising effect is gradient. So, the further we move from the emphatic consonant, the weaker the influence becomes on the vowel.

2.4.4 Raising Effect and Vowel Quality

The emphatic effect might vary from vowel to another based on their qualities, as mentioned above. Therefore, let us measure the F1 values of all vowels based on their qualities looking for any possible effect of vowel quality.

Table 11 shows the amount of effect on F1 vowels based on their quality and length.

Table 11: Averaged F1 values of all vowels in plain and emphatic environments adjacent to word-initial emphatics

Vowel type	Type of consonant		Difference in Hz
	emphatic	plain	
i	420	360	60
a	590	535	55
u	435	385	50
i:	375	330	50
a:	680	650	30
u:	425	325	30

As shown in **Table 11** and Figure 46, the raising effect of the emphatic consonants when they are word-initial was strongest on the adjacent short high vowel /i/ with a difference of 60 Hz (420 Hz vs. 360 Hz), followed by the short high vowel /a/ with a difference of 55 Hz (590 Hz vs. 535 Hz). This was followed by the short back vowel /u/ with a difference of 50 Hz (435 Hz vs. 385 Hz) and long high vowel /i:/, with a difference of 50 Hz (375 Hz vs. 330 Hz). Finally, the long low vowel /a:/ and back vowel /u:/ came last with a difference of 30 Hz (680 Hz vs. 650 Hz) and 30 Hz (425 Hz vs. 395 Hz), respectively.

Mean F1 of Different V1 Qualities in the Target Syllable

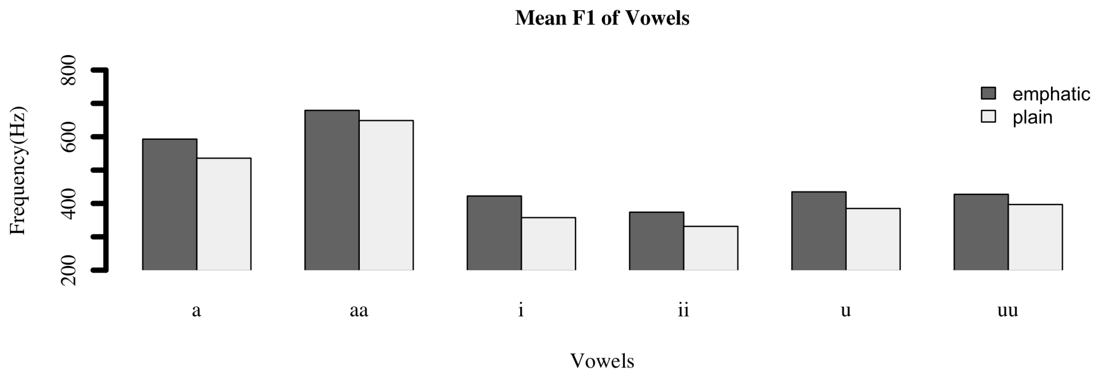


Figure 46: Bar plots illustrating different emphatic effect on vowels based on their qualities

It appears that the raising effect of emphatics was strongest on the short vowels and weakest on the long ones, especially the long vowels, /a:/ and /u:/.

2.4.4.1 Over Time Measurements

As can be seen in Figure 47, Figure 48, and **Figure 49**, the emphatic effect on F1 of vowels varies over time based on quality and length. At p25, the effect of the initial emphatic consonants was strongest on the adjacent short vowel /i/ with a difference of 80 Hz, followed by the low vowel /a/ with a difference of 70 Hz, then the long high vowel /i:/ with a difference of 65 Hz. This was followed by the long low /a:/, with a difference of 50Hz, and the short back vowel /u/, with a difference of 50 Hz and the long back vowel /u:/ with a difference of 40. At p50, the effect of initial emphatic consonants was strongest on the adjacent short high vowel /i/ with a difference of 65 Hz, followed by the short low vowel /a/ with a difference of 55 Hz, then the short low vowel /u/ with a difference of 45 Hz. This was followed by long high vowel /i:/, with a difference of 40 Hz, the long back vowel /u:/, with a difference of 30 Hz and the long low vowel /a:/ with a difference of 25 Hz. At this point of measurement, point 75, the short vowels are the most affected because the offsets of the short vowels are closer to the emphatic consonants than the long one. At p75, the effect of initial emphatic consonants was strongest on the vowel /i/ with a difference of 50 Hz, followed by the short vowel /a/ with a difference of 45 then adjacent short vowel /u/ with a difference of 40 Hz. This was followed by short /i:/, with a difference of 20 Hz, and long back vowel /u:/ with a difference of 20 Hz and long /a:/ with a difference of 20 Hz.

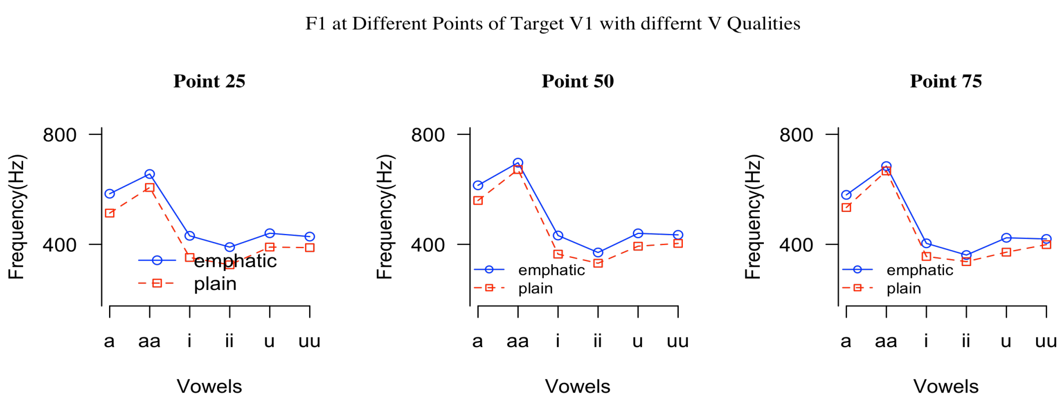


Figure 47: Bar plots illustrating different emphatic raising effect on vowels based on their qualities at different vowel points of measurements

Also, Figure 48 and **Figure 49** below show the effect on each vowel over time:

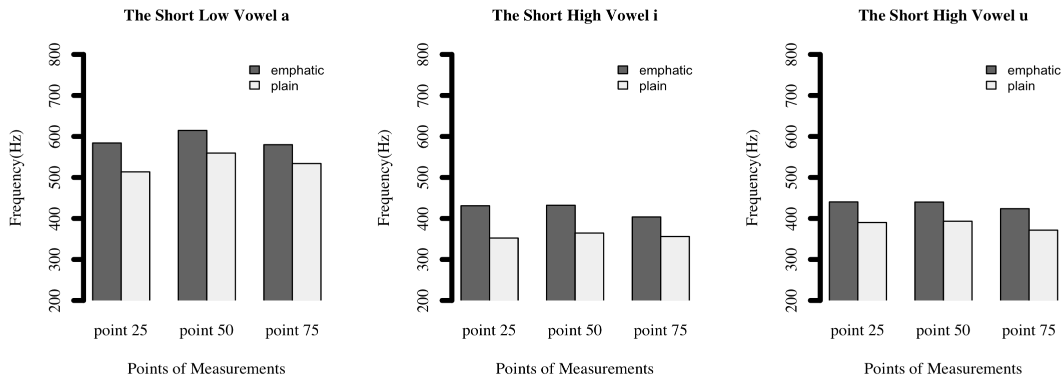


Figure 48: Bar plots illustrating different emphatic F1 raising effect on short vowels based on their qualities at different vowel points of measurements

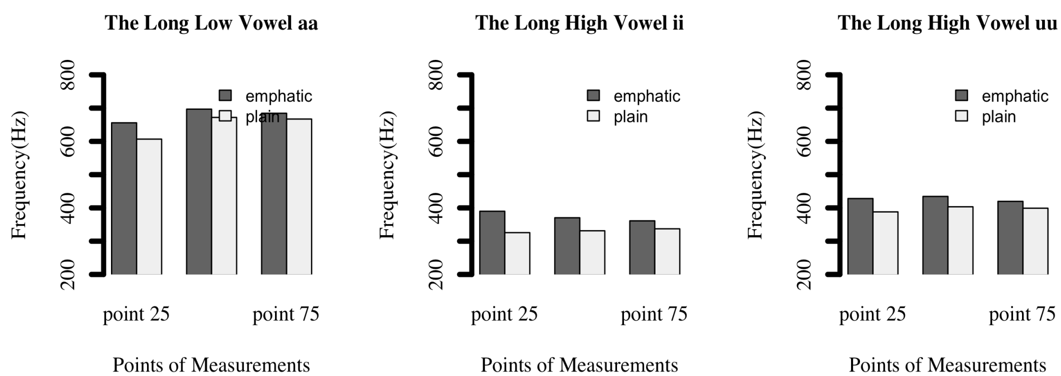


Figure 49: Bar plots illustrating different emphatic F1 raising effect on long vowels based on their qualities at different vowel points of measurements

By considering the effect of vowel quality over time, it appears that the vowels /u/ is affected more than /i:/ at point 50 when compared to the overall results above and by looking at p25. The long high vowel /ii/ is affected more at p25 because /i:/ is low in F1 so any change will be noticeable. However, at p.50, the midpoint of the long vowels is further than the short ones from the affecting consonants. Thus, this is why other short vowels, such as /u/, show more difference at this point. At the farthest point of measurement, which is point 75, the short vowel /u/ appeared as the most affected vowel as shown above. In addition, the long vowels were affected equally at this point.

2.4.4.2 Long Distance Raising Effect:

As seen in long distance lowering effect in section 2.3.4.2and section 2.3.8.2 above, the emphatic raising effect on the non-target vowel in the second syllable might vary based on the quality of the target vowel. As shown in **Figure 50** below, F1 was most raised when the vowel in the initial syllable was the low short vowel /a/ 15 Hz (525 Hz vs. 510 Hz). That was followed by the short high vowel /i/ with a difference of 10 Hz (510 Hz vs. 500 Hz), the long high vowel /i:/ with a difference 10 Hz (510 Hz vs. 500 Hz) and the short back vowel /u/ with a difference of 10 Hz (525 Hz vs. 515 Hz). The effect on the vowel /a/ in the non-target syllable was the least when the vowel in the initial syllable was the long vowels /u:/ with a difference of 5 Hz (525 Hz vs. 520 Hz) and /a:/ 5 Hz (525 Hz vs. 520 Hz), respectively.

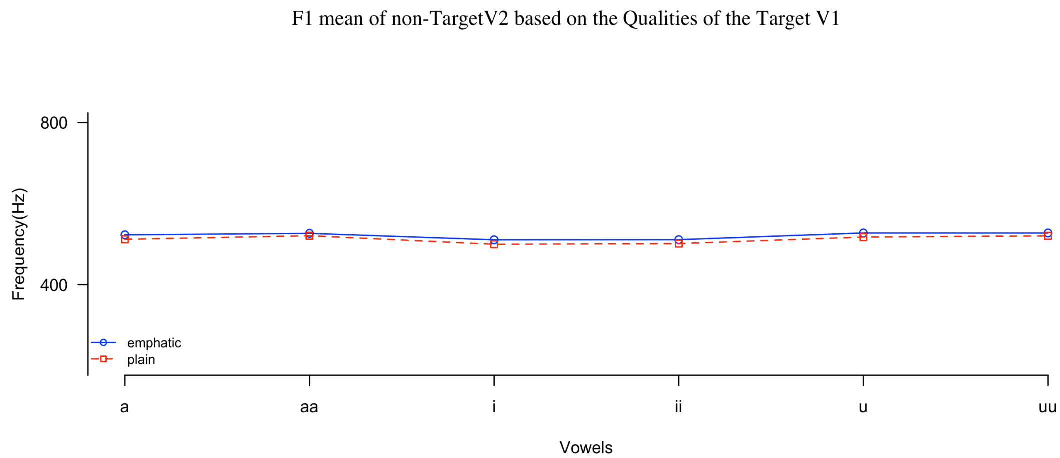


Figure 50: Line chart illustrating slight emphatic F1 raising effect on non-target vowels based on the quality of the vowel in the target syllable

The emphatic raising effect on the non-target vowel was not that strong as shown by the F1 values. However, after calculating F1 values of the non-target vowels based on the vowel in the previous syllable, it appears that the emphatic raising effect on the non-target vowel was strongest when the vowel in the first syllable was the low vowels /a/. When the high vowel /u:/ and the low vowel /a:/ were the target vowels, the non-target vowel /a/ was affected the least.

Figure 51 shows the gradient effect of word-initial emphatics on short and vowels combined of both syllables before turning to the statistical analysis. The effect gets stronger as the emphatic consonant approached.

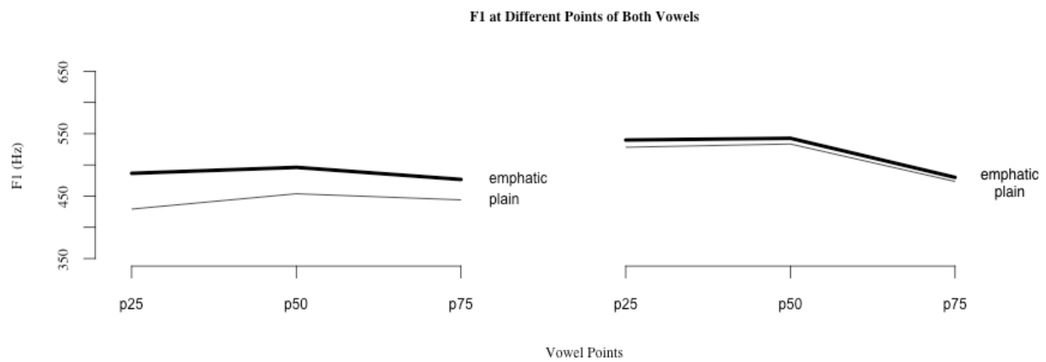


Figure 51: Line chart showing F1 increase in both syllables of words with initial emphatics

2.4.5 Statistical Analysis

In order to examine the statistical significance of the initial emphatic effect, mixed- effects linear regression models were fitted with F1 of the vowels as the dependent variable. One model is fitted for testing the effect of emphatics on the target syllable's vowels and another one for the non-target syllable's ones. **Table 12** displays the results of the fitted model when vowels are immediately preceded by emphatics in word-initial positions. The results of the fitted regression model in the table show that F1 was significantly raised when vowels were preceded by an emphatic consonant (t=–10, p<.0001). In addition, there was a significant interaction between the type of consonant and *distance*; the further we move from the emphatic consonant, the weaker the effect gets on the vowel (t=-8, p<.0001).

Table 12: Regression model for the F1 of the vowel in the target syllable

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	527	8	63.53	
c.C1	53	5	10.33	<.0001
c.V1a.vs.u	-168	5	-32.82	<.0001
c.lengthV1	81	5	16.91	<.0001
c.V1a.vs.i	-200	5	-38.90	<.0001
distance3	8	2	4.95	<.0001
c.V1a.vs.u:c.lengthV1	-102	9	-12.00	<.0001
c.C1:c.V1a.vs.u	-10	9	-0.99	=.32
c.C1:c.lengthV1	-22	9	-2.60	<.05
c.lengthV1:c.V1a.vs.i	-140	9	-16.36	<.0001
c.C1:c.V1a.vs.i	8	9	0.84	=.40
c.C1:distance3	-23	3	-8.01	<.0001
c.C1:c.V1a.vs.u:c.lengthV1	5	15	0.32	=.75
c.C1:c.lengthV1:c.V1a.vs.i	1	15	0.04	=.97

In addition, there was a significant interaction between the type of consonant and the length of the vowels (t=-3, p<.05). In other words, the presence of an emphatic has a significantly different effect on F1 depending on vowel length: the emphatic raises F1 significantly more in the presence of a short vowel, or equivalently, significantly less in the presence of a long vowel.

To see the effect of emphatics on the non-target syllable, we fitted a separate model and the results are shown in **Table 13** below. This table shows the results of the fitted model when the non-target vowels appear in the non-adjacent, or second, syllables.

Table 13: Regression model for the F1 of the vowel in the non-target syllable

Predictor	β	$SE(\beta)$	t	p
(Intercept)	515	8	64.54	
c.C1	10	2	5.07	<.0001
c.V1a.vs.u	4	2	2.11	<.05
c.lengthV1	6	2	3.52	<.001
c.V1a.vs.i	-13	2	-7.09	<.0001
distance3	56	5	10.55	<.0001
c.V1a.vs.u:c.lengthV1	-5	3	-1.69	=.09
c.C1:c.V1a.vs.u	-1	3	-0.18	=.85
c.C1:c.lengthV1	-5	3	-1.44	=.15
c.lengthV1:c.V1a.vs.i	-6	3	-1.96	<.05
c.C1:c.V1a.vs.i	-1	3	-0.18	=.85
c.C1:distance3	-5	2	2.32	<.05
c.C1:c.V1a.vs.u:c.lengthV1	2	6	0.40	=.69
c.C1:c.lengthV1:c.V1a.vs.i	4	6	0.69	=.49

The results of the fitted model in **Table 13** above show that F1 of the non-target syllable was significantly raised when vowels were preceded by an emphatic consonant in the preceding syllable (t=5, p<.0001). In addition, there was a significant interaction between the type of consonant and *distance*, so the effect of the emphatic consonant on the non-target vowel is stronger closer to the emphatic (t=2, p<.05).

2.4.6 Leftward Raising Effect (F1) on All Vowels Combined

As shown in **Figure 52** below, F1 of both target and non-target vowels were consistently raised as a result of presence of an emphatic consonant word-finally. Overall, **Figure 52** below shows that the presence of the word-final emphatic consonant raised F1 of the adjacent target vowel by an average difference of 40 Hz (495 Hz vs. 455 Hz). Also, the effect on the non-target vowel in the first syllable was also indicated by an increased F1, with an average of 15 Hz (500 Hz vs. 485 Hz).

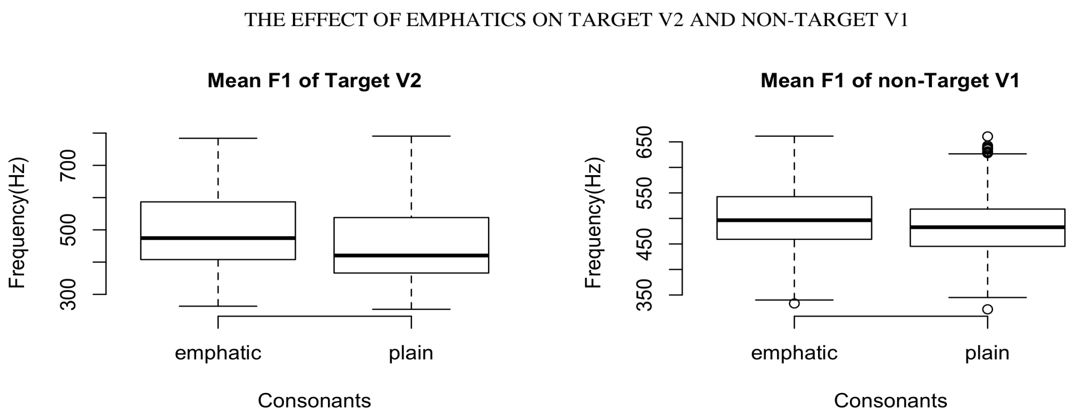


Figure 52: Box plots illustrating effect of emphatics on the target vowel (V2) and the non-target one (V1) in terms of F1

Figure 53 shows that the effect of the emphatic consonant on the target vowel in the second syllable decreased with distance: Closest to the emphatic consonant, F1 was raised by 55 Hz (505 Hz vs. 450 Hz) and the effect decreased gradually by going through the midpoint by a difference of 35 Hz (500 Hz vs. 465 Hz) and down to a difference of 20 Hz (475 Hz vs. 455 Hz) at the farthest point of measurement.

F1 Values at different points of the Target V2

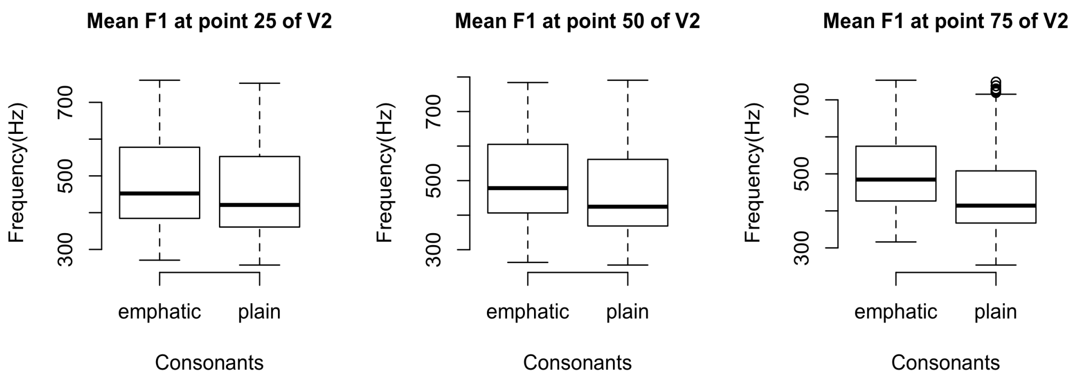


Figure 53: Box plots illustrating mean F1 at different points of the target vowel (V2) adjacent to emphatics at the end of the word

As mentioned above, the emphatic effect raised F1 of the non-target vowel in the first syllable by an average of 15 Hz (500 Hz vs. 485 Hz). **Figure 54** shows that the effect of the emphatic consonant on the non-target vowel in the preceding syllable was not as gradient as we saw in other raising and lowering effects on non-target vowels above. Closest to the emphatic consonant, F1 was raised by 15 Hz (505 Hz-490 Hz). However, F1 was raised with a difference 20 Hz (525 Hz vs. 505 Hz) at the midpoint of the vowel. Finally. F1 was raised by a difference of 15 Hz (470 Hz vs. 455 Hz) at the farthest point of measurement.

F1 Values at different points of the Non-Target V1

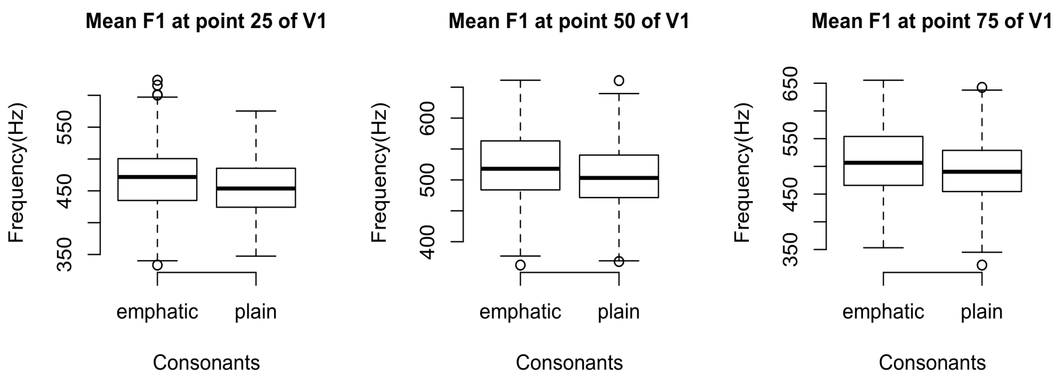


Figure 54: Box plots illustrating mean F1 at different points of the non-target vowel (V1) in the preceding syllable

Like the different results of word-initial vs. word-final effects, the word-initial emphatics affects stronger but the word-final extends further. After measuring all vowels combined, short and long, it is time to consider short and long vowels separately to explore any possible difference between the two.

2.4.7 Leftward Raising Effect on Short Vowels

Figure 55 shows that the presence of the word-final emphatic consonant caused F1 of target short vowels in the second syllable to go up by an average of 55 Hz (505 Hz vs. 450 Hz). Additionally, the overall effect of final emphatics raised F1 of the non-target vowel by an average of 20 Hz (530 Hz vs. 510 Hz).

THE EFFECT OF EMPHATICS ON TARGET SHORT V2 AND PRECEDING V1

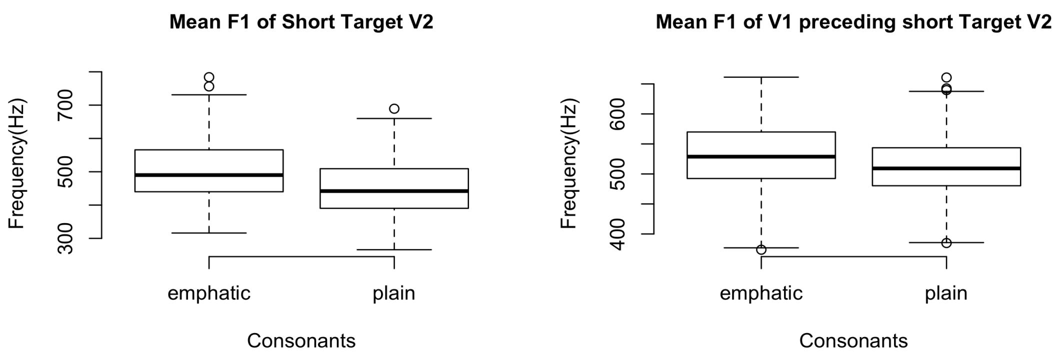


Figure 55: Box plots illustrating effect of emphatics on the target short vowel (V2) and the non-target one (V1) in terms of F1

By calculating three points of the short target vowels, we see the effect of the emphatic consonant on the target vowel diminished gradually. As shown in **Figure 56** below, by measuring the closest point to the emphatic, F1 was raised with a difference of 70 Hz (505 Hz vs. 435 Hz) and a difference of 50 Hz (515 Hz vs. 465 Hz) at the vowel's midpoint. At the farthest point of measurement, the emphatic effect goes down to a difference of 35 Hz (495 Hz vs. 460 Hz).

F1 Values at different points of the Target Short V2

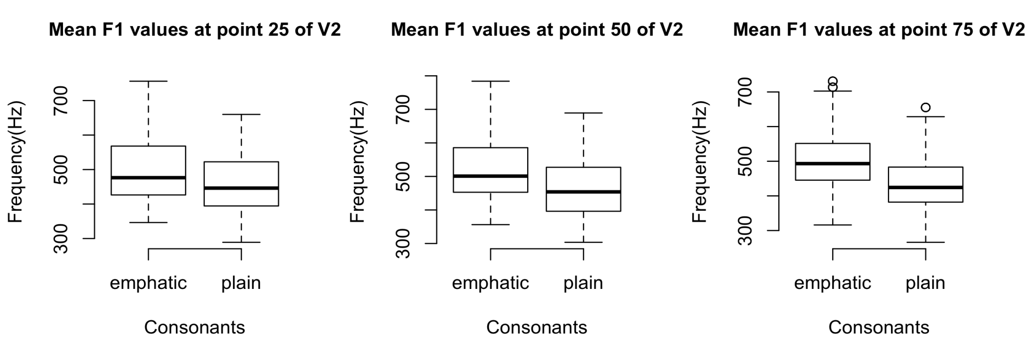


Figure 56: Box plots illustrating mean F1 of all points of the adjacent target short (V2)

As mentioned and seen from **Figure 55** above, the effect of word-final emphatics raised F1 of the non-target vowel by an average of 20 Hz. **Figure 57** illustrates that the effect of the emphatic consonant on the following non-target vowel becomes weaker with distance. F1 was raised at the closest point to the emphatic consonant by a difference of 20 Hz (490 Hz vs. 470 Hz) and at the midpoint by a difference of 20 Hz (555 Hz vs. 535 Hz). Then, the raising effect goes down to a difference of 15 Hz (540 Hz vs. 525 Hz) at the farthest point of measurement.

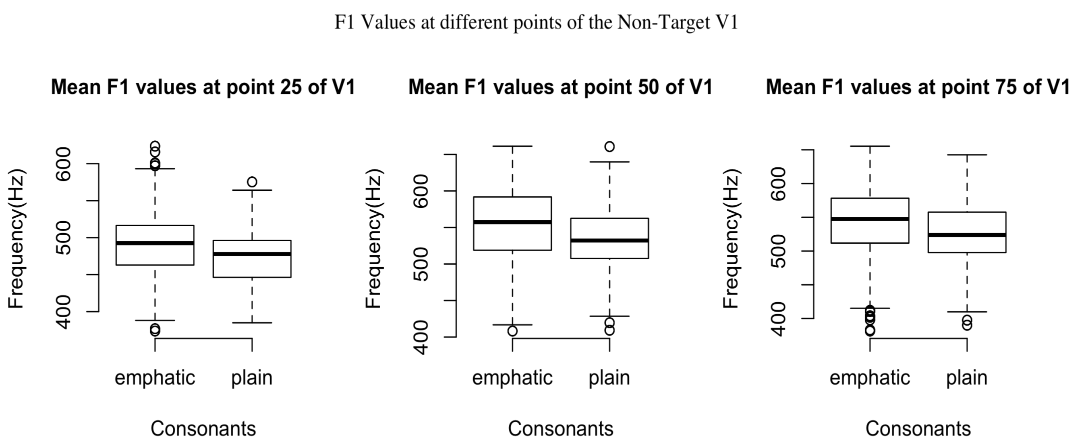


Figure 57: Box plots illustrating mean F1 at different points of the non-target vowel (V1) in the preceding syllable, which is always /a/

2.4.8 Leftward Raising Effect on Long Vowels

Figure 58 shows that the word-final emphatic consonant raised F1 of adjacent target long vowels in the second syllable by an average of 25 Hz (485 Hz vs. 460 Hz). Furthermore, it raised F1 of the non-target vowel in the preceding syllable by an average of 15 Hz (470 Hz vs. 455 Hz).

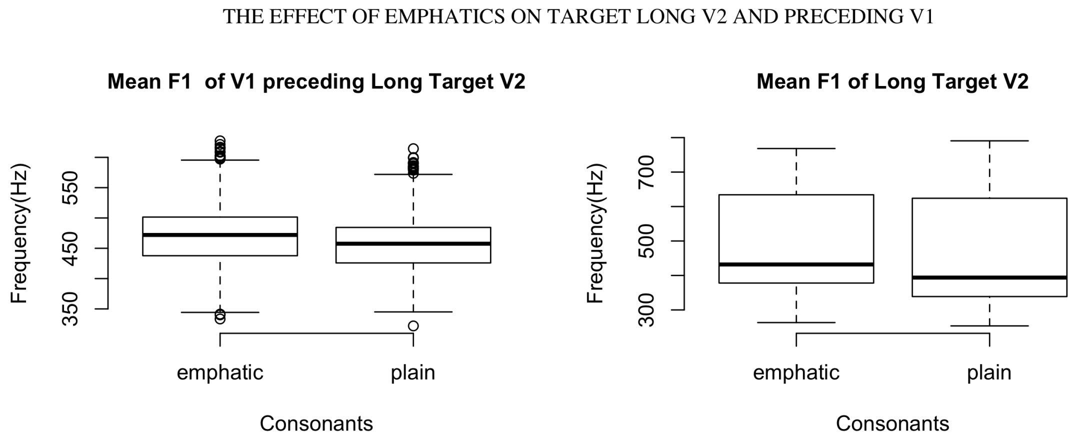


Figure 58: Box plots illustrating effect on the target long vowel (V2) and the non-target (V1) in terms of F1

The word-final emphatic consonant exerted raising effect on each point of measurement of the vowel. However, **Figure 59** shows that raising effect on the target long vowel in the word decreased with distance. F1 was raised by 45 Hz (510 Hz vs. 465 Hz) at the closest point to the emphatic consonant. The effect decreased gradually with a difference of 20 Hz (485 Hz vs. 465 Hz) at midpoint of the vowel and down to a difference of 10 Hz (460 Hz vs. 450 Hz) at the farthest point of measurement.

F1 Values at different points of the Target Long V2

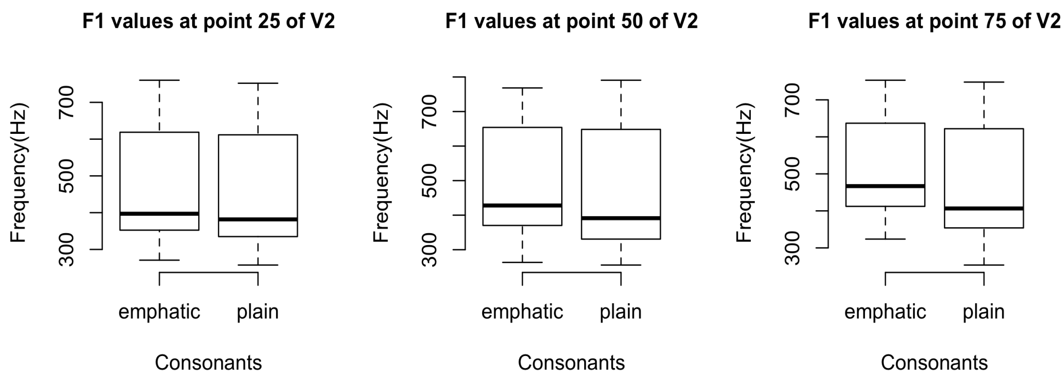


Figure 59: Box plots illustrating mean F1 at different points of the target long vowel (V2) in the syllable adjacent to emphatics

The raising effect on the non-target vowel in the preceding syllable showed F1 increase by an average of 15 Hz (470 Hz vs. 455 Hz) as seen in **Figure 58** above. **Figure 60** below displays that the emphatic raising effect on the preceding non-target vowel became gradually weaker. F1 of the closest point to the emphatic consonant was higher with a difference of 20 Hz (475 Hz vs. 455 Hz). However, that effect decreased gradually with a difference of 15 Hz (490 Hz vs. 475 Hz) and 15 Hz (450 Hz vs. 435 Hz) at the midpoint and the farthest point of measurement, respectively.

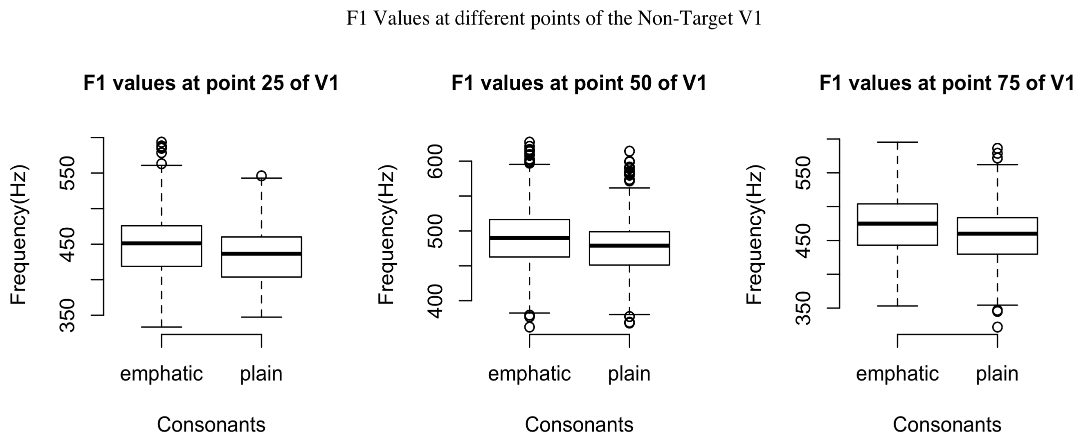


Figure 60: Box plots illustrating mean F1 at different points of the non-target vowel (V1) in the non-adjacent syllable

By considering the emphatic raising effect on target and non-target vowels, it appears that emphatics affected both of them. However, it affected the short vowels more than the long ones. In addition, the raising effect became weaker the further we move from the word-initial and word-final emphatic consonants on the target vowels. However, gradiency was noticed in the non-target vowels but not as gradient as shown in the target ones.

Emphatic effect on F1 of vowels has the same pattern on adjacent and non-adjacent vowels. However, the only difference is that gradiency is not as obvious as the one seen in emphatic lowering of F2. So, let us test the interaction between emphatic effect and vowel quality to see if we can have the same the results obtained by testing the word-initial emphatic effect.

2.4.9 Raising Effect and Vowel Quality

As seen when testing the word-initial emphatic effect, the raising effect affects vowels differently. **Table 14** shows F1 of all vowels based on length and quality in plain and emphatic environments.

Table 14: Averaged F1 values of all vowels based on length and quality in plain and emphatic environments when followed by emphatics

Vowel type	Type of consonant		Difference in Hz
	plain	emphatic	
i	395	455	60
a	540	595	55
i:	325	380	55
u	425	460	35
u:	395	425	30
a:	655	665	10

By looking at Figure 61, we see the role of vowel quality in having different emphatic effect on vowels based on their qualities. The raising effect of the emphatic consonants when they are word-final was strongest on the adjacent short high vowel /i/ with a difference of 60 Hz (455 Hz vs. 395 Hz). That was followed by the short low vowel /a/ with a difference of 55 Hz (595 Hz vs. 540 Hz) and the long high /i:/ with a difference of 55 Hz (380 Hz vs. 325 Hz). This was followed by the short /u/, with a difference of 35 Hz (460 Hz vs. 425 Hz), and the long /u:/ with a difference of 30 Hz (425 Hz vs. 395 Hz). The least affected vowel when emphatics occur word-finally is the long low vowel /a:/ showing a difference of 10 Hz (665 Hz vs. 655 Hz).

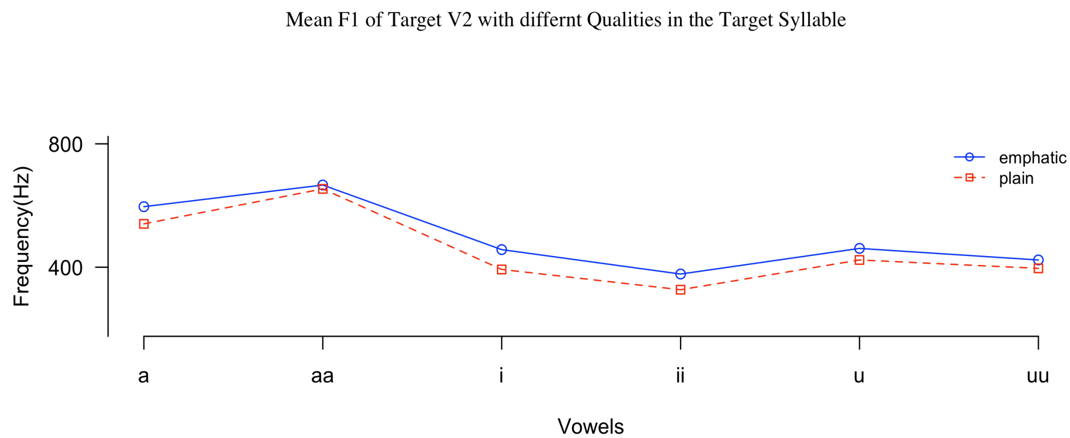


Figure 61: Bar plots illustrating different emphatic effect when they appear word-finally on vowels based on their qualities

As with the word-initial emphatic raising effect, the effect was mostly weaker on the long vowels, /u:/ and /a:/ and stronger on the short vowels /i/ and /a/.

2.4.9.1 Over Time Measurements

By considering the effect of vowel quality over time, some vowels are affected more than the other at specific some points as can be seen in **Figure 62**, **Figure 63**, and **Figure 64**. I will start the closest point to word-final target consonants, p75.

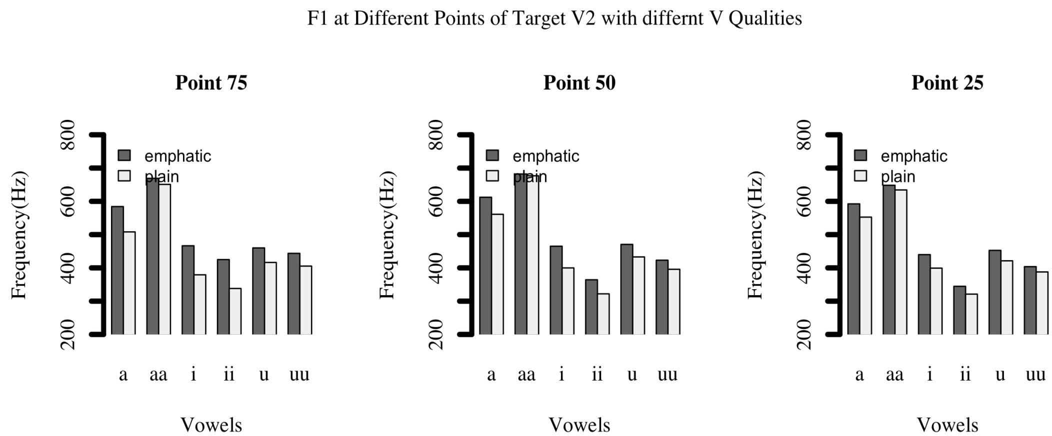


Figure 62: Bar plots illustrating different emphatic effect on vowels based on their qualities at different vowel points of measurements

At p75, the effect of final emphatic consonants was strongest on the adjacent short vowel /i/ with a difference of 85 Hz, followed by the long high vowel /i:/ with a difference of 85 Hz, then the short low vowel /a/ with a difference of 75 Hz. This was followed by the short back vowel /u/, with a difference of 45 Hz, and the long back vowel /u:/, with a difference of 40 Hz and the long low vowel /a:/ with a difference of 20 Hz. At midpoint, the same results are obtained compared to the overall results after the short low vowel /a/ is becoming the second most affected vowel after the short high vowel /i/. At this point of measurement, the effect of final emphatic consonants was strongest on the adjacent short high vowel /i/ with a difference of 65 Hz (400 Hz vs. 465 Hz), followed by the short low vowel /a/ with a difference of 50 Hz (560 Hz vs.610 Hz), then the long high vowel /i:/ with a difference of 45 Hz (320 Hz vs. 365 Hz).

This was followed by the short back vowel /u/, with a difference of 35 Hz (435 Hz vs. 470 Hz), and the long back vowel /u:/, with a difference of 30 Hz (395 Hz vs. 425 Hz). Finally, the long low vowel /a:/ was the least affected vowel with a difference of 5 Hz(675Hz vs. 680 Hz). At p25, which is the farthest point, the effect of emphatics was strongest on the adjacent short vowel /i/ with a difference of 40 Hz (400 Hz vs. 440 Hz), followed by the vowel /a/ with a difference of 35 Hz (550 Hz vs. 590 Hz), then the short vowel /u/ with a difference of 35 Hz (420 Hz vs. 455 Hz). This was followed by the short /i:/, with a difference of 25 Hz (320 Hz vs. 345 Hz), and the long low /a:/, with a difference of 15 Hz (635 Hz vs. 650 Hz) and the long back /u:/ with a difference of 15 Hz (390 Hz vs. 405 Hz).

By considering the effect of vowel quality over time, the most affected vowels are the short vowels /a/ and /i/. Moreover, it appears that the F1 values of vowels at point 50 have the same order reported in the overall results above. At point 75, the long high vowel /i:/ came second after its short counterpart instead of the low vowel /a/. At point 25, which is the farthest point of measurement, it is interesting that we see the most affected are the short ones while the least affected are the long ones. That might be caused by the fact that the offset of the long vowels is further than the short ones from the emphatic consonants at the end of the word, so that is why they are less affected.

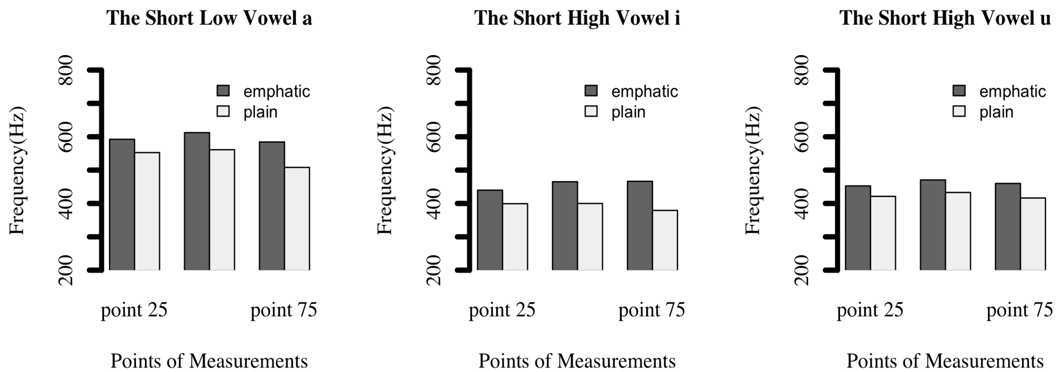


Figure 63: Bar plots illustrating different emphatic effect on short vowels based on their qualities at different vowel points of measurements

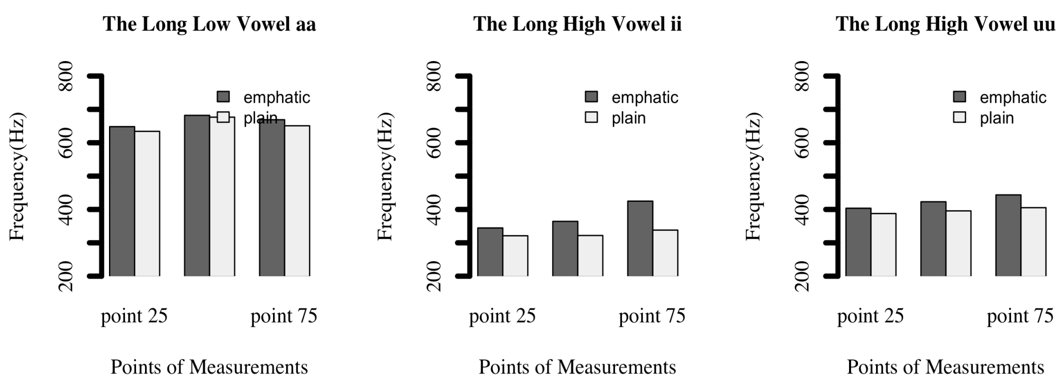


Figure 64: Bar plots illustrating different emphatic effect on long vowels based on their qualities at different vowel points of measurements.

2.4.9.2 Long Distance Raising Effect

With regard to the long-distance leftward effect of emphasis, I now consider the effect of emphatic consonants on the non- target vowel in the first syllable, which is always /a/. As shown in **Figure 65**, F1 of the non-target low vowel was most raised when the vowel in the final syllable was the low short vowel /a/ 25 Hz (540 Hz vs. 515 Hz). That was followed by the long low vowel /a:/ with a difference of 20 Hz (485 Hz vs. 465 Hz) and the short high vowel /i/ with a difference of 20 Hz (515 Hz vs. 495 Hz). Then, the long back vowel /u:/ came next with a difference of 15 Hz (475 Hz vs. 460 Hz). Finally, the low vowel /a/ was least affected when the vowels in the initial syllable were the short back vowel /u/ 10 Hz (530 Hz vs. 520 Hz) and long high vowel /i:/ 10 Hz (455 Hz vs. 445 Hz). So, by considering all vowels, it appears that the non-target vowel is most affected when the vowel in the target syllable are the low vowels /a/ and /a:/, in addition to the high vowel /i/.

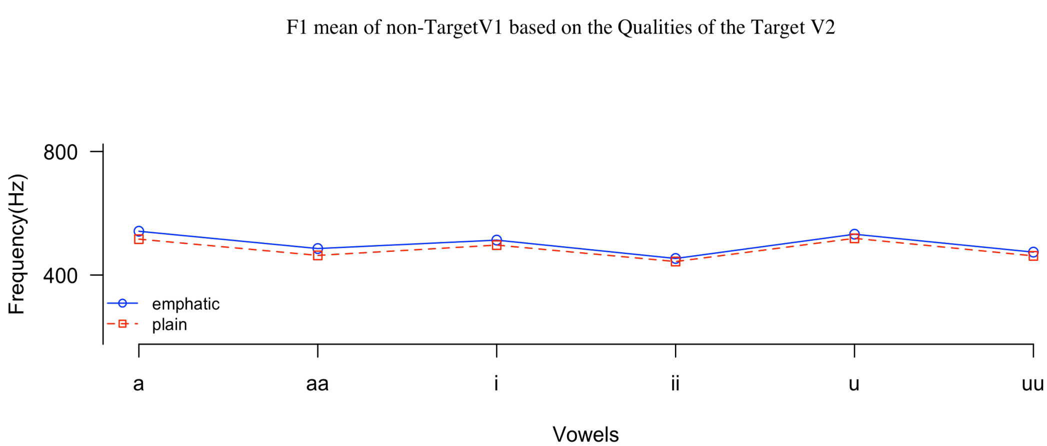


Figure 65: Line chart illustrating emphatic effect on non-target vowels based on the quality of the vowel in the target 2^{nd} syllable

Before doing the statistical analysis, this picture shows the effect of emphatics on the F1 of the all vowels combined. As in the case when emphatic consonant occurs word-initially, it shows the stronger effect on the adjacent syllable to the word-final emphatics. Moreover, it shows the gradient effect that strengthens as the emphatic consonant approached.

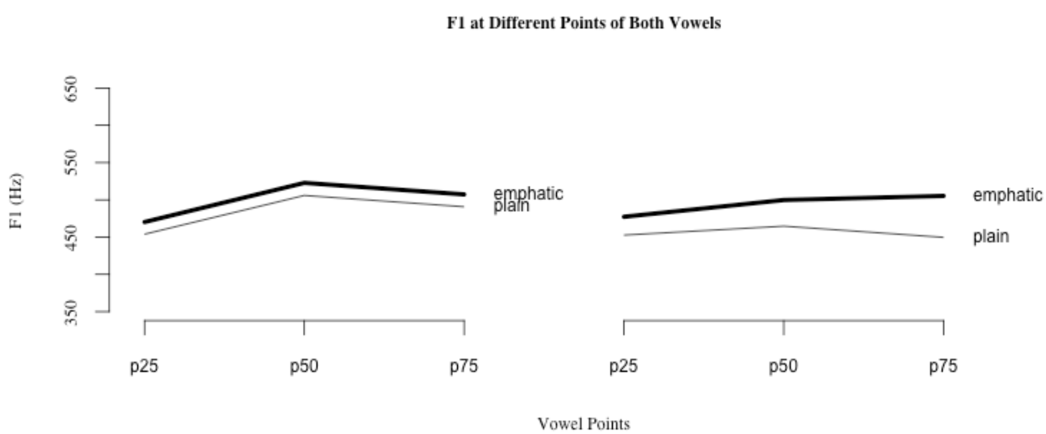


Figure 66: Line chart illustrating Degree of F1 increase in both syllables of words with final emphatics

2.4.10 Statistical Analysis

In order to examine the statistical significance of the final emphatic effect, mixed- effects linear regression models were fitted with F1 as the dependent variable. One model is fitted for testing the effect of emphatics on vowels in the target syllable and another one is fitted for those in the non-target one. Table **15** shows the results of the fitted model when target vowels in second syllables are adjacent to word-final emphatics.

Table 15: Regression model for the F1 of vowel in the target syllable

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	536	8	70.42	
c.C3	49	3	16.01	<.0001
c.V2a.vs.u	-143	3	-47.34	<.0001
c.lengthV2	68	3	24.15	<.0001
c.V2a.vs.i	-174	3	-57.59	<.0001
distance3	-5	2	-2.86	<.001
c.V2a.vs.u:c.lengthV2	-131	5	-25.99	<.0001
c.C3:c.V2a.vs.u	-13	5	-2.10	<.05
c.C3:c.lengthV2	-34	5	-7.22	<.0001
c.lengthV2:c.V2a.vs.i	-171	5	-33.90	<.0001
c.C3:c.V2a.vs.i	14	5	2.01	<.05
c.C3:distance3	-32	3	-10.72	<.0001
c.C3:c.V2a.vs.u:c.lengthV2	30	9	3.29	<.001
c.C3:c.lengthV2:c.V2a.vs.i	27	9	2.96	<.05

The results of this model in **Table 15** shows that F1 was significantly increased when vowels were followed by an emphatic consonant (t=16, p<.0001). Additionally, there was a significant interaction between the type of consonant and *distance*, so the further we move from the emphatic consonant, the weaker the effect gets on the vowel (t=-11, p<.0001). In addition, there was a significant interaction between the type of consonant and the difference between the low vowel /a/ and high back vowel /u/ (t=-2, p<.05). Alternatively, there is a difference between the low vowel /a/ and back vowel /u/ in emphatic environment. In addition, there was a significant interaction between the type of consonant and the difference between the low vowel /a/ and high front vowel /i/ ($t=2$, $p<.05$). Therefore, there is a difference between the low vowel /a/ and high vowel /i/ in emphatic environment. Furthermore, there was a significant interaction between the type of consonant and length of the vowels ($t=-7$ $p<.0001$). In other words, the presence of an emphatic has a significantly different effect on F1 depending on vowel length: the emphatic raises F1 significantly more in the presence of a short vowel, or equivalently, significantly less in the presence of a long vowel. These results also show that there was a significant three-way interaction between the type of consonant, the type of length and the vowel qualities /a/ vs. /i/. There is a significant difference between the F1 of long low vowel /a/ and long front vowel /i/ in emphatic environments ($t=2.96$, $p<.05$). Moreover, there was a significant three-way interaction between the type of consonant, the type of length and the vowel qualities /a/ vs. /u/. So, there is a significant difference between the F1 of long low vowel /a/ and long front vowel /i/ in emphatic environments ($t=3.29$, $p<.001$).

To see the effect of emphatics on the non-target syllable, we fitted a separate model as in **Table 16** below. This table shows the results of the fitted model when the vowels appear in the first syllables, which are not adjacent to emphatics in final positions.

Table 16: Regression model for the F1 of the vowel in the non-target syllable

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	511	8	60.73	
c.C3	23	2	11.11	<.0001
c.V2a.vs.u	-1	2	-0.51	=.61
c.lengthV2	-54	2	-28.46	<.0001
c.V2a.vs.i	-22	2	-10.75	<.0001
distance3	37	1	27.07	<.0001
c.V2a.vs.u:c.lengthV2	-4	3	-1.09	=.27
c.C3:c.V2a.vs.u	-12	4	-3.27	=.001
c.C3:c.lengthV2	-4	3	-1.04	=.30
c.lengthV2:c.V2a.vs.i	-1	3	-0.41	=.68
c.C3:c.V2a.vs.i	-10	4	-2.73	<.05
c.C3:distance3	0.27	2	0.11	=.91
c.C3:c.V2a.vs.u:c.lengthV2	2	6	0.37	=.71
c.C3:c.lengthV2:c.V2a.vs.i	-3	6	-0.46	=.64

The results of the above model in **Table 16** show that F1 of the preceding non-target syllable was significantly raised when vowels were followed by an emphatic consonant in the following syllable (t=–11, p<.0001). In addition, there was a significant interaction between the type of consonant and the difference between the low vowel /a/ and high back vowel /u/ in the following syllable (t=-3, p=.001). In other words, there is a difference between the emphatic effect on the vowel in the non-target syllable depending on which vowel is in the target syllable: low vowel /a/ or back vowel /u/. Also, there was a significant interaction between the type of consonant and the difference between the low vowel /a/ and high front vowel /i/ in the following syllable ($t=-3$, $p<.05$). In other words, there is a significant difference between the emphatic effect on the vowel in the non-target syllable depending on which vowel is in the target syllable: low vowel /a/ or high front vowel /i/.

2.5 Effect of stress on F2

It has noticed above that word-initial emphatics exert more effect than the word-final ones. As stated by Alammar (2015), one reason might be stress because when investigating word-initial emphatic effect, all adjacent vowels are stressed. In contrast, when emphatics appear word-finally, only half of the data items have stress on adjacent vowels due to how stress patterns in the language. To test the possible role of stress on the emphatic effect on the neighboring vowels, words with similar phonetic environments are tested. To do that, the difference between the F2 means of the stressed vowels in emphatic and plain environments is compared to that in which the vowels are unstressed after shifting stress to the second syllable by lengthening the syllable. As a reminder, to test the possible effect of initial emphatic consonants on the following vowel, words that start with emphatic consonants are used, e.g., /t^{ʕ}**a**bbad/. However, to test the effect of word-final emphatic consonants on the following vowel, words that have emphatic consonants word-medially are used, e.g., /b**a**t^{ʕ}t^{ʕ}ad/. So, the target vowel will always be the vowel in the first syllable. That was used to make it possible to shift stress while keeping the same phonetic environments the same.

As shown in **Figure 67**, when the target emphatic consonant is word-initial and stress is on the final syllable, the difference in F2 between the vowels in emphatic and plain environments in the first syllable is a little bigger with a difference of (500 Hz) [1590 Hz vs. 1090 Hz] compared to a difference of (480 Hz) [1600 Hz vs. 1120 Hz] when stress is on the initial syllable.

Mean F2 When Stress is initial vs. Final

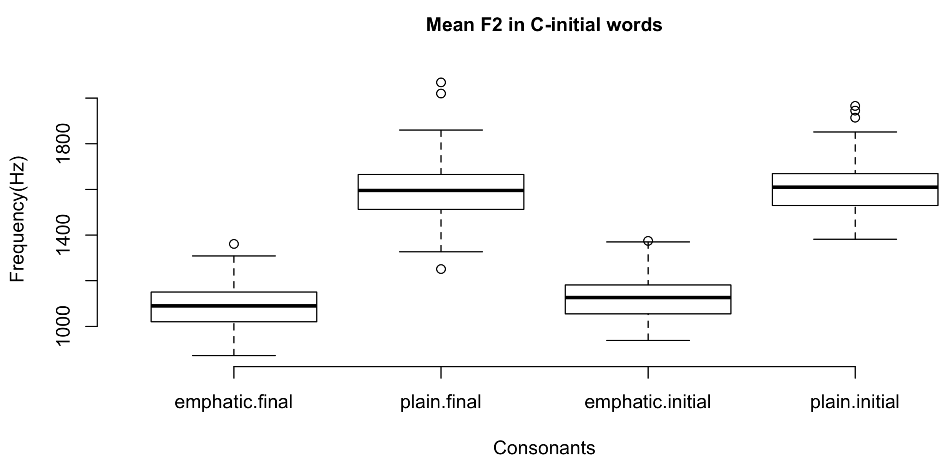


Figure 67: Box plots illustrating F2 depression when initial target vowel is stressed vs. unstressed in words with word-initial emphatics. Note: final=final stress; initial= initial stress

The same trend is also noticed when the target emphatic consonant occurs word-medially. As can be seen in **Figure 68**, the difference between plain and emphatic vowels in the first syllable is slightly larger with a difference of (540 Hz) [1650 Hz vs. 1110 Hz] when stress is on the final syllable. When stress is word-initial, the F2 difference in means between the vowels is (520 Hz) [1650 Hz vs. 1130 Hz].

Mean F2 When Stress is initial vs. Final

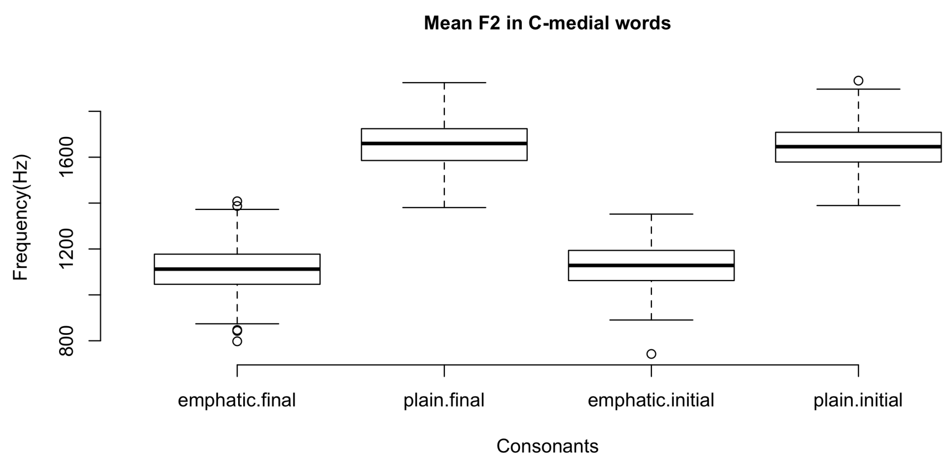


Figure 68: Box plots illustrating F2 depression when initial target vowel is stressed vs. unstressed in words with word-medial emphatics. Note: final=final stress; initial= initial stress

So, shifting stress does not help one emphatic effect over the other. In other words, regardless of the position of the emphatic consonant, the effect of stress is the same. If the vowel adjacent to word-final or word-initial emphatics is stressed, it will be slightly less affected than the unstressed one. So, shifting stress away makes the emphatic effect minimally greater on the adjacent vowel.

It is interesting to test the difference for the closest points to the emphatic consonant: point 25 when the target consonant is word-initial and point 75 when it is word-medial. By calculating the difference in F2 means between vowels in emphatic and plain environments, it appears that shifting stress to the final syllable makes the closest point to the word-initial consonant affected more. It can be seen in **Figure 69** that when stress is word-initial, the difference is (560 Hz) compared to a difference of (580 Hz) when stress is word-final.

Similarly, when the target consonant occurs word-medially, the F2 values of the closest point to the middle consonant are affected more when stress is on the final syllable with a difference of (600 Hz) [1690 Hz vs. 1090 Hz] compared to the words with initial stress (580 Hz) [1690 Hz vs. 1110 Hz].

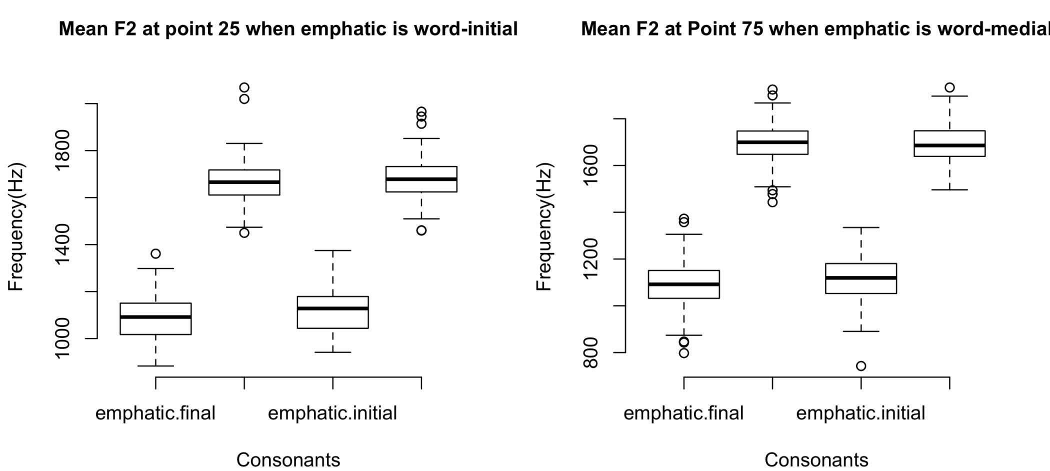


Figure 69: Box plots illustrating amount of F2 depression at closest point to emphatics when initial vowel is stressed vs. unstressed in words with word-initial emphatics. Note: final=final stress; initial= initial stress

By considering the effect of emphatics on target vowels over time, **Figure 70** shows that shifting stress on the final syllable results in bigger difference between plain and emphatic F2 values of vowels in all points of measurements. At point 25, the difference is (580 Hz) [1090 Hz vs.1670 Hz]; at point 50, the difference is (510 Hz) [1100 vs. 1610 Hz]; at point 75, the difference is (420 Hz) [1080 vs. 1500].

Having stress on the initial syllable, on the other hand, results in the following smaller F2 values for all points of measurement: at point 25, the difference is (560 Hz) [1120 vs.1680]; at point 50, the difference is (480 Hz) [1140 vs. 1620]; at point 75, the difference is (410 Hz) [1110 vs. 1520].

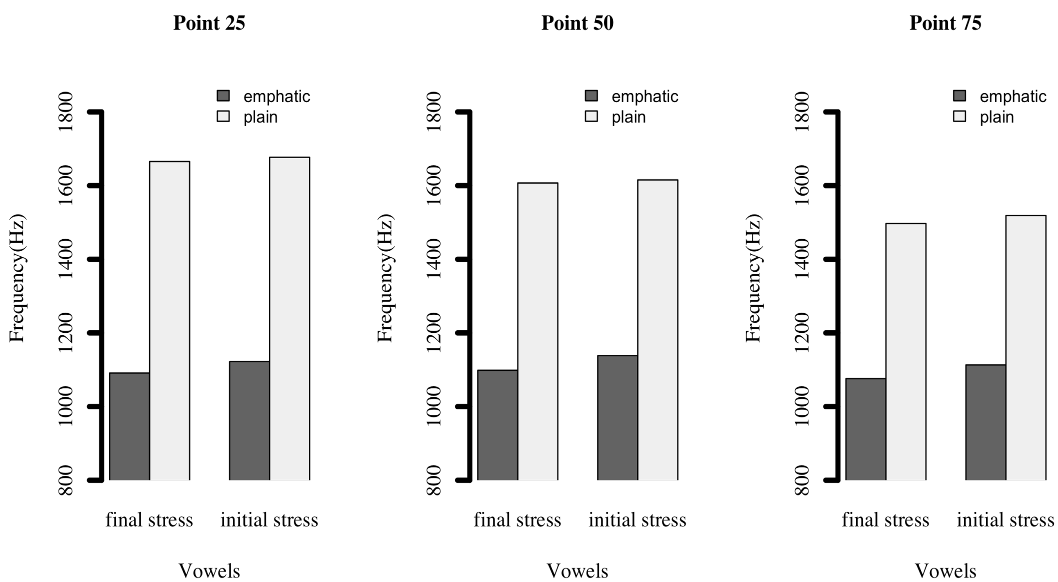


Figure 70: Bar plots illustrating the amount of F2 depression at different point of measurements when initial vowel is stressed vs. unstressed in words with word-initial emphatics.

Likewise, **Figure 71** shows that shifting stress to the final syllable results in the following minimal bigger differences between plain and emphatic F2 means at all points of measurement when emphatic words occurs word-medial as shown. At the closest point to the consonant, point 75, the difference is (600 Hz) [1090 vs. 1690]; at point 50, the difference is (540 Hz) [1120 vs. 1660]; at point 25, which is the farthest point, the difference is (470 Hz) [1130 vs. 1600].

However, having stress on the initial syllable results in the following smaller F2 values, compared to those when the vowel is not stressed above. At point 75, the difference is (580 Hz) [1110 vs. 1690]; at point 50, the difference is (520 Hz) [1140 vs. 1660; at point 25, the difference is (460 Hz) [1130 vs. 1590].

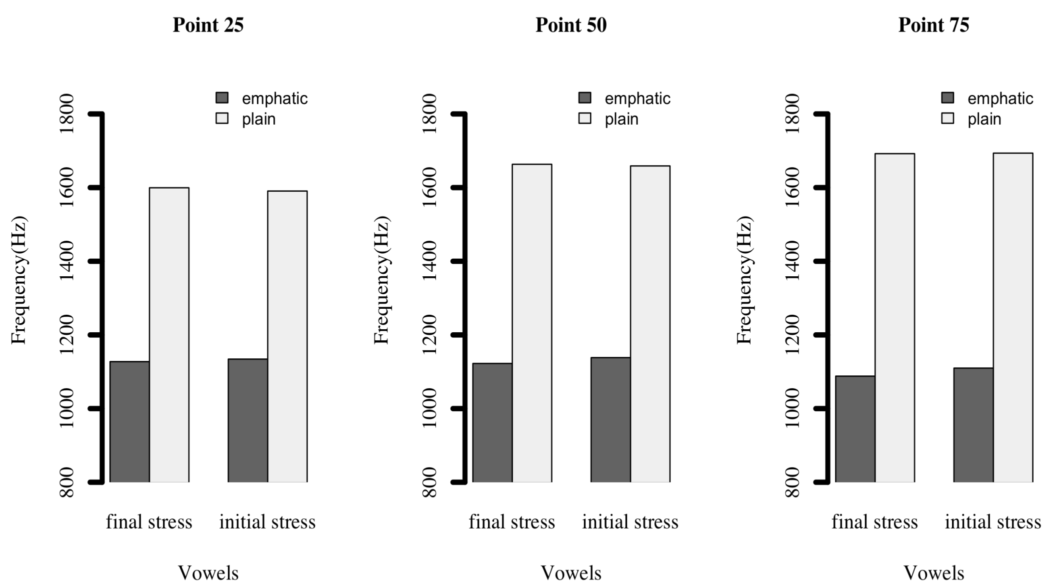


Figure 71: Bar plots illustrating the amount of F2 depression at different point of measurements when initial vowel is stressed vs. unstressed in words with word-medial emphatics.

In addition to the non-presence of stress effect, the stress data results show the same strong effect and gradiency shown by the main data on word-initial and word-final emphatic effect.

2.5.1 Statistical Analysis

To test the possible role of stress on the emphatic effect on the neighboring vowels when the emphatic consonant is word-initial, the following model was fitted with F2 as the dependent variable. **Table 17** shows the results of the fitted model when target vowels are in the first syllable immediately preceded by word-initial emphatics.

Table 17: Regression model for the effect of stress on vowel's F2 when target consonant is word-initial

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	1474	17	86.15	
c.C1	-490	28	-17.46	<.0001
Distance3	-126	10	-12.20	<.0001
c.lengthV2	19	24	-0.78	=.44
c.C1: distance3	151	6	24.08	<.0001
c.C1: c.lengthV2	-23	42	-0.54	=.59

The results of this model in **Table 17** above shows that, as expected and shown in the models fitted above, F2 was significantly lowered when vowels were preceded by an emphatic consonant ($t=-17$, $p<.0001$). In addition, there was a significant interaction between the type of consonant and *distance*, so the further we move from the emphatic consonant, the weaker the effect becomes on the vowel (t=24, p<.0001). However, there was not a significant interaction between the type of consonant and the length of the following vowel; in other words, shifting stress does not change F2 of the first vowel significantly (t=-0.54, p=.59).

To test the possible role of stress on the emphatic effect on the neighboring vowels when the emphatic consonant is word-medial, the following model fitted. **Table 18** shows the results of the fitted model when target vowels are in the first syllable immediately followed by word-medial emphatics.

Table 18: Regression model for the effect of stress on vowel's F2 when target consonant is word-medial

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	1517	17	87	
c.C1	-530	28	-19.09	<.0001
Distance3	-65	8	-8.08	<.0001
c.lengthV2	-0.7	18	-0.04	=.97
c.C1: distance3	-130	7	-18.87	<.0001
c.C1: c.lengthV2	-19	32	-0.58	=.56

The results of the above model shows that, as expected, F2 was significantly lowered when vowels were followed by an emphatic consonant (t=–19, p<.0001). In addition, there was a significant interaction between the type of consonant and *distance*, so the further we move from the emphatic consonant, the weaker the effect gets on the vowel (t=19, p<.0001). However, there was not a significant interaction between the type of consonant and the length of the following vowel; in other words, shifting stress does not change F2 of the first vowel significantly (t=-0.58, p<.56).

It is interesting to fit two models to see the difference for p25, which are the closest part to the target consonant when emphatics appear word-initially. **Table 19** shows the results of the fitted model when onset of the vowel, p25, is immediately preceded by word-initial emphatics.

Table 19: Regression model for the effect of stress on vowel's F2 at point 25 when target consonant is word-initial

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	1530	21	72.08	
c.C1	-564	29	-19.64	<.0001
c.lengthV2	-16	32	-0.51	=.61
c.C1: c.lengthV2	-20	57	-0.34	=.73

There was not a significant interaction between the type of consonant and the length of the following vowel. So, shifting stress does not change F2 of the first vowel's closest point significantly (t=-0.34, p<.0001).

Similarly, the following model is fitted to test if there is any significance difference effect of stress on the F2 values of p75 for C-medial data, which are the closest parts to the target medial consonant. **Table 20** shows the results of the fitted model when offset of the vowel, p75, is immediately followed by word-medial emphatics.

Table 20: Regression model for the effect of stress on vowel's F2 at point 75 when target consonant is word-medial

Predictor	β	$SE(\beta)$	t	p
(Intercept)	1544	23	68.33	
c.C1	-594	33	-17.87	<.0001
c.lengthV2	-6	37	-0.17	=.86
c.C1: c.lengthV2	-20	66	-0.31	=.76

By fitting this model it appears that there was not a significant interaction between the type of consonant and the length of the following vowel. Therefore, shifting stress does not change F2 of the first vowel's closest point, point 75, significantly (t=-0.31, p=.76).

2.6 Effect of Stress on F1

To test the possible role of stress on the emphatic raising effect on the neighboring vowels, words with similar phonetic environments are tested by measuring F1 of the vowels. Then, the difference between the means of the stressed vowels in emphatic and plain environments is compared to that in which the vowels are unstressed after shifting stress to the second syllable as explained above.

As for F1, **Figure 72** shows that when the target emphatic consonant occurs word-initially and stress falls on the first syllable, the difference in F1 means between emphatic and plain environments is 55 Hz [535 Hz vs. 590 Hz]. Likewise, when stress falls on the final syllable in word-initial emphatic consonants, the difference stays the same with a difference of 55 Hz [490 Hz vs. 545 Hz].

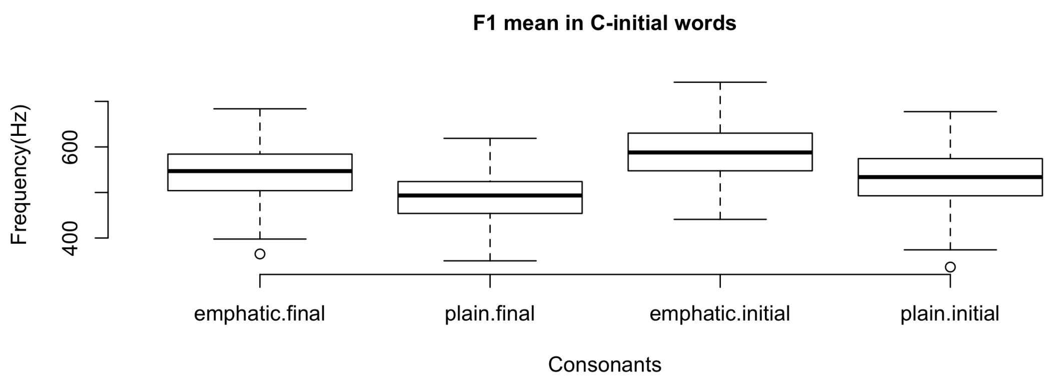


Figure 72: Box plots illustrating the amount of F1 increase when initial target vowel is stressed vs. unstressed in words with word-initial emphatics. Note: final=final stress; initial= initial stress

Moreover, when the target emphatic consonant occurs word-medially and stress falls on the first syllable, **Figure 73** shows that the difference in means between emphatic and plain environments is (65 Hz) [575 Hz vs. 510 Hz] compared to the cases when stress falls on the final syllable (65 Hz) [530 Hz vs. 465 Hz.

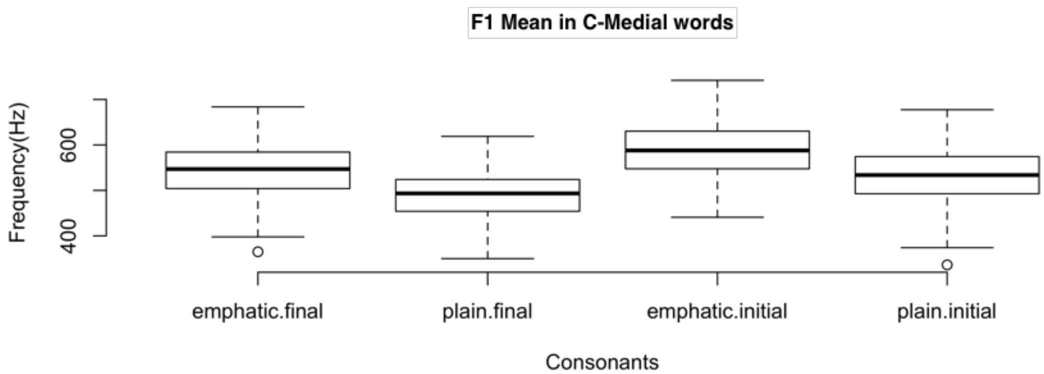


Figure 73: Box plots illustrating the amount of F1 increase when initial target vowel is stressed vs. unstressed in words with word-medial emphatics. Note: final=final stress; initial= initial stress

So, being stressed or unstressed shows almost no change to F1 values of the target vowels. Hence, it appears that stress does not alter the raising effect of emphatic consonants on F1 and F2 of neighboring vowels.

It is interesting to see the difference for p25 C-initial and p75 for C-medial data, which are the closest parts to the target consonants, to investigate any possible effect of stress on the values of emphatic of emphatics.

By measuring the difference in F1 means between vowels in emphatic and plain environments, it appears that by having stress on the final syllable or first syllable does not alter the effect of emphatics on the vowel, as shown in **Figure 74**. The F1 values of the closest point to the initial target syllable were affected with a difference of (70 Hz) [480 Hz vs. 550 Hz] in words with final stress. Equally, in words with initial stress, the difference was (70 Hz) [515 Hz vs. 585 Hz].

However, when the target consonant occurs word- medially, **Figure 74** shows the F1 values of the closest point to the middle consonant is affected slightly more when stress is on the first syllable with a difference of (75 Hz) [495 Hz vs. 570 Hz] compared to the words with final stress (70 Hz) [455 Hz vs. 525 Hz].

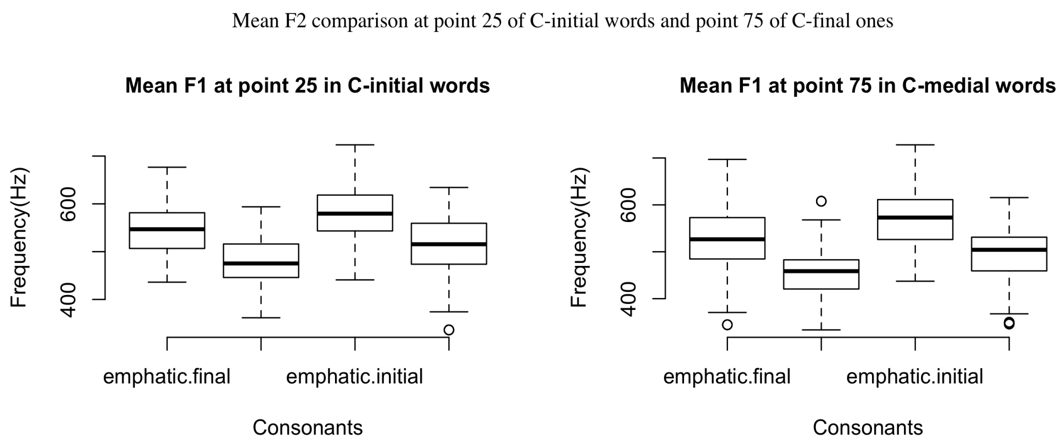


Figure 74: Box plots illustrating the amount of F1 increase at closest point to emphatics when initial vowel is stressed vs. unstressed in words with word-initial emphatics. Note: final=final stress; initial= initial stress

Since stress almost make no change to the effect of emphatics on the F1 values of the vowels, no need to test the vowels over time as done on the F2 values above.

2.6.1 Statistical Analysis

To test the possible role of stress on the emphatic effect on the neighboring vowels F1 values when the emphatic consonant is word- initial, the following model was fitted with F1 of the vowels as the dependent variable. **Table 21** shows the results of the fitted model when target vowels are in the first syllable immediately preceded by word-initial emphatics.

Table 21: Regression model for the effect of stress on vowel's F1 when target consonant is word-initial

Predictor	β	$SE(\beta)$	*t*	*p*
(Intercept)	525	11	45.96	
c.C1	57	10	6.01	<.0001
Distance3	-0.96	6	-0.17	=.87
c.lengthV2	-43	11	-4.19	<.0001
c.C1: distance3	-23	4	-5.63	<.0001
c.C1: c.lengthV2	-1	17	-0.05	=.96

The results of the model in **Table 21** shows that F1 was significantly raised when vowels were preceded by an emphatic consonant (t=6, p<.0001). In addition, there was a significant interaction between the type of consonant and *distance*. Therefore, the further we move from the emphatic consonant, the weaker the effect gets on the vowel (t=-6, p<.0001). However, there was not a significant interaction between the type of consonant and the length of the following vowel; in other words, shifting stress does not change F1 of the first vowel significantly (t=0.05, p=.96).

To test the possible role of stress on the emphatic effect on the neighboring vowels F1 values when the emphatic consonant is word-medial, another model was fitted. **Table 22** shows the results of the fitted model when target vowels are in the first syllable immediately followed by word-medial emphatics.

Table 22: Regression model for the effect of stress on vowel's F1 when target consonant is word-medial

Predictor	β	$SE(\beta)$	*t*	*p*
(Intercept)	506	12	43.87	
c.C1	65	10	6.67	<.0001
Distance3	-4	6	-0.64	=.52
c.lengthV2	-45	10	-4.45	<.0001
c.C1: distance3	14	4	3.74	<.05
c.C1: c.lengthV2	-2	16	-0.16	=.87

The results of the model in this table shows that F1 was significantly raised when vowels were followed by an emphatic consonant (t=7, p<.0001). In addition, there was a significant interaction between the type of consonant and *distance*, so the further we move from the emphatic consonant, the weaker the effect gets on the vowel (t=4, p<.05). However, there was not a significant interaction between the type of consonant and the length of the following vowel; in other words, shifting stress does not change F1 of the first vowel significantly (t=-0.16, p=.87).

It is interesting to fit two models to see the difference for p25 for C-initial data, which are the closest part to the target consonant. **Table 23** shows the results of the fitted model when onset of the vowel, p25, is immediately preceded by word-initial emphatics.

Table 23: Regression model for the effect of stress on vowel's F1 at point 25 when target consonant is word-initial

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	515	14	37.75	
c.C1	68	17	4.03	<.0001
c.lengthV2	-35	19	-1.83	=.66
c.C1: c.lengthV2	-1	34	-0.02	=.98

By looking at the results in this table, it appears that there was not a significant interaction between the type of consonant and the length of the following vowel. Shifting stress does not significantly change F1 values of the closest point of the first vowels (t=-1, p=.98).

Similarly, the following model is fitted to test if there is any significance difference effect of stress on the F1 values of p75 for C-medial data, which are the closest parts to the target medial consonant. **Table 24** shows the results of the fitted model when offset of the vowel, p75, is immediately followed by word-medial emphatics.

Table 24: Regression model for the effect of stress on vowel's F1 at point 75 when target consonant is word-medial

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	494	14	35.36	
c.C1	72	15	4.77	<.0001
c.lengthV2	-44	17	-2.61	<.05
c.C1: c.lengthV2	-5	30	-0.16	=.87

The results in this table shows that there was not a significant interaction between the type of consonant and the length of the following vowel. So, having stress on the initial or final syllable does not change F1 values of the first vowel's closest point, point 75, significantly (t=-0.16, p=.87).

2.7 Blocking of Emphatic Effect by High Consonants and Vowels

In addition to gradiency, non-presence of blocking has been used as an indication of whether emphatic in Zilfaawi Arabic is phonetic or phonological (Zawaydeh, 1999). Many authors reported that consonants with opposing phonological qualities block initial emphatic consonants effect from extending to non-target vowel (Ghazeli, 1977; Giannini and Pettorino (1982); Card, 1983; among others). Therefore, to see whether emphatic effect in Zilfaawi Arabic is phonetic or phonological by testing segmental blocking, a set of specific words is used, in which the middle consonant is one of the high segments /j, ʃ, dʒ, i:, u:/ and the vowel in both syllables is the low vowel /a/, such as /tˤaʃʃ**a**d/ vs. /taʃʃ**a**d/. Measuring the non-target low vowel in the following non-adjacent syllables resulted in different values based on the segment in the middle of the word.

2.7.1 Blocking of Lowering Effect by High Consonants

As seen in **Figure 75**, this figure shows that by measuring F2 values of the vowels in the following non-adjacent syllable in both plain and emphatics environments, F2 was most depressed when the middle consonant is the non-high consonant /b/ with a difference of (65 Hz) [1565 Hz vs. 1630 Hz]. When the middle consonant is the high semi-vowel /j/, the difference was (45 Hz) [1860 Hz vs. 1905 Hz]. Then, the difference in means between emphatic and plain vowels was (35 Hz) [1785 Hz vs. 1820 Hz] when the middle consonant was the high affricate consonant /dʒ/. Finally, F2 was least lowered when the middle consonant is the high fricative consonant /ʃ/ with a difference of 30 Hz [1725 Hz vs.1755 Hz].

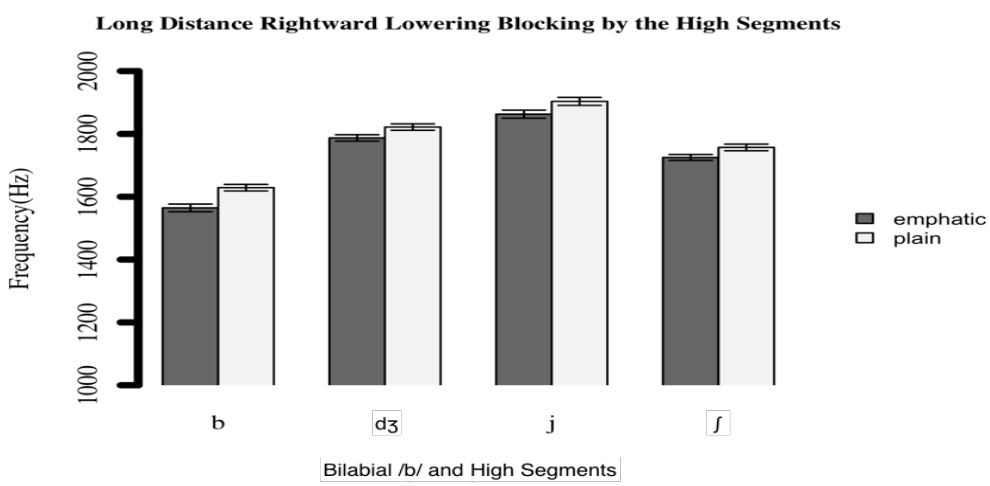


Figure 75: Bar plots illustrating possible blocking of initial emphatic effect on non-target vowels by high segments word-medially.

When the emphatic consonant is word-final, another set of words is tested in which the consonant in the middle is one of the high segments /j, ʃ, dʒ/ and the vowel in both syllables is the low vowel /a/, e.g., /d**a**ʃʃat^{ʕ}/ vs. /d**a**ʃʃat/. Based on the middle segment in the word, measuring the non-target low vowel in the syllable (first syllable) preceding the target second syllable resulted in different values. By calculating the F2 values of the vowels in both plain and emphatics environments, **Figure 76** illustrates that F2 was most depressed when the middle consonant is /b/ with a difference of (135 Hz) [1650 Hz vs. 1515 Hz]. Then, the difference in means between emphatic and plain vowels was (65 Hz) [1970 Hz-2035 Hz] when the middle consonant was the semi-vowel /j/. When the middle consonant is /dʒ/, the difference was (55 Hz) [1875 Hz-1820 Hz]. F2 values were least decreased when /ʃ/ appears as the middle consonant with a difference of (50 Hz) [1870 Hz-1820 Hz].

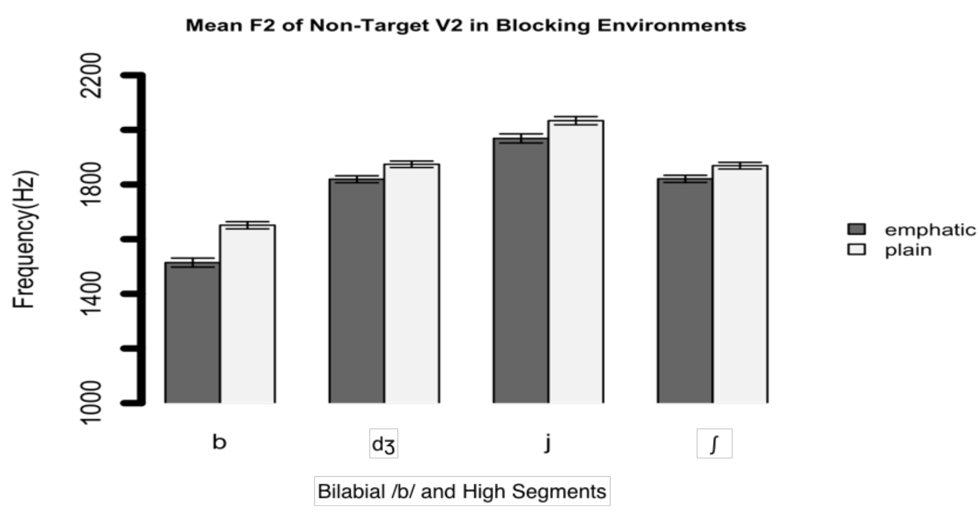


Figure 76: Bar plots illustrating possible blocking of final emphatic effect on non-target vowels by high segments word-medially.

It appears that the segments with opposing phonological qualities affects the extent and magnitude of the emphatic lowering effect on the non-target syllable when they show up as middle consonants. By considering both directions, this blocking was strongest with the consonant /ʃ/ and weakest with the semi-vowel /j/ as middle segments.

2.7.1.1 Statistical Analysis

To see if the high segments in the middle of the word would significantly block the effect of initial emphatic consonants, a regression model is fitted focusing only on the second syllable. **Table 25** shows the results of this model.

Table 25: Regression model for high segments blocking of the emphatic effect on F2 of non-target vowels when target consonant is word-initial

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	1681	27	63.04	
c.C1	-55	25	-2.20	=.037
c.b.vs.j.sh.g	-206	32	-6.48	<.0001
c.C1: c.b.vs.j.sh.g	-29	52	-0.55	=.58

The results of this model shows that F2 of the following non-target vowels was significantly lowered by having an emphatic consonant in the preceding syllable when the middle consonant is one of the high segments: j, sh, g (t=–2.2, p=.04). Moreover, the difference between F2 values of the non-target vowel when the middle consonant is /b/ or one of the high segments is not significant (t=–0.55, p=.58).

In addition, another model was fitted to see if the high segments would significantly block the emphatic lowering effect when emphatic consonants occur word-finally. **Table 26** displays the model's results with no significance difference between the medial non-high and high segments.

Table 26: Regression model for high segments blocking of the emphatic effect on F2 of non-target vowels when target consonant is word-final

Predictor	β	$SE(\beta)$	*t*	*p*
(Intercept)	1715	33	52.30	
c.C3	-110	40	-2.77	<.05
c.b.vs.j.sh.g	-295	37	-7.98	<.0001
c.C3: c.b.vs.j.sh.g	-81	66	-1.22	=.22

The results of this model shows that F2 of the preceding non-target vowels was significantly lowered as a result of having an emphatic consonant in the following syllable (t=–2.77, p<.05). However, the effect differences on the non-target vowels, whether the middle consonant is one of the high segments or /b/, is not significant (t=–1.22, p=.22).

2.7.2 Blocking of Lowering Effect by High Vowels

Because the vowels /i:/ and /u:/ are high segments too, they might block the emphatic effect when they appear between the emphatic consonant and the non-target vowel, e.g., /$t^ʕ$i:bb**a**d/. So, the following models are fitted for the initial emphatic effect and final emphatic effect to test if long high vowels would block the lowering effect from affecting the non-target vowels. The data used for this test is the set of words where the non-target vowels are /a/ while the vowels adjacent to the target emphatics consonants are either the long high vowel /i:/ or /u:/. The middle consonant is the bilabial consonant /b/, regardless of the position of the emphatic consonant.

2.7.2.1 Statistical Analysis

Let us start with the high vowel /i:/ when the emphatic consonants appear word-initially. One regression model is fitted to test whether the long high vowel /i:/ would block the emphatics from exerting some effect on the non-target vowel /a/ in the second syllable. **Table 27** shows the results of the fitted regression model.

Table 27: Regression model for long high vowel /i:/ blocking of the emphatic effect on F2 of non-target vowels when target consonant is word-initial

Predictor	β	$SE(\beta)$	t	p
(Intercept)	1657	19	85.80	
c.C1	-21	4	-5.38	<.0001
Distance3	-117	5	-25.88	<.0001
c.C1: distance3	-5	8	-0.56	=.58

These results of the fitted model shows that F2 of the following non-target syllable was significantly lowered when vowels were preceded by an emphatic consonant in the preceding syllable although the type of the vowel in the target syllable is the long high vowel /i:/ (t=–5.83, p<.0001).

Another model was fitted when the high vowel back vowel /u:/ appears in words with word-initial emphatic consonants. **Table 28** shows the results of the model.

Table 28: Regression model for long high back vowel /u:/ blocking of the emphatic effect on F2 of non-target vowels when target consonant is word-initial

Predictor	β	$SE(\beta)$	*t*	*p*
(Intercept)	1519	26	58	
c.C1	-29	5	-5.40	<.0001
Distance3	-272	6	-48.04	<.0001
c.C1: distance3	3	10	0.34	=.74

Similarly, the results of this fitted model in **Table 28** above shows that F2 of the following non-target syllable was significantly lowered when vowels were preceded by an emphatic consonant in the preceding syllable although the type of the vowel in the target syllable is /u:/ (t=–5.40, p<.0001).

Because high segments were reported to block emphatic effect caused by word-initial emphatics but not the word-final ones (Ghazeli, 1977, Card, 1983; among others). In Zilfaawi, no blocking when the high vowels intervene between the word-intial emphatics and non-adjacent vowels. The next step is test blocking by high vowels /i:/ and /u:/ in words with word-final emphatic consonants.

A regression model is fitted to test if the long high vowel /i:/ in the second syllable would block the emphatics effect on the non-target vowel /a/ in the first syllable. **Table 29** shows the results of the fitted regression model when emphatics appear word-finally.

Table 29: Regression model for long high vowel /i:/ blocking of the emphatic effect on F2 of non-target vowels when target consonant is word-final

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	1657	27	63.03	
c.C3	-46	9	-5.16	<.0001
Distance3	-180	18	-9.99	<.0001
c.C3: distance3	3	13	0.24	=.81

This fitted model's results show that F2 of the preceding non-target vowels were significantly lowered when they were followed by an emphatic consonant in the following syllable with a high vowel /i:/ in the target syllable (t=–5.16, p<.0001).

Another model was also fitted to test whether the high vowel back vowel /u:/ would significantly prevent the non-target vowel in the first syllable from being affected by word-final emphatics. **Table 30** shows the results of the fitted regression model.

Table 30: Regression model for long high back vowel /u:/ blocking of the emphatic effect on F2 of non-target vowels when target consonant is word-final

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	1547	16	96	
c.C3	-71	6	-11.72	<.0001
Distance3	-361	28	-12.69	<.0001
c.C3: distance3	-00.9	13	-0.001	=.99

The above fitted model's results in **Table 30** show that F2 of the preceding non-target syllable was significantly lowered when vowels were followed by an emphatic consonant in the following syllable although the type of the vowel in the target syllable is /u:/ (t=–12, p<.0001).

Therefore, the high long vowels, /i:/ and /u:/, do not block the emphatic lowering effect when they appear in the target syllables between the target consonant, word-initially or word-finally, and the vowels in the non-target syllables. This might help in deciding whether emphasis is actually phonetic or phonological in Zilfaawi Arabic.

2.8 Blocking of Raising Effect

In this section, the same set of words with high segments /j, ʃ, dʒ/ as middle consonants is used, e.g., /tˤaʃʃ**a**d/ vs. /taʃʃ**a**d/, to test possible blocking of high segments for emphatic F1 raising from extending to the non-target vowel in the non-adjacent syllable.

2.8.1 Blocking of Raising Effect by High Consonants

Based on the segments in the middle of the word, the following different values are obtained as shown in Figure 77 below. F1 was most raised when the middle consonant is /b/ with a difference of 10 Hz /510 Hz vs. 520 Hz/.

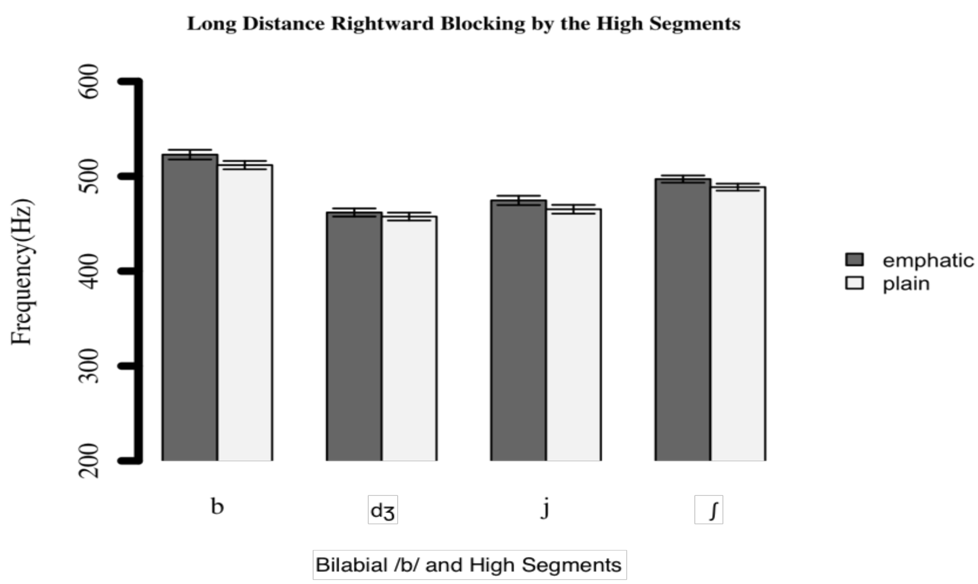


Figure 77: Bar plots illustrating possible blocking of initial emphatic effect, F1 increase, on non-target vowels by having high segments word-medially.

When the middle consonant is the high semi-vowel /j/, the difference was (10 Hz) [465 Hz vs. 475 Hz]. Then, the difference in means between the emphatic and the plain vowels was (5 Hz) [455 Hz vs. 460 Hz] when the middle consonant was the high affricate consonant /dʒ/. Likewise, F1 was raised with a difference of (5 Hz) [490 Hz vs. 495 Hz] when the middle consonant is the high fricative consonant /ʃ/.

When the emphatic consonant is word-final, the other set of words where the consonant in the middle is one of the high segments /j, ʃ, dʒ/ is tested, such as /d**a**ʃʃat[ʕ]/ vs. /d**a**ʃʃat/. Based on the middle segment in the word, measuring the non-target low vowel in the first syllable containing the non-target vowel resulted in different values.

As can be seen in **Figure 78**, F1 was most raised when the vowel in the final syllable was /a/ and the middle consonant is /b/ with a difference of 25 Hz [515 Hz vs. 540 Hz/. When the middle consonant is the high semi-vowel /j/, the difference was (15 Hz) [425 Hz vs. 440 Hz]. When the middle consonant was the high affricate consonant /dʒ/, the difference was (10 Hz) [445 Hz vs. 455 Hz]. F1 was least raised when the consonant is /ʃ/ with a difference of (5 Hz) [465 Hz vs. 470 Hz].

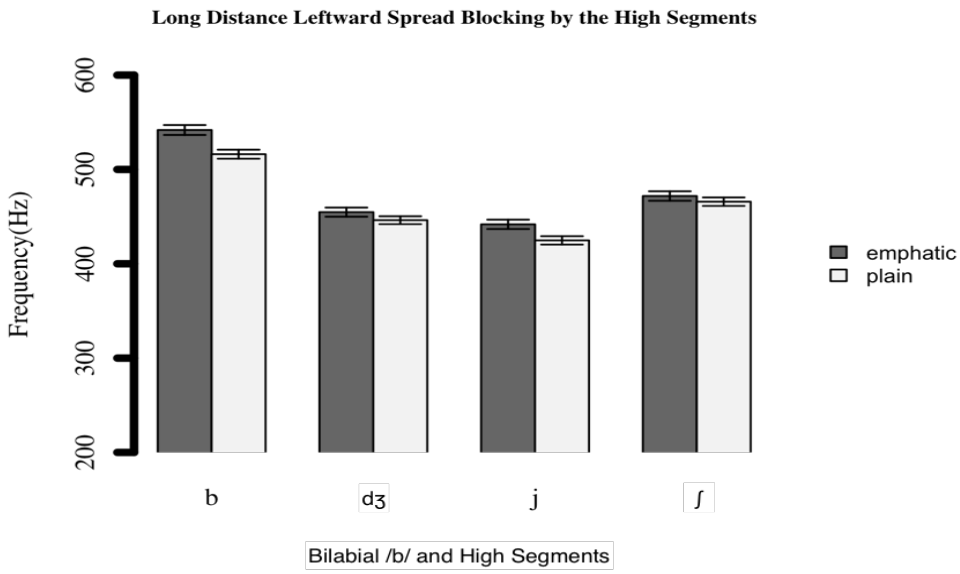


Figure 78: Bar plots illustrating possible blocking of final emphatic effect, F1 increase, on non-target vowels by having high segments word-medially.

Based on these values, it appears that the segments with opposing phonological qualities affects the extent and magnitude of the emphatic raising effect coming from word-final emphatics more than the one coming from initial emphatics. Moreover, this blocking coming from word-final emphatics was strongest with the consonant /ʃ/ and weakest with the semi-vowel /j/.

2.8.1.1 Statistical Analysis

To test if the high segments would significantly block the emphatic raising effect when emphatic consonants occur word-initially by having data with /a/ in both syllables and different segments in the middle, I fitted the following model focusing only on the second syllable. **Table 31** below shows the results of the fitted model.

Table 31: Regression model for high segments blocking of the emphatic effect on F1 of non-target vowels when target consonant is word-initial

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	500	9	58.29	
c.C1	10	8	1.29	=.20
c.b.vs.j.sh.g	42	9	4.82	<.0001
c.C1: c.b.vs.j.sh.g	4	13	0.29	=.77

The results of this fitted model show that F1 of the non-target vowels was not significantly raised when they were preceded by an emphatic consonant in the preceding syllable while of the middle consonant is one of the high segments: j, sh, g (t=–1.29, p=.20). Also, the difference between high segments and /b/ is not significant (t=0.29, p=.77)!

In addition, another model was fitted to see if the high segments would significantly block the emphatic raising effect when emphatic consonants occur word- finally. **Table 32** shows the results of the fitted regression model.

Table 32: Regression model for high segments blocking of the emphatic effect on F1 of non-target vowels when target consonant is word-final

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	498	10	55.42	
c.C3	21	8	2.43	<.05
c.b.vs.j.sh.g	74	8	9.43	<.0001
c.C3: c.b.vs.j.sh.g	15	14	1.07	=.28

This fitted model's results show that F1 of the preceding non-target syllable was significantly raised as a result of having a word-final emphatic consonants in the following syllable regardless of the type of the middle consonant: b, j, sh, or g ($t=2.43$, $p<.05$). However, the effect differences on the non-target vowels, whether the middle consonant is one of the high segments or /b/, is not significant ($t=1.07$, $p=.28$).

2.8.2 Blocking of Raising Effect by High Vowels

To test the significance of raising effect on the non-target vowel when the target vowel is either /i:/ or /u:/, the following models are fitted. One model is fitted test the significance when the emphatic consonant is word-initial and another when the emphatic consonant is word-final. That is done to test if high vowel /i:/ or /u:/ would block the raising effect from affecting the non-target vowels. The same set of data used for lowering effect test above is reused in these models.

2.8.2.1 Statistical Analysis

Let us start with the high vowels /i:/ and /u:/ when the emphatic consonants appear word-initially. First, the following regression model is fitted to test whether the long high vowel /i:/ would block the emphatics from exerting raising effect on the non-target vowel /a/ in the second syllable. **Table 33** shows the results of the fitted regression model with F1 as the dependent variable.

Table 33: Regression model for long high vowel /i:/ blocking of the emphatic effect on F2 of non-target vowels when target consonant is word-initial

Predictor	β	$SE(\beta)$	t	p
(Intercept)	504	10	51.82	
c.C1	10	2	4.74	<.0001
Distance3	45	3	15.99	<.0001
c.C1: distance3	5	5	1.08	=.28

The results in this table show that F1 of the following non-target syllable was significantly raised when vowels were preceded by an emphatic consonant in the preceded syllable although the type of the vowel in the target syllable was /i:/ ($t=5$, $p<.0001$).

Another regression model was fitted when the high back vowel /u:/ appears in words with word-initial emphatic consonants. **Table 34** shows the results of the fitted regression model with F1 as the dependent variable.

Table 34: Regression model for long high back vowel /u:/ blocking of the emphatic effect on F1 of non-target vowels when target consonant is word-initial

Predictor	β	$SE(\beta)$	*t*	*p*
(Intercept)	522	10	52.98	
c.C1	7	2	3.23	<.05
Distance3	56	3	18.70	<.0001
c.C1: distance3	4	5	0.75	=.46

The results in this table shows that F1 of the following non-target syllable was significantly raised when vowels were preceded by an emphatic consonant in the preceding syllable although the type of the vowel in the target syllable was /u:/ (t=3, p<.05).

Therefore, the high vowels do not block emphatic effect on the non-target vowel when they appear in the target syllables.

Now, let us test the significant effect of the high vowels, /i:/ and /u:/, when emphatic consonants appear word-finally. A regression model is fitted to test if the long high vowel /i:/ in the second syllable would block the emphatics raising effect on the non-target vowel /a/ in the first syllable. **Table 35** shows the results of the fitted regression model when emphatics appear word-finally.

Table 35: Regression model for long high vowel /i:/ blocking of the emphatic effect on F1 of non-target vowels when target consonant is word-final

Predictor	β	$SE(\beta)$	*t*	*p*
(Intercept)	446	9	49.51	
c.C3	10	3	3.42	<.001
Distance3	22	8	2.97	<.05
c.C3: distance3	5	5	1.06	=.28

Here, the results show that F1 of the preceding non-target syllable was significantly raised when vowels were followed by an emphatic consonant in the following syllable although the type of the vowel in the target syllable was /i:/ ($t=3$, $p<.001$).

Another model was also fitted to test whether the high vowel back vowel /u:/ would significantly prevent the non-target vowel in the first syllable from being affected by word-final emphatics. **Table 36** shows the results of the fitted regression model.

Table 36: Regression model for long high back vowel /u:/ blocking of the emphatic effect on F1 of non-target vowels when target consonant is word-final

Predictor	β	$SE(\beta)$	*t*	*p*
(Intercept)	465	9	49.33	
c.C3	12	2	5.73	<.0001
Distance3	17	8	2.15	<.05
c.C3: distance3	-4	5	-0.89	=.37

By looking at these results, it appears that F1 of the preceding non-target syllable was significantly raised when vowels were followed by an emphatic consonant in the following syllable although the type of the vowel in the target syllable was /u:/ (t=6, p<.0001).

Therefore, the high vowels do not block when they appear in the target syllables. Similar to the results obtained by fitting the models for F2, the high long vowels, /i:/ and /u:/, do not block the emphatic raising effect when they appear in the target syllables regardless of their position in the word.

2.9 Emphatic Effect across Morpheme Boundaries

It has been reported that affixes do not always undergo the same process that their roots undergo (Rose & Walker, 2011). As the final indicator used in this dissertation, if affixes in Zilfaawi Arabic show the same behavior and they are not affected, this might give us an indication that the emphatic effect is phonological and not phonetic. In this section, I will investigate the effect of emphatics on vowels of affixes, which are part of the real words, xas^{ʕ}s^{ʕ}-at 'she specified' and /a-s^{ʕ}idlih/ 'I look away for him'. In these words, the emphatic consonant occurs stem-initially or stem-finally and the possible affix occurs as a prefix or suffix.

As a reminder, the affix vowel is always /a/ regardless of whether the emphatic consonant is word-final or word-initial. F1 and F2 of affixes' vowels adjacent to emphatic consonants are measured and compared to the vowels in the words in which they have the emphatic consonant's counterpart and to words with no morpheme boundaries, for example /**a**-**s**idlih/ 'I look away for him' vs. /**a**-**s**ˤidlih/ 'I look away' vs. /**as**ˤi:lih/ 'genuine, fem'.

2.9.1 Leftward Lowering Effect on Prefixes

Overall, emphatics exert some influence on the vowels of the prefix across morpheme boundaries. As shown in **Figure 79**, the presence of the stem-initial emphatic consonant lowered F2 of the prefix's vowel by an average of (350 Hz) [1690 Hz vs. 1340 Hz].

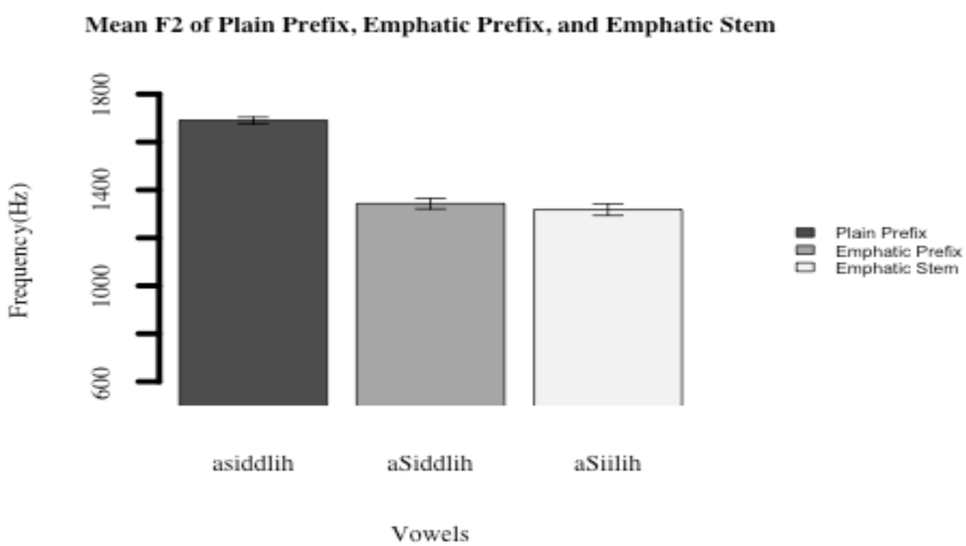


Figure 79: Bar plots illustrating the effect of emphatics on vowels of prefixes, F2 decrease, by comparing them to their plain counterparts and those of the stem. *Note: the symbol corresponds to the IPA symbol /sˤ/.*

When comparing the vowels of the prefix and the stem, no major difference was noticed. The stem's vowel was affected slightly more with a difference of (20 Hz) [1340 Hz vs. 1320 Hz].

As reported previously in the discussion of the stems vowels, the effect of the emphatic consonant on the target vowel in the prefix decreased with distance after measuring all three points of the vowel. **Figure 80** shows that F2 was lowered by 420 Hz [1680 Hz versus 1260 Hz] on the closest point to the emphatic consonant, which is p75. The effect decreased gradually with a difference of 350 Hz [1690 Hz vs. 1340 Hz] at the midpoint of the vowel, and with a difference of 280 Hz [1710 Hz vs. 1430 Hz] at the farthest point of measurement. The difference between the stem and the prefix is maintained throughout the points by a difference of 30 Hz at the closest and midpoints of the vowels, and by a difference of 20 Hz at the farthest point of measurement.

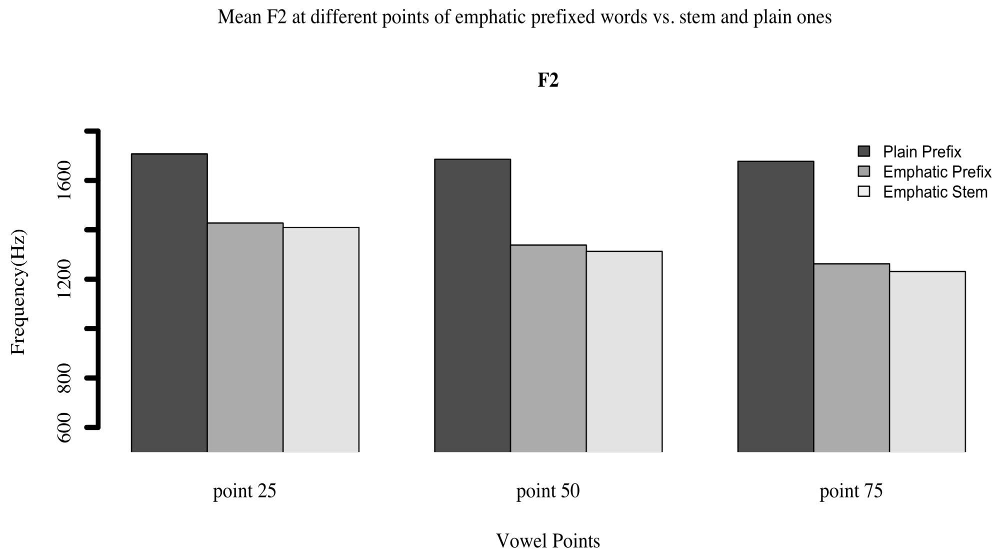


Figure 80: Bar plots displaying the lowering effect of emphatics on vowels of prefixes at different points of measurement

2.9.2 Rightward Lowering Effect on Suffixes

Similarly, emphatics affect the vowel of the suffix across the morpheme boundaries by reducing its F2 values. The presence of the stem-initial emphatic consonant lowered F2 of the suffix's vowel by an average of (340 Hz) [1620 Hz vs. 1280 Hz], as can be seen in **Figure 81** below.

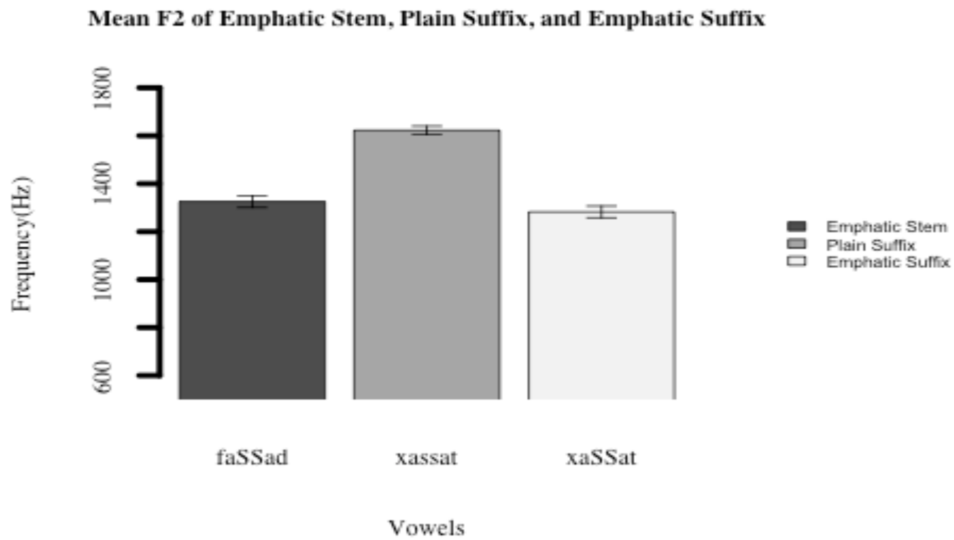


Figure 81: Bar plots illustrating the effect of emphatics on vowels of suffixes, F2 decrease, by comparing them to their plain counterparts and those of the stem. *Note: the symbol corresponds to the IPA symbol /sˤ/*

Unlike the vowels in prefixes and stems, the suffix's vowel is affected more than is the stem's by the presence of emphatics, with a difference of 50 Hz (1330 Hz vs. 1280 Hz).

Considering all points of measurement, **Figure 82** illustrates that the effect of the emphatic consonant on the target vowel in the suffixed word also decreased with distance: For those closest to the emphatic consonant (p25), F2 was lowered by a difference of 450 Hz (1600 Hz vs. 1150 Hz) and the effect decreased gradually going through the midpoint by a difference of 340 Hz (1610 Hz vs.

1270 Hz) and down to a difference of 230 Hz (1650 Hz vs. 1420 Hz) at the farthest point of measurement.

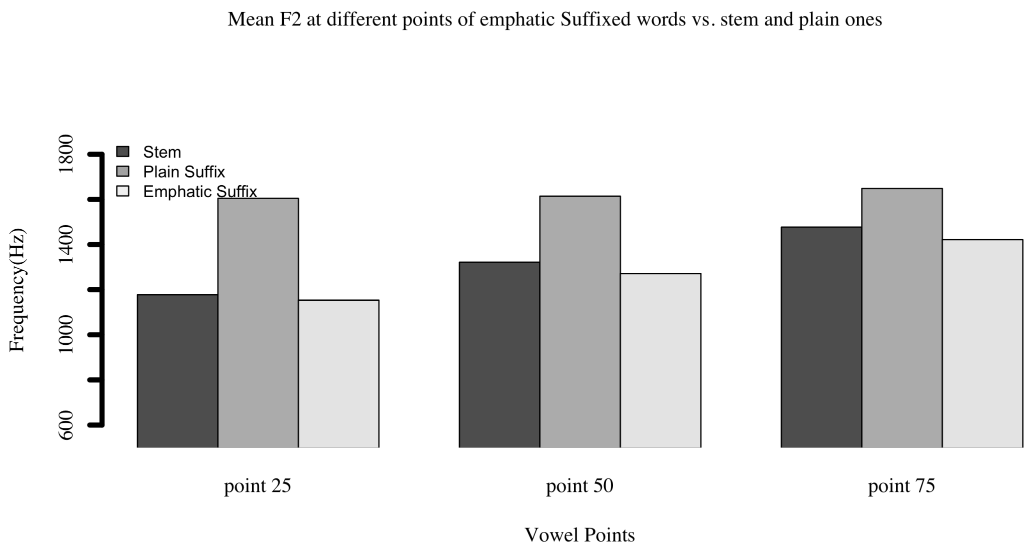


Figure 82: Bar plots shows the measurement of the effect of emphatics, F2 decrease, on vowels in suffixes over time.

The difference between the stem and the suffix is maintained throughout all points with a difference of 30 Hz at the closest point of the vowel, 50 Hz at the midpoint, and 60 Hz at the furthest point of measurement.

It seems that emphatic consonants exert very close amount of effect on affixes' vowels, whether they are prefixes or suffixes. The absence of plain affixes in emphatic environments might indicate that the effect of emphatics is not phonological as reported in some other dialects in which the emphatic effect is phonological (Younes, 1993; Zawaydeh, 1999). Looking at the vowels of both prefixes and suffixes, they show the same gradient trend shown by the lowered stem's vowel in the sections above. However, when comparing the vowel of the affix to that of the stem, the vowel of the stem is affected more than is the prefix, while the suffix's vowel is affected more than is the stem.

2.9.3 Statistical Analysis

A regression model is fitted to test whether the presence of the stem-initial emphatic consonant significantly lowered F2 of the prefix's vowel or not. Furthermore, a comparison was made between the difference of the stem's vowel and that of the prefix. **Table 37** below shows the results of this fitted model.

Table 37: Regression model for the emphatic effect on the vowel's prefix vowels

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	1520	33	45.54	
c.C1	-379	59	-6.43	<.0001
c.affix.vs.stem	-7	55	-0.13	=.90
distance3	-97	12	-7.79	<.0001
c.C1:c.affix.vs.stem	63	110	0.58	=.56
c.C1:distance3	-151	13	-11.94	<.0001

By looking at the results in this table, they show that the presence of an emphatic consonant lowered F2 of the prefix's vowel across the morpheme boundaries significantly (t=-6, p<.0001). In addition, there was a significant interaction between the type of consonant and *distance*, namely that the further we move from the emphatic consonant, the weaker the effect gets on the vowel (t=12, p<.0001). However, there was not a significant difference based on whether the vowels are part of a stem or of a prefix (t=0.58, p=.56).

What about when the vowel is part of the suffix? To test whether the presence of the stem-initial emphatic consonant lowered the F2 of the suffix's vowel significantly and to test the significance of the difference between the stem's vowel and the suffix's one, the following model is fitted and the results are shown in **Table 38**.

Table 38: Regression model for the emphatic effect on the vowel's suffix vowels

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	1470	29	50.42	
c.C2	-331	53	-6.27	<.0001
c.affix.vs.stem	34	48	-0.71	=.48
distance3	-165	9	-18.83	<.0001
c.C2:c.affix.vs.stem	18	96	0.19	=.85
c.C2:distance3	-238	20	-12.21	<.0001

As expected, emphatics decreased the F2 values of the vowel of the suffix across the morpheme boundaries significantly (t=-6, p<.0001). In addition, there was a significant interaction between the type of consonant and *distance*, namely that the effect gets weaker on the vowel, the further we move from the emphatic consonant (t=12, p<.0001). However, there was not a significant difference based on whether the vowel was part of a stem or of a suffix (t=0.19, p=.85).

2.9.4 Leftward Raising Effect on Prefixes

Overall, emphatic consonants affect the vowel of the prefix across the morpheme boundary. As shown in **Figure 83**, the presence of the stem-initial emphatic consonant raised the F1 of the prefix's vowel by an average of 65 Hz [460 Hz vs. 525 Hz].

Nonetheless, no major difference was noticed between the raising effect of the vowels in the stem and those that were part of the prefix. The stem's vowels were affected slightly more, with a difference of 15 Hz [525 Hz vs. 540 Hz].

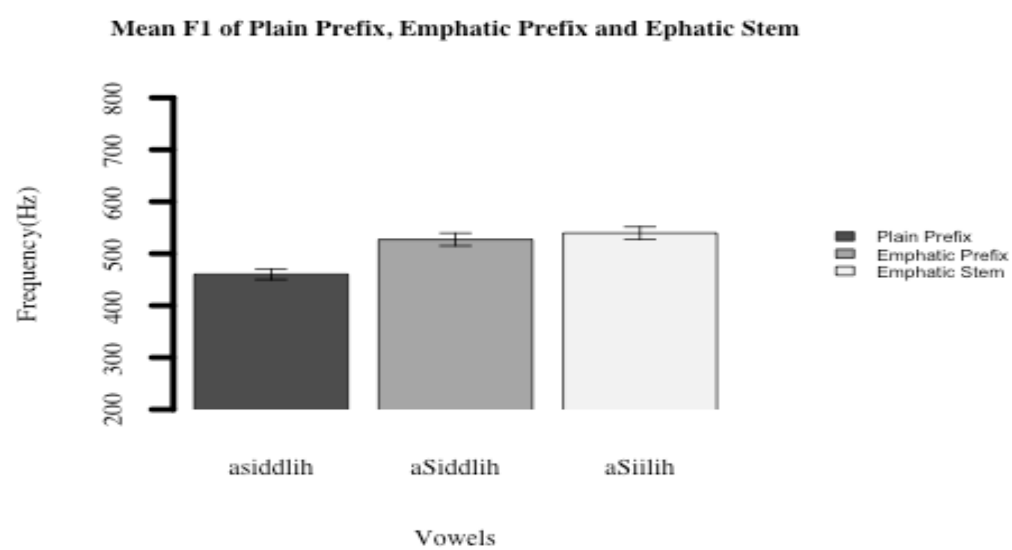


Figure 83: Bar plots illustrating the effect of emphatics on vowels of prefixes, F1 increase, by comparing them to their plain counterparts and those of the stem. *Note: the symbol corresponds to the IPA symbol /sˤ/.*

As can be seen in **Figure 84** below, when measuring all measurement points of the vowels, the effect of the emphatic consonant on the target vowel in the prefixed word decreased with distance. The F1 was raised by a difference of 75 Hz (445 Hz vs. 520 Hz) at the closest point to the emphatic consonant (p75). The effect decreased gradually going through the midpoint by a difference of 65 Hz (475 Hz vs. 540 Hz), and down to a difference of 60 Hz (460 Hz vs. 520 Hz) at the farthest point of measurement.

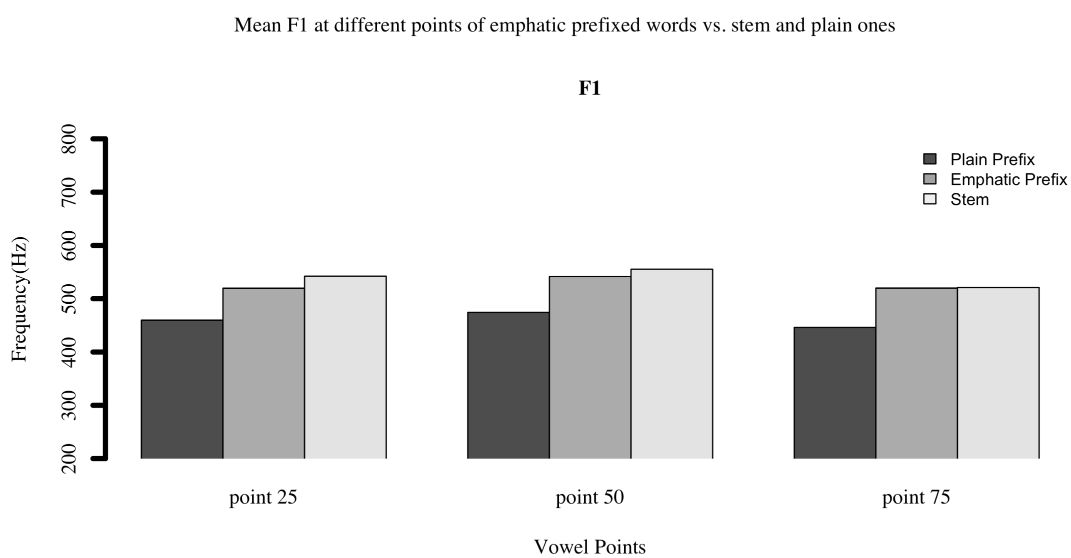


Figure 84: Bar plots illustrating measurement of the effect of emphatics, F1 increase, on vowels of prefixes over time.

The difference between the stem and prefix is maintained throughout the points by a difference of (20 Hz) at the closest point (p75) and (15 Hz) at the midpoint of the vowels and (1Hz) at the farthest point of measurement (The stem's vowel is higher).

2.9.5 Rightward Raising Effect on Suffixes

Similarly, **Figure 85** shows that emphatics influence the vowel in the suffix across the morpheme boundaries. Thus, the presence of the stem-final emphatic consonant raised the F1 of the suffixes' vowel by an average of 35 Hz [540 Hz vs. 575 Hz].

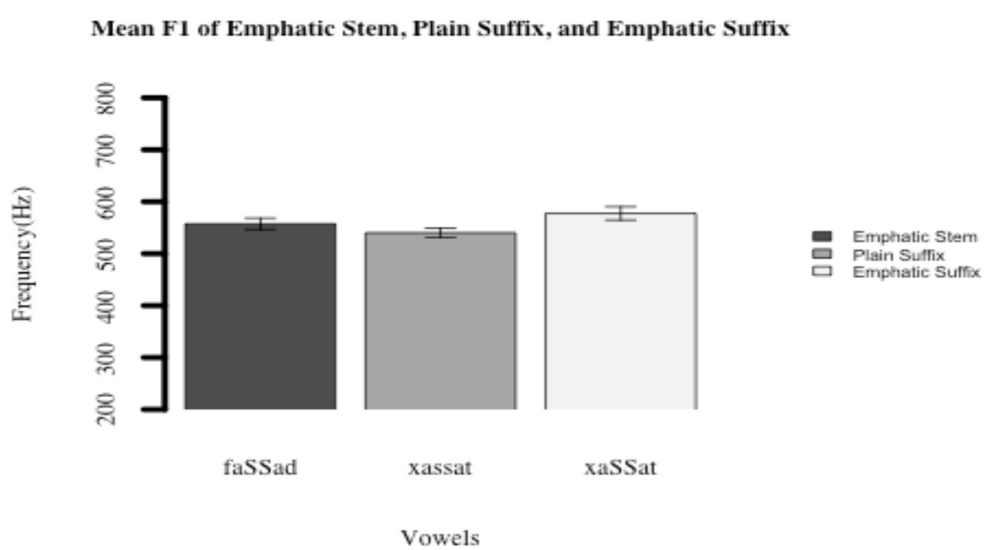


Figure 85: Bar plots illustrating the effect of emphatics on vowels of suffixes, F1 increase, by comparing them to their plain counterparts and those of the stem. *Note: the symbol corresponds to the IPA symbol /s^{ʕ}/.*

When the emphatic consonant and the vowel are within the same stem, the emphatic raising effect on both vowels is close. However, the suffix's vowel is affected more with a difference of 20 Hz (575 Hz vs. 555 Hz).

As shown in **Figure 86**, the effect of the emphatic consonant on the target vowel of the suffix diminished with distance: For those closest to the emphatic consonant (p25), F1 was raised by a difference of 50 Hz (535 Hz vs. 585 Hz) and the effect decreased gradually by going through the midpoint by a difference of 35 Hz (565 Hz vs. 600 Hz) and down to a difference of 30 Hz (520 Hz vs. 550 Hz) at the farthest point of measurement.

The difference between the stem and the suffix was maintained throughout the points too by a difference of (10 Hz) at the closest point (p25), a difference of (25 Hz) at the mid point of the vowels and a difference of (25 Hz) at the farthest point of measurement.

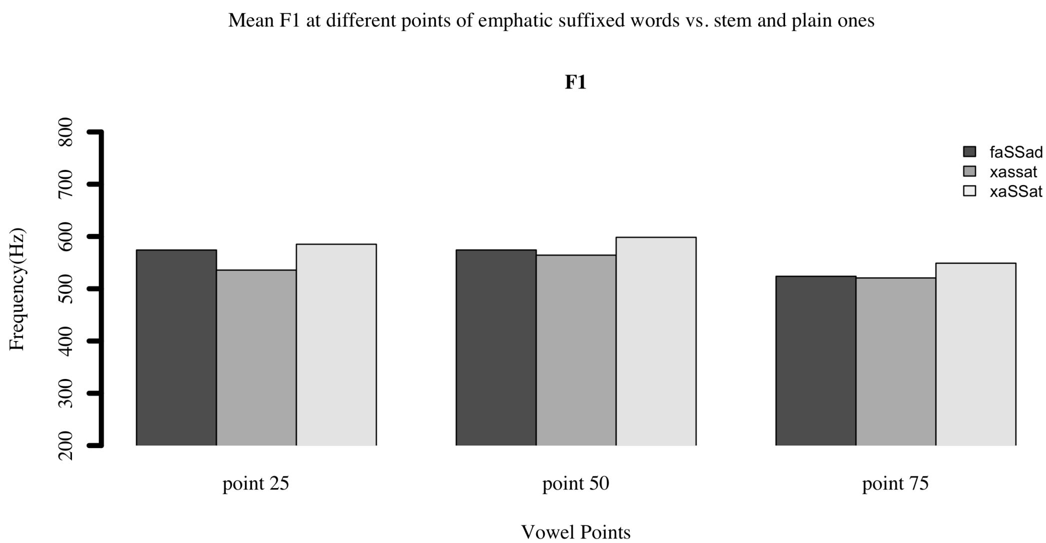


Figure 86: Bar plots illustrating the measurement of the effect of emphatics, F1 increase, on vowels of suffixes over time.

It seems that emphatic consonants affect the prefix's vowels more than they do those of the suffix. The vowels in both prefixes and suffixes show the same trend of gradiency. However, when comparing the vowel in the affix to that in the stem, the vowel in the stem is affected more than is that in the prefix, while the suffix's vowel is affected more than is the stem's vowel.

2.9.6 Statistical Analysis

To test whether the presence of the stem-initial emphatic consonant raised the F1 of the prefix's vowel significantly and to compare this to the stem's vowel, a regression model is fitted. The results of this model are presented in **Table 39**.

Table 39: Regression model for the emphatic effect on the F1 values of the prefix vowel

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	494	27	18	
c.C1	78	47	1.7	=.09
c.affix.vs.stem	-3	47	-0.06	=.95
distance3	-15	7	-2.0	<.05
c.C1:c.affix.vs.stem	-19	94	-0.21	=.83
c.C1:distance3	9	9	1.0	=.31

As shown in this table, the presence of the emphatic consonant raised the F1 of the prefix's vowel across the morpheme boundaries (t=1.7, p=.09). However, this raising is close but not significant. In addition, there was no significant difference regardless of whether the vowels were part of a stem or of a prefix (t=1, p=.31).

What if the vowel is a suffix's vowel rather than a prefix's vowel? To test whether the presence of the stem-initial emphatic consonant raised the F1 of the suffix's vowel significantly and to compare this to the stem's vowel, another model is fitted. **Table 40** shows the results of this regression model.

Table 40: Regression model for the emphatic effect on the F1 of the prefix's vowel

Predictor	*β*	*SE(β)*	*t*	*p*
(Intercept)	546	23	24	
c.C2	42	39	1.07	=.29
c.affix.vs.stem	-25	39	-0.64	=.52
distance3	35	6	5.62	<.0001
c.C2:c.affix.vs.stem	9	78	0.12	=.90
c.C2:distance3	17	8	2.03	<.05

The table illustrates that emphatic consonants do not raise the F1 values of the prefix's vowel across the morpheme boundaries significantly (t=1.07, p=.09). Moreover, there was not a significant difference based on whether the vowels were part of a stem or of a prefix (t= 0.12, p=.90). A significant result is obtained due to the interaction between the type of consonant and *distance* (t=2.03, p<.05).

Having presented the results of the acoustic results in detail, it is now time to combine them and to discuss the significant findings to answer the research questions of this dissertation with some reference to the relevant literature.

2.10 Discussion

The results of the present study revealed several major findings and answers to the questions in this dissertation. First, the results of the acoustic study showed that vowels in the vicinity of emphatics in Zilfaawi Arabic are acoustically distinct from vowels in the vicinity of the plain counterparts. The results indicated that the main acoustic correlates of emphatics are a drop in the F2 and a rise in the F1 of both target and non-target vowels when emphatics occur in word-initial and word-final positions. These findings are supported by previous studies on other Arabic dialects that reported significant F1 raising and F2 lowering on vowels neighboring emphatic consonants (Giannini & Pettorino, 1982; Khattab et al., 2006; Al- Masri, 2009; Shar and Ingram, 2010; Hassan and Esling, 2011; among others). F1 values increase and F2 values decrease in all measurement positions of both target and non-target vowels in Zilfaawi, in contrast to some studies that reported the emphatic effect in some but not all measurement positions (Al-Masri, 2009). Al-Masri (2009) showed that the F2 was lowered significantly only at the onset position of the target vowel when the target consonant was word-initial, and in all vowel positions when the target consonant was word-final.

Unlike some of the previous studies, which failed to find or did not report a significantly increased F1 (Al-Ani, 1970) for Standard Arabic, (Card, 1983), for Palestinian Arabic (Wahba, 1993), or for Alexandrian Arabic), the findings of the present study reported an increase in the F1 in the vicinity of emphatic consonants in word-initial and word-final positions. Al-Masri (2009) found more consistent F1 effects in Jordanian. In fact, his study showed that, in disyllabic words with final target consonants, the F1 was significantly raised in all measurement positions of the target vowel and in the vowel in the preceding syllable (except at the midpoint). In the present study, the F1 increased in both target and non-target syllables significantly when the target consonant was word-initial or word-final.

One of the key concepts of acoustic theory is that the coarticulatory effects on the adjacent vowels can be used as cues for the articulation of consonants (Fant 1960; Recasens, 1985). Thus, the formants of neighboring vowels can be used as indications to characterize the emphatic consonants as either pharyngealized or uvularized (Zawaydeh, 1999; McCarthy, 1994; Shar, 2012; Ladefoged & Maddieson, 1996). Since the F2 drop and the F1 increase take place at almost all of positions of the vowels in this dialect of Arabic, I claim that emphasis is produced by backing the tongue root towards the back of the pharynx, also known as pharyngealization. It is not produced by retracting the tongue dorsum, known as uvularization.

Contrary to Shahin (1997) who reported that emphasis affects short vowels only, this study shows that emphasis affects short and long vowels of all qualities. However, in line with the results reported by Wahba (1993) and Al-Masri (2009) (among others), this study has shown that the short low vowels' F2 values were the most affected among vowels when the emphatics were word-initial (rightward effects). However, with regard to leftward, or anticipatory effects, vowels were affected based on their vowel qualities. The low vowels /a/ and /a:/ were the most affected, followed by /i/ and /i:/. The least affected where the back vowels /u/ and /u:/, respectively. As Habis (1998, p. 38) reported,

> [T]here is a general agreement among phoneticians that all the vowels fall under the coarticulatory effects of neighboring emphatics and that the effects vary from one vowel to another. It is also generally assumed that the effect is clearer on /a(:)/ than on other vowels.

P.38. Recasens (1984; 1989; 1991) claimed that articulatory regions are free to coarticulate with neighboring consonants when they are not involved in vocalic constrictions. According to this view, a low vowel would be free to coarticulate with an emphatic and be more affected in emphatic environments. However, when pronouncing a less or non-back vowel, such as /i/, which does not have that a back gesture, the tongue has to move to articulate the vowel using the front part of the tongue, which is antagonistic to the tongue root retraction associated with the secondary articulation in emphatics (Bin-Muqbil, 2006). In addition, the fact that high vowels are less affected than are low ones might be because that the tongue is less free to move when it is fronted and raised at the same time (Recasens, 1984). This would make the high vowels more constrained and resistant to emphatic lowering. Acoustically speaking, the requirements for the high vowel /i/, low F1 and high F2, are in conflict with those of the emphatics, high F1 and low F2. This high vowel resistance to F2 lowering has been reported in some other languages such as American English, (Steven and House, 1963), Dutch (Pols, 1977), and Catalan (Recasens, 1985; Recasens & Espinosa 2009). Of all the vowels, the long back vowel /u:/ and the short back vowel /u/ are the least affected vowels. This might be because the high back vowels are inherently back; hence, they have low F2 values (Younes, 1982).

With regard to the F1 values, the difference between vowels was not as great as that for F2. The short vowels were more affected than were the long ones. Of the short vowels, the values of the high vowel /i/ were the most affected ones. This might be due to the fact that /i/ is inherently high and hence has low F1: thus any F1 change will be noticeable. Moreover, it might also be due to the fact that high vowels are shorter than are low ones and are therefore more affected (Moon & Lindblom, 1994; Younes, 1982).

The results of this study indicate the emphasis effect on the adjacent vowels when the target consonants occur word-initially, rightward, was significantly stronger than was the effect when the target consonants occur word-finally. Thus, in the vicinity of initial target emphatics, vowels show significantly higher F1 and lower F2 values compared to the vowels in the vicinity of final target emphatics. This might be the case because, when emphatics are word-initial, all the words, in this study, have stress on the first syllable but when emphatics are word-final, 50% of the words have final stress and the other 50% of them have stress word-initially. However, this study showed that having stress word-initially does not make the emphasis effect bigger on the initial syllable. On the contrary, shifting stress to non-target final syllables makes the F2 difference between plain and emphatic environments slightly, and insignificantly, bigger. Thus, one possible reason might be that initial segments have a more prominent status because no segments come before them: hence, strong articulation is imposed on the first target in Zilfaawi Arabic. Cho and Keating (2001; 2009) claimed that consonants in the initial position tend to have a stronger articulation compared to those in non-initial or weak prosodic positions. The strong effect by initial consonants in other processes is also reported by researchers such as Stevens and House (1963) and Öhman (1966), as cited by Chafcouloff & Marchal, (1999), who reported that the effect of initial consonant was greater than that of the final one on the medial vowel in CVC syllables. Cooper (1991) reported that English voiceless aspirated stops were produced with larger glottal opening gesture in word-initial positions in comparison to those in word-final positions. Jun (1993) found that the Korean aspirated stop /p/ had a longer VOT in word-initial positions compared to medial positions. In addition, it may be that the word-initial effect is stronger because it is at the beginning of the word and nothing before the emphatic consonant helps to perceive the pharyngealization. In contrast, when emphatics appear word-finally, pharyngealization effect is perceived by the help of the extended pharyngealization throughout the word with no to strengthen that effect for perception reasons.

Contrary to the stronger effect of word-initial emphatics on the following adjacent vowels, the long-distance effect of word-final emphatics on the non-adjacent vowels extends further, meaning that anticipatory effects on non-adjacent vowels are stronger than carryover effects. For example, F2 of the /a:/ in the non-adjacent syllable was lowered by 40 Hz when emphatics are word-initial and 120 Hz when they were word-final. In line with the results of this study, many authors have reported that the anticipatory emphasis spread is less restricted and more salient, extends more, than carryover emphasis spread (Ghazeli, 1977; Watson, 2002; Al-Masri, 2009; among others). Moreover, it has been found that the anticipatory emphasis spread is categorical in Jordanian and Palestinian Arabic while the carryover emphasis spread was gradient and less prominent (Davis, 1995; Zawaydeh, 1999). This might be because the production of the first segments in the word prior to the production of the final emphatic might be influenced by the anticipation and planning to produce that the final emphatic. However, the initial emphatic does not spread as far as the final one because once it is produced, it becomes inactive. (Dell et al, 1997; Hansson, 2001).

One major conclusion of this study is that pharyngealization in Zilfaawi Arabic is a phonetic, rather than a phonological, process, which affects neighboring vowels. Some of evidence for it being a phonetic process is that the emphatic effect weakened when we moved further away from the target emphatic consonant in both directions: leftward and rightward. Thus, unlike the findings of some studies of Arabic dialects, such as Cairene Arabic (Younes, 1993) and Jordanian Arabic (Zawaydeh, 1999), which posited that the emphatic effect might be categorical for some directions, both word-initial and word-final pharyngealization in Zilfaawi Arabic are gradient in target and non-target syllables for F2 and F1.

Other support for the notion that pharyngealization in Zilfaawi is a phonetic process lies in the fact that emphatic effect is never blocked by any of the high consonants when the target consonants occur word-finally. Moreover, it is never blocked by any of the high long vowels /i:, u:/ when target consonants occur word-initially or word-finally. Choosing /i:/ and /u:/ because of the antagonistic behavior and length of the high vowel /i:/ and the fact of being the least affected vowel for the back high vowel /u:/, based on the current study's results. The non-blocking of the high segments, vowels and consonants, in this study is in contrast to other studies that reported emphasis spread blocking in some dialects of Arabic, such as /u/ in Jordanian Arabic (Al-Masri, 2009), (/i, j, ʃ, ʒ, u/) in Northern Palestinian Arabic (Younes, 1982), (/i:, i, j, ʃ, ʒ/) in Jerusalem

Palestinian Arabic (Card, 1983), (/i, j, ʃ, ʒ/) in Moroccan Arabic (Heath, 1987), (/i, j, ʃ, ʒ/) in Southern Palestinian Arabic (Davis, 1993; 1995), (/i, e/) in Libyan Arabic (Ghazeli, 1997), and (/ʃ, ʧ, ʤ/) in Abu-Shusha Palestinian Arabic (Shahin, 1997).

Further support for the notion that pharyngealization is a phonetic process is that the effect is not blocked by morpheme boundaries, resulting in significantly affected prefix and suffix vowels. This is in line with some studies that reported no blocking of the phonetic emphatic effect by morpheme boundaries (Younes, 1993; Zawaydeh, 1998). With regard to Ammani-Jordanian Arabic, Zawaydeh (1998), claimd that emphasis spreads into prefixes and suffixes. Compared to languages with different processes, such as nasalization, Moll and Daniloff (1971) reported that no word boundary effect was found in American English when comparing the two sequences of phonetic nasalization: CVVn vs. CV#Vn. As in Zilfaawi Arabic, both vowels were affected regardless of the morpheme boundaries. This has been supported by other researchers in other languages such as French (Benguerel *et al.* 1977) and Hindi (Dixit and MacNeilage 1972).

2.11 Conclusion

The acoustic results in this experiment show that emphatics are articulated differently from their non-emphatic counterparts. Because emphatics cause F1 values to increase and F2 ones to decrease, I conclude that emphatics are characterized as pharyngealized consonants. So, they are articulated by a constriction in the lower pharynx with a retraction of the tongue root. Furthermore, the acoustic results show that the emphatic effect in Zilfaawi Arabic is phonetic based on the following indications: The emphatic effect is gradient, and it is never blocked by neither segments with opposing qualities, nor by morpheme boundaries. In addition to these major findings, the experiments revealed that, compared to when emphatics occur word-initially, pharyngealization extends further and exerts a stronger effect on the non-adjacent vowel when emphatics occur word-finally. However, the emphatic effect on adjacent vowels when target consonants occur word-initially is stronger than is the effect when the target consonants occur word-finally. Accordingly, stress was investigated as a possible cause of the stronger effect of emphatics on neighboring vowels by varying stress on the first syllable but no significant role of stress was found.

Many previous studies have claimed that phonetic emphasis in Arabic is phonetic, but with no relevant frameworks to account for these phonetic patterns. Therefore,, a model is needed to show how this phonetic effect on neighboring vowels is derived in Zilfaawi Arabic. In the next chapter, the constraint-based model by Flemming (2001) is adopted, in which the effect of mechanical properties of vocal tract on linguistic sound patterns is presented as universal constraints that interact with faithfulness constraints, creating specific sound patterns. This model is based on universal constraints, which makes it a step towards a possible cross-dialectal analysis of Arabic emphasis.

Chapter Three

3 Modeling of Emphatic Lowering Effect

Having established the F2-lowering effect of emphatic consonants on following vowels in Chapter 2, this chapter presents an analysis of this phonetic lowering effect using the scalar constraint-based model developed by Flemming (2001) to derive this coarticulation. The emphatic lowering effect on the Arabic vowels /a/, /i/, and /u/ is analyzed as being driven by interaction between conflicting weighted constraints: a phonetic constraint favoring less effortful articulator movements interacting with faithfulness constraints protecting vowel and consonant realizations from diverging from their acoustic targets. The conflicts between the constraints are resolved by assigning a specific "cost of violation" for each constraint. The optimal consonant and vowel realizations are those that incur the least total violation cost. Thus, the emphatic lowering effect differs from one CV sequence to another, for example /**tˤ**a/ and /**tˤ**i/ based on the weights of the constraint and differences in the acoustic targets of vowels and consonants.

Emphatic lowering is a common phenomenon, as it occurs in Semitic languages such as Arabic (Davis, 1995; Watson, 1999; Zawaydeh, 1999; Shar, 2010; among others), Aramaic (Hoberman, 1988), and St'at'imcets Salish (Shahin, 1997; Zemánek 1996). However, some specific patterns caused by emphatics differ from one language or dialect to another. Zilfaawi is presented in this research as one of the languages that show patterns that differ from one sequence to another. These patterns are also different from those in other dialects of Arabic such as Urban Jordanian Arabic (Al-Masri, 2009), in which the F2 was not significantly lowered at the midpoint of the target vowel in the CV sequence. Thus, an account is provided to capture this coarticulatory lowering in Zilfaawi using universal weighted constraints that are used to account for other coarticulatory phenomena in other languages such as German, English, French, Hindi, and Korean, among others (Flemming, 2011; Cho, 2007), showing the connection between these different phenomena. In the analysis of these languages and Zilfaawi Arabic in this dissertation, a set of universal weighted constraints is used and phonetic, rather than phonological, representations, such as F2, are implemented.

In Section 3.1, I begin with a presentation of the weighted constraint model proposed by Flemming (2001). In Section 3.2 and Section 3.3, this model is then adapted using the same set of constraints with different weights and with some modifications to account for coarticulation in each CV sequence in Zilfaawi Arabic. The optimal candidates for the sequences /$t^ʕ$a/ and /$t^ʕ$i/, but for not /$t^ʕ$a/, are derived successfully. The conclusion is presented in Section 3.4.

3.1 The Weighted-Constraint Model

Using F2 values in consonant-vowel coarticulation as an example, Flemming (2001) developed his framework to model interactions of constraints for scalar phonetic representations to account for phonetic and phonological processes. Coronal consonants have a phonetic fronting effect on neighboring back vowels in English, for example /tʰut/ "toot," and in some other languages. This coarticulation, which is observed between neighboring vowels and consonants, can be regarded as a compromise between faithful renditions of F2 targets of consonants and vowels and a preference for the least effortful movement between them. The compromise between the identity constraints that require the F2 targets of the consonant and the vowel to be realized faithfully and the constraint that requires the F2 values of adjacent vowels and consonants to be the same will specify F2 values for the consonant and vowel. These conflicting constraints are formalized as follows (Flemming, 2001, p. 19):

(8)

	Constraint	Cost of violation
IDENT(C)	$F2(C) = L$	$w_c(F2(C) - L)^2$
IDENT(V)	$F2(V) = T$	$w_v(F2(V) - T)^2$
MinimizeEffort	$F2(C) = F2(V)$	$w_e(F2(C)\ F2(V))^2$

In the above representation, *L*, the consonant locus, and *T*, the vowel target, are denoted as the targets that remain fixed for each consonant and vowel and the coefficients w_c, w_v and w_e are positive weights. *F2*(*C*) is the actual realization of F2 at consonant release and *F2*(*V*) is the actual realization of F2 at the steady state. The constraints, IDENT(C) and IDENT(V), prevent vowel and consonant realizations from diverging from their acoustic targets. In other words, they require the target values (*L*, *T*) to be equal to the actual F2 values at consonant release, *F2*(*C*), and the vowel steady state, *F2*(*V*), respectively. Based on the assumption that more rapid movements require more effort, the MinimizeEffort constraint requires there to be no movement between the consonant's F2 values and those of the vowel, thereby promoting zero velocity. Therefore, velocity in the model is proportional to articulatory effort.

Based on the above, the constraints IDENT(C), IDENT(V) and MinimizeEffort are in conflict with each other. Therefore, satisfying IDENT constraints results in a violation of the MinimizeEffort constraint when *L* and *T* are far away from each other. However, the constraint MinimizeEffort penalizes any difference between F2 values of the consonant and the vowel assuming that greater effort results from more rapid movements. Accordingly, the chosen values of F2(*V*) and F2(*C*) should be identified as those that can satisfy the stated constraints in the best possible way, as is standard in Harmonic Grammar (Legendre, Miyata & Smolensky, 1990/2006; Smolensky & Legendre, 2006).

In Flemming (2001), as in Harmonic Grammar, the constraints are not ranked as in Optimality Theory (Prince & Smolensky, 1993/2004), but they are associated with a cost of violation. Resolving the conflict between the constraints is achieved by finding the best values of F2(*C*) and F2(*V*) that incur the least overall cost of violation of the constraints. Computing the cost of violations of the IDENT constraints will be achieved by finding the square of the deviation from the targets of consonant and vowel, multiplied by their positive constraint weights, w_c and w_v, respectively. With regard to the MinimizeEffort constraint, the cost will be quantified as the squared difference between the actual F2 values of the consonant and vowel, multiplied by the positive constraint weight, w_e, (Flemming, 2001). The weight associated with each constraint verifies its comparative importance. For example, having a lower w_v and a higher w_c and w_e means that the consonant's F2 values cannot move as much as can the vowel's F2 values in order to have a smaller difference between the F2 values of the vowel and consonant. Therefore, violating high-weighted constraints incurs a higher cost of violation while violating low-weighted ones does not. The F2 values of the consonant and vowel, F2(*C*) and F2(*V*), are selected to achieve the least overall cost of violation as shown below (Flemming, 2001, p. 20):

(9) $\text{Cost} = w_c(F2(C) - L)^2 + w_v(F2(V) - T)^2 + w_e(F2(C) - F2(V))^2$

3.2 Adaptation to Emphatic Lowering

As in many different dialects of Arabic, emphatics in Zilfaawi Arabic lower the F2 values of the neighboring vowels. Articulatorily, this occurs as a result of retracting the tongue root toward the back of the upper pharynx. However, this lowering effect is different from one vowel to another. By testing the first two formant values of the vowels, I argued in the previous chapter that the emphatic effect on the adjacent vowels—lowering F2 values and raising F1 values—is a phonetic rather than a phonological process that varies from one vowel to another. Therefore, we need a model that refers to phonetically detailed representations to analyze the acoustic results to capture the variable emphatic lowering that varies from one vowel to another that we arrived at in the chapter above. **Table 41** shows the lowering effect of the emphatic /t^{ʕ}/ on the midpoints of the following vowels as part of the results reported in Chapter 2.

Table 41: F2 of different vowel midpoints preceded by plain and emphatic /t/

Vowel	a	i	u
Plain /t/	1610Hz	1910Hz	1070Hz
Emphatic /t^{ʕ}/	1150Hz	1450Hz	890Hz

Many models have been proposed to account for coarticulation in the literature (Lindblom, 1983, 1989, 1990; Keating, 1985, 1988, 1990a, 1990b; Browman & Goldstein, 1986, 1989, 1992; Recasens, 2002). However, one of the best models that can meet the requirements is the framework proposed by Flemming (2001) because it can derive the optimal outputs regardless of whether the process is phonetic or phonological using weighted constraints and scalar representations. This framework can be used to analyze phonetic consonant-vowel coarticulation or the vowel lowering effect as a compromise between preserving the F2 targets of vowels and consonants and a preference for minimized movement between these F2 targets, hence resulting in close values. This can be achieved by having scalar conflicting constraints associated with a cost of violation that can evaluate the continuous phonetic representations, such as F2 values, and abandoning the strict domination used in models such as OT to allow the candidate to satisfy conflicting constraints to some degree. In addition, the vowels' variability can be analyzed by adjusting the weights of the constraints, as I show below in Section 3.3.

Based on Liljencrants and Lindblom's (1972) work, I assume that the best universal vowels tend to be the most peripheral ones. Therefore, the estimates of the F2 targets, *T*, for the vowels /a/, /i/, and /u/, were based on a subset of the data that consisted of the mean of the most peripheral 15% of each vowel's formant values. In other words, I took the highest 15% of F1 values for /a/, the highest

15% of F2 values for /i/, and the lowest 15% of F2 values for /u/ in the neutral context, /tVbbad/. Therefore, the target for each vowel is the mean of the previously mentioned six observations for each vowel. The resulting estimated F2 target, *T,* for each vowel is as follows: 1620 Hz for the vowel /a/, 2160 Hz for the vowel /i/, and 890 Hz for the vowel /u/. To compute the amount of emphatic lowering on each vowel, we use the difference between the mean of the actual F2 values, F2(*V*), and the vowels' targets, *T*. The difference between the two values will be called "vowel undershoot" (Lindblom, 1963; Flemming, 2001).

In addition to vowels, the consonant may also be affected and its F2 values, F2(C), may change based on the type of the vowel that follows. To estimate the F2 value of the consonant locus, *L*, a comparison is made between the acoustic realization of the emphatic consonant /tˤ/ followed by the vowels /a/, /i/, and /u/. These measurements are then averaged across vowels and speakers and the resulting mean is taken as the consonant locus, *L*. The estimated F2 locus, *L,* for the consonant /tˤ/ is 1130Hz. The difference between the two values, *L* and F2(C)*,* will be called "consonant undershoot" (Lindblom, 1963; Flemming, 2001).

As a reminder, the F2 values come from the measurements described in Chapter 2 - fifteen speakers repeated each target word three times. These target words were placed in the carrier phrase [ʔiktibi ____ sit marra:t] "write (fem.) ____ six times!". To eliminate any stress confound, I used only the initially stressed stimuli. A script was used to carry out an automatic measurement of the vowel midpoints. Consonant measurements of F2 at consonant release were verified manually as the first discernable glottal pulses in the tˤV transition (Sussman et al, 1993).

In this chapter, the focus is on the F2-lowering effect of word-initial emphatics on following vowels by examining F2 values of the first vowel's midpoint, following Flemming (2001). Of the consonants, the stop emphatic /tˤ/ will be the segment to be modeled because it is easier to ascertain the vowel boundaries. The vowel goes down by 280Hz when the consonant is /tˤ/, and by 260Hz and 370Hz when the consonants are /sˤ/ and /ðˤ/, respectively.

3.3 Application to Emphatic Lowering

In this section, I will apply Flemming's model to the data I have gathered on Zilfaawi Arabic. Consonants and following vowels may have very different F2 targets (*L* and *T*, respectively), as in the Zilfaawi Arabic case of /tˤi/, where the consonant has a low F2 target and the vowel has a high one. Therefore, the model predicts that both F2 targets of both consonant and vowel might give up their targets, *L* and *T*, and move toward each other, showing a preference for reduced-speed articulatory movements (Flemming, 2001; Lindblom, 1963). In Zilfaawi Arabic, the preference for this minimized movement would result in a lowering effect on the adjacent vowels' F2 values, as reported in the previous chapters. In addition to the strong lowering of the vowel, the consonant's F2 values are sometimes raised somewhat as well. However, the segments' F2 values' displacements differ from one sequence to another in ZA, as shown in **Table 42** and explained in detail in chapter two above.

Table 42: Different displacement of F2 targets based on sequence

Sequence	$t^{ʕ}a$	$t^{ʕ}i$	$t^{ʕ}u$
	L = 1130 T = 1620	L = 1130 T = 2160	L = 1130 T = 890
consonant F2	1140	1310	940
vowel F2	1150	1450	890

Note. L = the locus of the consonant; *T* = the target of the vowel.

In the /$t^{ʕ}a$/ sequence, the vowel's F2 values are moving toward the emphatic consonant with a very small change in the consonant's F2 values. In the /$t^{ʕ}i$/ sequence, both F2 values of the vowel and the consonant move toward each other, giving up their targets, *T* and *L*, respectively. In the /$t^{ʕ}u$/ sequence, the emphatic consonant's F2 values are moving toward the vowel with almost no vowel's F2 values displacement.

To analyze emphatic lowering and the different patterns reflected by the different CV sequences, an optimization model was formalized in accordance, wherein, for a given CV sequence, the actual realized values of the consonant and vowel, F2(*C*) and F2(*V*), were selected to achieve the least total cost of violation as shown in (9) above, repeated here:

(10) $$\text{Cost} = w_C(F2(C) - L)^2 + w_V(F2(V) - T)^2 + w_e(F2(C) - F2(V))^2$$

Because three different vowels are used in this study and each vowel is affected to a different degree, three different versions of IDENT(V) will be used — IDENT(a), IDENT(i), and IDENT(u)— in addition to the constraints IDENT(C) and MinimizeEffort as in the following:

(11)

	Constraint	Cost of violation
IDENT(C)	$F2(C) = L$	$w_C(F2(C) – L)^2$
IDENT(a)	$F2(\text{a}) = T$	$w_\text{a}(F2(\text{a}) – T)^2$
IDENT(i)	$F2(\text{i}) = T$	$w_i(F2(\text{i}) – T)^2$
IDENT(u)	$F2(\text{u}) = T$	$w_u(F2(\text{u}) – T)^2$
MinimizeEffort	$F2(C) = F2(V)$	$w_e(F2(C) – F2(V))^2$

As in Flemming's (2001) work, the constraint $F2(C) = L$ requires that the actual realized F2 value of the consonant /tˤ/ be identical to the F2 of the target consonant (L). The cost of violating this constraint, which is referred to as IDENT(C), will be computed as the square of the divergence from the target of the consonant, L, multiplied by the positive constraint weight w_C. The faithfulness vowel constraint $F2(\text{a}) = T$ requires that the actual realized F2 value of the vowel /a/ be identical to the F2 of the target vowel (T). The same also applies to all other vowels' constraints, $F2$(i) = T and $F2$(u) = T. The cost of violating one of these IDENT constraints, IDENT(a), IDENT(i), and IDENT(u), will be computed as the square of the divergence from the targets of the vowel multiplied by its relevant positive constraint weight: w_a, w_i, w_u. Moreover, the constraint $F2(C) = F2(V)$, MinimizeEffort, requires the actual F2 values of the consonant and vowel to be the same. The cost of violating this constraint will be quantified as the squared difference between the realized F2 values of the consonant and the vowel multiplied by the positive weight, w_e.

Targets and actual realized F2 values of consonants and vowels are obtained from the data using the method described above in Section 3.2. However, we need to determine the weights of the constraints, which can be obtained from the measurements shown in the formulas in (12) below. These formulas connect the observed values (F2(C), F2(V), L, and T) with the parameters of the model: w_e, w_c, w_v. Nonetheless, the formulas do not allow us to discover all the three weights of the constraints. Therefore, since w_e, w_c, and w_v are relative weights, I stipulated that $w_c = 1$ and calculated the other two values using the following two equations (Flemming, 2001, p. 22):

(12)

$$\mathrm{F2}(C) = \frac{we}{wc+we}(\mathrm{F2}(V) - L) + L$$

$$\mathrm{F2}(V) = \frac{we}{wv+we}(\mathrm{F2}(C) - T) + T$$

The weight of the constraint IDENT(C) was chosen as the stipulated one because the consonant /$t^ʕ$/ is expected to have the same degree of faithfulness regardless of the context in which it appears in the language. Therefore, we expect this constraint to have the same weight and cost of violation, unlike the other constraints such as IDENT(V). Another option is to stipulate the weight of the constraint MinimizeEffort because it is the driving force for emphatic lowering. However, since one of the model's requirements is to fix the weight of one constraint and calculate the weight of the others relative to the fixed one, the more theoretically grounded choice was made, which was to fix the weight of IDENT(C). As we will see in the following section, the weight of MinimizeEffort does not vary from one sequence to another as much as IDENT(V). The weight of MinimizeEffort is around one in two of the three cases, as we will see below.

3.3.1 Cost Optimization and Optimal Values Selection

Selecting the optimal F2(V) and F2(C) through optimizing the overall violation cost of the above constraints pattern differently based on vowel backness: /a/, /i/, and /u/. In general, we expect the non-back vowels /a, i/ to move more than does the back vowel /u/. This might be justified if we consider that the F2 target, T, of the vowel /u/ is already low, contrary to the other vowels' F2 targets.

After formulating the constraints and obtaining the weights of each one, I begin with the low vowel /a/ preceded by the /tˤ/ in the emphatic environment. The locus of the emphatic consonant /tˤ/ and the target of the vowel /a/ are 1130Hz and 1620Hz, as shown as *L* and *T* in Table 43. In addition, the weight of each constraint is shown under the relevant constraint in the table. To find the optimal candidate, we need the F2 values that incur the least total cost of the function in (9) above, which appears as the "total cost" in Table 43. The optimal candidate incurs some violation of each constraint and minimal violation of the heavily weighted constraints as in the following:

Table 43: Realization of /tˤa/ with locus of /tˤ/ as 1130 Hz and the target of /a/ as 1620 Hz.

F2(*C*) *L= 1130*	F2(*V*) *T= 1620*	IDENT(C) 1	IDENT(a) .02	MinimizeEffort 1	Total cost
☞**a. 1140**	**1150**	100	4802	100	5002
b. 1130	1620	0	0	240100	240100
c.1180	1230	2500	3307	2500	8307
d. 1620	1620	230400	0	0	230500

Let me first illustrate the violation profile of the 'winner', the optimal candidate in (a). The cost of violating the constraint IDENT(C) is 100 because *L* is 1130Hz and the actual F2(*C*) is 1140Hz; the difference between them is 10Hz. The resulting number 10 is squared, which results in 100. Multiplying this number by the weight of the constraint IDENT(C), which is 1, results in 100. This number appears in the table as the cost of violating the constraint IDENT(C). The same applies to the other constraint costs, taking the way of computing the cost of violation in the above into consideration. Summing all costs yields the total cost of violation for each candidate.

The values in (a) are the observed mean F2 values across all speakers and repetitions. By definition, they are optimal because they incur the least total cost of violation among all candidates. They violate the heavily weighted constraints slightly but they violate the least-weighted one, IDENT(a), the most. Thus, they have a smaller difference between F2(*C*) and F2(*V*) by bringing the vowel down, resulting in greater satisfaction of the heavily weighted constraint MinimizeEffort. Unlike candidate (a), candidate (b)—which lacks the compromise— fully satisfies the identity (faithfulness) constraints, but violates the heavily weighted constraint MinimizeEffort by having a large difference between F2(C) and F2(*V*), resulting in a high cost of violation. Candidate (c) shows a compromise between *L* and *T*. However, its total violation cost is high compared to candidate (a) because of violating the heavier-weighted constraint IDENT(C) more by having a bigger difference between *L* and F2(*C*). Candidate (d) has no violation of the constraint MinimizeEffort. Therefore, it is up to the other IDENT constraints to decide which segment is moving more. When looking at both constraints' weights, it appears that it is more important to have a consonant that is closer to its locus than a vowel is to its target. However, candidate (d) does the opposite by fatally moving the consonant while being faithful to the vowel's target. By contrast, candidate (a) is optimal by having a good compromise between the constraints and respects IDENT(C) and MinimizeEffort. Therefore, the vowel in candidate (a) undershoots its F2(*T*) while keeping its F2(*L*) barely changed.

On the one hand, as in Flemming (2001), the violation cost of the constraint MinimizeEffort is high because it is more important to have a small transition between the consonant and vowel than it is to have vowels and consonants that are close to targets. On the other hand, as reflected by the weights of the IDENT constraints, IDENT(a) and IDENT(C), .02 vs. 1, it is more important to have a consonant that is closer to its locus than it is to have a vowel that is close to its target, as can be seen by looking at candidate (d), which means having a more emphatic effect on the vowel.

Turning now to the high vowel /i/, the locus of /$t^ʕ$/ is 1130Hz and the target of /i/ is 2160Hz. These are shown in the table as *L* and *T*, respectively. The weight of each constraint is shown under the relevant constraint in the table. To be optimal, the candidate F2 values need to incur the least total cost of violation by incurring some violation of each constraint and minimal violation of the heavily weighted constraints as in the following:

Table 44: Realization of /$t^{ʕ}$i/ with locus of /$t^{ʕ}$/ as 1130Hz and the target of /i/ as 2160Hz

F2(*C*) *L*=1130	F2(*V*) *T*=2160	IDENT(C) 1	IDENT(i) .25	MinimizeEffort 1.3	Total cost
☞**a. 1310**	**1450**	32400	127800	25200	185400
b. 1130	2160	0	0	1364014	1364014
c.1130	1130	0	268960	0:	268960
d. 2160	2160	1060900	0	0	1060900

By summing the cost of each constraint, the optimal values (a), which are the observed mean values, are the ones that incur the least total cost of violation by having a good compromise among all three constraints. They slightly violate the heavily weighted constraints but they violate the least-weighted one, IDENT(i), the most. Therefore, they have a smaller difference between F2(*C*) and F2(*V*) by bringing the vowel down and raising the consonant up. Unlike candidate (a), candidate (b)—which lacks the compromise—violates the heavily weighted constraint by being faithful to its targets resulting in a big difference between F2(*C*) and F2(*V*). Consequently, candidate (b) incurs a fatal high total cost of violation and ending as a non-optimal candidate. Candidates (c) and (d) have no violation of the heavily weighted constraint MinimizeEffort. However, being faithful to either IDENT(i) or IDENT(C) does not help in optimizing the total cost of violation and being optimal. Each candidate has to incur some violation of each constraint by moving both the consonant and the vowel to be optimal.

In contrast to the example of the vowel /a/, in which the consonant barely raises while the vowel lowers, the vowel /i/ undershoots its F2 values while the consonant /tˤ/ raises its F2 values, such that the two sounds accommodate each other in the sequence /tˤi/. Therefore, a compromise among all constraints should be achieved to minimize the cost function, although the vowel is doing much of the work by moving further from *T* than the consonant is from *L*.

As shown in the above two tables, the model does a good job of accounting for the behavior of the emphatic consonant /tˤ/ and the adjacent vowels /a/ and /i/. For the sequence /tˤa/, the F2 values of the vowel in the context of /tˤ/ are lower while those of the consonant change little or not at all. For the sequence /tˤi/, F2 values of the vowel in the context of /tˤ/ lower substantially and those of the consonant raise more than they do with the vowel /a/.

Using Flemming's model (2001) that refers to the phonetic representations and uses weighted constraints, I analyzed the coarticulation in Zilfaawi Arabic between the emphatic consonants and the vowels /a/ and /i/. Using the MinimizeEffort constraint with a higher cost of violation results in a smaller transition and more undershoot for F2 values of the vowel and consonant. However, the weights of the constraints IDENT(C) and IDENT(V) determine which segment's F2 values move more. Additionally, the emphatic-vowel coarticulation variability was captured by adjusting the weights of the IDENT(V) constraints based on the vowel quality that differs from one sequence to another.

The low vowel /a/, whose weighted constraint has the least cost of violation among vowels, appears to be more susceptible than /i/ to emphatic lowering showing much displacement of F2 values and moving closer to /tˤ/. One reason might be that when producing the vowel /a/, the articulatory regions are free to coarticulate with neighboring consonants because /a/ does not require any tongue positioning that is contrary to backing. Another reason might be that, as Al-Masri (2009) reported, the low vowel is more influential in perceiving emphasis compared to the other vowels. After cutting the vowel /a/ from the plain sequence /ta/ and swapping it with /a/ in the emphatic sequence /tˤa/, 93.5% of the participants in his study reported hearing the plain /t/ instead of the emphatic /tˤ/. This is supported by (Herzallah, 1990) who reported that the emphatic and plain low vowel /a/ are perceptually distinct among native speakers of Northern Palestinian Arabic. Therefore, it may be necessary to keep the low vowel as low as possible to ease the perception of emphatics.

Unlike the vowel /a/, the non-back vowel /i/, which has the highest F2 values among all three vowels, does not become lowered to the limit of having almost no transition with the emphatic consonant /tˤ/. In this sequence, we have a bigger difference between the targets of the consonant /tˤ/ and the vowel /i/. Therefore, both segments in the sequence /tˤi/ move toward each other, violating both identity constraints. Moreover, the transition between the consonant /tˤ/ and the vowel /i/ is not as small as we observed in the sequence /tˤa/. This might be explained by the fact that the tongue has to move to articulate the vowel using the front part of the tongue, which is antagonistic to the tongue root retraction associated with the secondary articulation in emphatics (Bin-Muqbil, 2006). This causes F2 values of the consonant /tˤ/ to be higher and those of the vowel to be lower as we saw in the optimal values of the example in Table 44.

The question now is, what about the sequence /tˤu/? Compared to the sequences /tˤa/ and /tˤi/, both segments /tˤ/ and /u/ in this sequence have the same quality; both segments have low F2 values. Therefore, we expect less F2 values displacement between them when compared to both /tˤa/ and /tˤi/. The locus of /tˤ/ and target of /u/ are 1130Hz and 880Hz, respectively, as shown as *L* and *T* in the table below. As shown in the other tables, the weights of each constraint are shown under the relevant constraint in Table 45. The F2 values need to incur the least total cost of violation to be optimal.

Table 45: Realization of /$t^{ʕ}$u/ with locus of /$t^{ʕ}$/ and target of /u/ as 1130Hz and 880Hz, respectively.

F2(*C*) *L*=1130	F2(*V*) *T*=880	IDENT(C) 1	IDENT(u) 19	MinimizeEffort 3.8	Total cost
☞**a. 940**	**890**	36100	1900	9500	47500
b. 1130	880	0	0	237500	237500
c.880	880	62500	0	0	62500
d. 1120	1110	100	1005100	380	1005580

The optimal values (a), which are the observed mean values, are those that incur the least total cost of violation in the cost function in (2) above. They violate the heavily weighted constraints, IDENT(u) and MinimizeEffort minimally, but they violate the least-weighted one, IDENT(C), maximally. As a result, they have a smaller difference between F2(*C*) and F2(*V*) by bringing the consonant /$t^{ʕ}$/ down and raising the vowel /u/. This vowel raising is surprising because we expect the vowel to lower when it is adjacent to an emphatic consonant in Zilfaawi Arabic. Unlike candidate (a), the non-optimal candidate (b)—which lacks the compromise—violates the heavily weighted constraint MinimizeEffort by being faithful to the consonant and vowel targets resulting in a big difference between F2(*C*) and F2(*V*). Although candidate (c) completely satisfies the constraint MinimizeEffort by having no difference between F2(*V*) and F2(*C*) and being faithful to the vowel, it lacks the compromise between the constraints and it lowers the consonant more resulting in higher cost of violation. Candidate (d) shows a more faithful consonant while raising the vowel to satisfy MinimizeEffort resulting in a very high total cost of violation. As reflected by the cost of the IDENT constraints, 1 vs. 19, it is more important to have a vowel that is closer to its target than it is to have a consonant that is closer to its locus. Thus, the consonant undershoots its F2 values while keeping F2 values of the vowel barely changed to satisfy the constraint MinimizeEffort and to be optimal as in candidate (a).

Applying the model to Arabic emphatics, the model works well when both segments' F2 values in the sequence CV are far from each other and the segments are not of the same quality—as in the sequences /tˤa/ and /tˤi/—with the F2 realization of the consonant raised and the F2 realization of the vowel lowered. In these two sequences, the model reflects the discussion in Section 2.3, showing that vowels are lowered in the presence of an emphatic. However, when both segments are back as in /tˤu/, a discrepancy between the model and the observations—reported in **Table 41** above—emerged. The model shows almost no F2 change in the vowel, with /u/ raising by 10Hz to reach 890Hz, and the consonant lowering to meet it, in contrast to the relevant vowel lowering effect reported in Section 2.3— and repeated in **Table 41**. One possible reason for this discrepancy between the model's results of /tˤu/ and the acoustic results reported in table 40 might be that the model cannot account for coarticulatory effect if both segments are of the same quality as in the sequence /$t^ʕ$u/. Another reason might be that either the vowel target or consonant target, locus, is not accurate.

In the acoustic study reported in Section 2.3, I compared the mean F2 realization of all vowels, averaged across speakers and repetitions, in the plain and emphatic contexts. In the current chapter, instead of using the means as the vowel targets in the model, I used the most peripheral realizations of the vowels — the 15% most peripheral tokens. Therefore, peripheral values might not the best vowel targets to be used to obtain the behavior of /$t^ʕ$/ and the vowel /u/ with no discrepancy between the model and the acoustic results. If the model had used mean realizations as targets, T=1070 Hz for /u/, both the vowel and the consonant would have been analyzed as lowering, with both segments realized lower than their target F2 values. However, by applying the mean realization as targets in **Table 46**, the model is unable to derive the correct optimal consonant and vowel. Regardless of the weight of the constraints, the intended winner, candidate (a), is harmonically bounded by candidate (b) that lowers the vowel just to the level of the consonant only as shown in **Table 46**. Keeping the realization of the consonant at 940Hz, IDENT(C) makes no preference between the candidates in **Table 46**, while the other two constraints prefer candidate (b) whose vowel realization is closer to the consonant, thus incurring a smaller violation of MinimizeEffort, and closer to the vowel target T, thus incurring a smaller violation of IDENT (u) regardless of its weight.

Table 46: The intended realization of /tˤu/ is harmonically bounded if mean realizations of the vowel /u/ is used as the target

F2(*C*) *L*=1130	F2(*V*) *T*=1070	IDENT(C) 1	IDENT(u) 19	MinimizeEffort 3.8	Total cost
a. 940	**890**	36100	615600	9500	661200
☞*b. 940	940	36100	321100	0	357200

Contrary to the analysis of other vowels /a/ and /i/, the analysis of /u/ in **Table 46** is unsuccessful because the model is unable to derive the actual realized F2 values of the vowel to be the optimal ones, if the mean realization is used as the target of the vowel /u/. However, as illustrated in Table 45 above, choosing peripheral F2 values as targets for /u/ was problematic as well, because the vowel was not analyzed as lowered by the preceding emphatic. Using neither the most peripheral realizations nor the mean realization of the vowel /u/ as a target helped to derive the realized F2 values of the consonant and vowel to be the optimal ones.

The other possible reason for not obtaining the behavior of /tˤ/ and the vowel /u/ in the model might be that the consonant locus is not accurate. Thus, one solution would be to lower the F2 locus for /tˤ/, which means the target would be more extreme than the average of observed values, 1130 Hz. That means the consonant locus needs to be smaller than 890 Hz, which is the vowel's actual value. By doing this, the vowel would lower to become closer to the consonant causing emphatic lowering. However, the model cannot reach the observed the consonant's F2 value because the optimal candidate, 940-890, will lose to the candidate 890-890, which raises the consonant just to the level of the vowel only.

Because neither changing the vowel target nor the consonant locus was successful, one stipulated unintuitive solution would be to use the top 15%, or more, of the vowel realizations with the highest, rather than the lowest, F2 as the vowel's target in the /tˤu/ sequence. After recalculating the weights associated with the constraints, doing such stipulation may help the model to derive the realized F2 values of the consonant and vowel to be the optimal ones with no discrepancy as seen above. This stipulation could be applied with other processes depending on the formant in which we are interested in if it were the case that the model could not account for processes when segments were of the same quality. For example, in palatalization, we can choose the top 15% realizations of the vowels with the highest F2 values.

3.4 Conclusion

Chapter 2 demonstrated that, Zilfaawi Arabic is one of the Arabic dialects that shows phonetic patterns of pharyngeal coarticulation which evidence segment specific patterns. Because Arabic dialects differ in the phonetic realization and extent of pharyngealization effects (cf. Urban Jordanian Arabic (Al-Masri, 2009)), we need theoretical models which can account for such cross-dialect variation in a principled way. I used a model that employs universal constraints and implements phonetic representations, viz. the framework of Flemming (2001), to analyze the emphatic lowering and its variations in Zilfaawi Arabic. This coarticulatory emphatic lowering and its specific magnitude is analyzed as an interaction between constraints protecting the F2 targets of the vowels and consonants and others penalizing the acoustic difference between adjacent F2 values of consonants and vowels. After assigning a cost for each constraint, the optimal values are the ones that incur the least total violation cost by having a smaller transition. In the model, the vowels' F2 values lower to get closer to those of the preceding emphatic consonant in most cases except in the sequence /tˤu/ in which both segments are back. This in turn led to a possible reinterpretation of the definition of targets in the model without success. The model generally succeeded in capturing the different patterns shown by the different emphatic and vowel sequences: /tˤa/ and /tˤi/. That was possible because of the use of different identity constraints with unique weights that differ from one vowel to another. The model's results show that consonants are more stable than vowels in Zilfaawi Arabic, which are more affected and accommodating through coarticulation.

There are two factors that determine the amount of emphatic lowering on the adjacent vowels in this analysis. The first is the difference between the vowel target, (*T*), and the consonant locus, (*L*), because having a bigger difference between the two resulted in a greater undershoot. In the /tˤa/ sequence, in which the difference between *T* and *L* for F2 is 490Hz, the vowel undershoot is 20Hz while the consonant goes up by 10Hz. In the /tˤi/ sequence, in which the difference between *T* and *L* is 1030Hz, the vowel undershoot is 710Hz while the consonant goes up by 280Hz. The second factor that determines the amount of coarticulation is weights of the constraints. Because the heavily weighted constraint MinimizeEffort is always satisfied by having the least effortful transition between the two adjacent segments, to some degree, the weights of the constraints IDENT(C) and IDENT(V) will determine which segment moves more (Flemming, 2001).

The use of such universal constraints and implementing the phonetic representations such as F2 in the model make it possible to account for phonetic, lowering of vowel F2 by pharyngeals in Zilfaawi Arabic. This in turn suggests that the same approach shows promise for accounting for emphatic F2 lowering or F1 raising in different dialects of Arabic and in other languages such as St'at'imcets Salish.

Chapter Four

4 Conclusion and Future Directions

This research aimed to enhance a better understanding of the nature of emphatics and their effects on the vowels near them by conducting an acoustic study on emphasis in Zilfaawi Arabic. The acoustic correlates of emphasis in Zilfaawi Arabic are F2 drop and F1 increase in almost all measurement positions of both adjacent and non-adjacent vowels. Using these results as evidence for the articulation of consonants, the emphatic effect on neighboring vowels is a pharyngealization process produced by backing the tongue root towards the pharynx. Pharyngealization affects short and long vowels of all qualities in adjacent and non-adjacent syllables. However, the amount of effect on vowels varies from one vowel quality to another. The low vowel is the most affected vowel while the high vowels /i/ and /u/ are the least affected ones. The weaker effect on the vowel /i/ is attributed to the fact that its acoustic requirements, low F1, high F2, conflict with those of the emphatics. The high back vowel /u/ is inherently low with low F2, so it is affected only slightly compared to the low vowel. This study found no evidence of phonological pharyngealization in ZA. The emphatic effect is phonetic as evidenced by the following: the effect's gradient decline with distance, the lack of blocking by high vowels and consonants, and the lack of blocking by morpheme boundaries.

The emphatic effect on adjacent vowels when the target consonants occur word-initially was stronger than the effect when the target consonants occur word-finally. However, when the emphatics occur word-finally, pharyngealization extends more and affects the non-adjacent vowel more than when emphatics occur word-initially. This study found no big effect of stress on emphatic effects, although many authors report a stress effect on the magnitude and timing of vowel and consonant gestures. So, a possible reason for the lack of a stress effect might be that the initial segments have a more prominent status and hence they are strengthened, as reported by other researchers (Cho and Keating, 2001; Cho and Keating, 2001; among others.

As noted above, Zilfaawi Arabic has a phonetic pharyngealization that causes coarticulatory effects that differ from one vowel to another, so a model has been proposed to derive this emphatic effect based on these vowel patterns. I presented a weighted-constraint account (Flemming, 2001) to account for these effects. Based on Flemming's model (2001), instead of being ranked, the constraints are assigned specific weights reflecting their importance in the dialect and cost of violation. Emphatic lowering is analyzed as an interaction between constraints protecting the F2 targets of the vowels and consonants and others penalizing the acoustic difference between adjacent F2 values of consonants and vowels. The optimal values are the ones that incur the least total violation cost by having a smaller transition. The model succeeded in capturing the patterns shown by the different emphatic and vowel sequences: /tˤa/ and /tˤi/. The interaction of back /u/ and back/pharyngealized /tˤ/ is a challenge to the model leading to a possible reinterpretation of the definition of targets in an acoustically based constraint based model. The model presented here extends Flemming's work on coarticulation in /du/ syllables to more consonant-vowel combinations, and characterization of a tongue-based secondary articulation. The model can be further tested by applying it to cross-language and cross-dialectal differences in pharyngealization in the future. The patterns shown by different vowels and various patterns reflected by different dialects of Arabic could be results of the different weights assigned to the constraints. Pharyngealization is a common phenomenon that differs from one dialect to another and from one language to another (Aramaic (Hoberman 1987; Berber (Basset 1969, Nicolas 1953, Zemánek 1996; St'at'imcets Salish, Shahin, 1997). This analysis of Zilfaawi Arabic will be one step towards cross-dialect comparisons within Arabic and between Arabic and other languages.

The broad descriptive foundation provided by the data in this study could be profitably extended to future research in a wide range of important areas of speech research. For example, only a small number of perception studies have been done on pharyngealization in Arabic. A natural followup would be to determine the formant changes reported in this acoustic study would map on to the perception of by native speakers. Another extensions of this work would be enhancing our understanding of both articulation and acoustics of pharyngealizaion by pairing articulatory measures (such as MRI) with in-depth acoustic investigation. Articulatory and/or acoustic studies would be further enriched by cross-dialectal study using the same number of speakers of each dialect, including a gender comparison, following the same procedures, using the same materials, and analyzing them using the same statistical model. Also, a study like this would potentially bring more consistency and insight to understanding the nature of pharyngealization which has until now been plagued by conflicting results even within dialects. Through all of this work, we can make advances toward a clearer picture of the similarities and differences between Arabic dialects and the pharyngealization processes that are so important to their phonetic character.

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Appendices

Appendix A

Effects of emphatics/ blocking of emphasis spread by vowels in target syllables (*Target C word-initial)*

No.	Plain	Gloss	Emphatic	Gloss
1.	saabbad	Nonsense	sˤaabbad	Nonsense
2.	sabbad	Nonsense	sˤabbad	Nonsense
3.	sibbad	Nonsense	sˤibbad	Nonsense
4.	siibbad	Nonsense	sˤiibbad	Nonsense
5.	subbad	Nonsense	sˤubbad	Nonsense
6.	suubbad	Nonsense	sˤuubbad	Nonsense
7.	taabbad	Nonsense	tˤaabbad	Nonsense
8.	tabbad	Nonsense	tˤabbad	Nonsense
9.	tibbad	Nonsense	tˤibbad	Nonsense
10.	tiibbad	Nonsense	tˤiibbad	Nonsense
11.	tubbad	Nonsense	tˤubbad	Nonsense
12.	tuubbad	Nonsense	tˤuubbad	Nonsense
13.	ðaabbad	Nonsense	ðˤaabbad	Nonsense
14.	ðabbad	Nonsense	ðˤabbad	Nonsense
15.	ðibbad	Nonsense	ðˤibbad	Nonsense
16.	ðiibbad	Nonsense	ðˤiibbad	Nonsense
17.	ðubbad	Nonsense	ðˤubbad	Nonsense
18.	ðuubbad	Nonsense	ðˤuubbad	Nonsense

Effects of emphatics/ blocking of emphasis spread by vowels in target syllables (*Target C word-final)*

No.	Plain	Gloss	Emphatic	Gloss
1.	dabbaas	Nonsense	dabbaasˤ	Nonsense
2.	dabbaat	Nonsense	dabbaatˤ	Nonsense
3.	dabbaað	Nonsense	dabbaaðˤ	Nonsense
4.	dabbas	He stapled sth	dabbasˤ	Nonsense
5.	dabbat	Nonsense	dabbatˤ	Nonsense
6.	dabbað	Nonsense	dabbaðˤ	Nonsense
7.	dabbiis	Nonsense	dabbiisˤ	Nonsense
8.	dabbiit	Nonsense	dabbiitˤ	Nonsense
9.	dabbiið	Nonsense	dabbiiðˤ	Nonsense
10.	dabbis	Staple!	dabbisˤ	Nonsense
11.	dabbit	Nonsense	dabbitˤ	Nonsense
12.	dabbið	Nonsense	dabbiðˤ	Nonsense
13.	dabbus	Nonsense	dabbusˤ	Nonsense
14.	dabbut	Nonsense	dabbutˤ	Nonsense
15.	dabbuus	A pint	dabbuusˤ	Nonsense
16.	dabbuut	Nonsense	dabbuutˤ	Nonsense
17.	dabbuuð	Nonsense	dabbuuðˤ	Nonsense
18.	dabbuð	Nonsense	dabbuðˤ	Nonsense

Appendix B

Word-final target C and blocking of high consonants

No.	Plain	Gloss	Emphatic	Gloss
1.	d**a**ʃʃas	Nonsense	d**a**ʃʃasˤ	Nonsense
2.	d**a**ʃʃat	Nonsense	d**a**ʃʃatˤ	Nonsense
3.	d**a**ʃʃað	Nonsense	d**a**ʃʃaðˤ	Nonsense
4.	d**a**dʒdʒas	Nonsense	d**a**dʒdʒasˤ	Nonsense
5.	d**a**dʒdʒat	Nonsense	d**a**dʒdʒatˤ	Nonsense
6.	d**a**dʒdʒað	Nonsense	d**a**dʒdʒaðˤ	Nonsense
7.	d**a**jjas	Nonsense	d**a**jjasˤ	Nonsense
8.	d**a**jjat	Nonsense	d**a**jjatˤ	Nonsense
9.	d**a**jjað	Nonsense	d**a**jjaðˤ	Nonsense

Word-initial target C and blocking of high consonants

No.	Plain	Gloss	Emphatic	Gloss
1.	sa**ʃʃa**d	Nonsense	sˤa**ʃʃa**d	Nonsense
2.	ta**ʃʃa**d	Nonsense	tˤa**ʃʃa**d	Nonsense
3.	ða**ʃʃa**d	Nonsense	ðˤa**ʃʃa**d	Nonsense
4.	sa**dʒdʒa**d	Made sb prostrate.	sˤa**dʒdʒa**d	Nonsense
5.	ta**dʒdʒa**d	Nonsense	tˤa**dʒdʒa**d	Nonsense
6.	ða**dʒdʒa**d	Nonsense	ðˤa**dʒdʒa**d	Nonsense
7.	sa**jja**d	He went straight.	sˤa**jja**d	Nonsense
8.	ta**jja**d	Nonsense	tˤa**jja**d	Nonsense
9.	ða**jja**d	Nonsense	ðˤa**jja**d	Nonsense

Appendix C

Carryover emphasis spread and stress (emphatic)

No.	emphatic	Gloss	emphatic	Gloss
1.	**sˤá**bbad	Nonsense	**sˤa**bbaˈːd	Nonsense
2.	**tˤá**bbad	Nonsense	**tˤa**bbaˈːd	Nonsense
3.	**ðˤá**bbad	Nonsense	**ðˤa**bbaˈːd	Nonsense

Carryover emphasis spread and stress (plain)

No.	plain	Gloss	plain	Gloss
1.	**sá**bbad	Nonsense	**sa**bbaˈːd	Nonsense
2.	**tá**bbad	Nonsense	**ta**bbaˈːd	Nonsense
3.	**ðá**bbad	Nonsense	**ða**bbaˈːd	Nonsense

Appendix (D)

Anticipatory emphasis spread and stress (emphatic)

No.	emphatic	Gloss	emphatic	Gloss
1.	b**ásˤsˤ**ad	Nonsense	b**asˤsˤ**aˈːd	Nonsense
2.	b**átˤtˤ**ad	Nonsense	b**atˤtˤ**aˈːd	Nonsense
3.	b**áðˤðˤ**ad	Nonsense	b**aðˤðˤ**aˈːd	Nonsense

Anticipatory emphasis spread and stress (plain)

No.	plain	Gloss	Plain	Gloss
1.	b**áss**ad	Nonsense	b**ass**aˈːd	Nonsense
2.	b**átt**ad	Nonsense	b**att**aˈːd	Nonsense
3.	b**áðð**ad	Nonsense	b**aðð**aˈːd	Nonsense