THE ACOUSTIC AND PERCEPTUAL CORRELATES OF EMPHASIS IN

URBAN JORDANIAN ARABIC

BY

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Abstract

Acoustic and perceptual correlates of emphasis, a secondary articulation in the posterior vocal tract, in Urban Jordanian Arabic were studied. CVC monosyllables and CV.CVC bisyllables with emphatic and plain target consonants in word-initial, word-medial and word-final positions were examined. Spectral measurements on the target vowels at vowel onset, midpoint and offset revealed a significant increase in F1 and F3 and a decrease in F2 in emphatic compared to plain environments. Emphasis was observed more in the environment of high and low front vowels than high back vowels, anticipatory emphasis spread was more salient than perseveratory emphasis spread, and males showed more emphasis than females. Spectral moment measures of the target consonants themselves revealed inconsistent or no effects of emphasis. Results from a perception experiment with cross-spliced monosyllables showed that perception of emphasis follows the vowel, not the consonant, in the emphatic syllable, thus confirming the results of the acoustic experiments.

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Chapter One

Introduction and literature review

1.1. Introduction

Emphasis is a feature of Semitic languages under which some consonants are produced with a secondary articulation in the back part of the oral cavity. Emphasis has been studied extensively in many dialects of Arabic, mostly through the contrast between plain and emphatic segments. It has been dealt with as a phenomenon pertaining to pharyngealization and/or uvularization. Both pharyngeals and uvulars are produced in the back part of the oral cavity with slightly varying places of articulation. Many sounds in Semitic languages are primarily produced in this region, and secondary articulation involving this region is also characteristic of Semitic languages.

Research on emphasis dates back to the era of classical Arab linguists in the eighth century AD. They described emphasis in terms of production with scattered attempts to describe the vocal tract configuration during the production of emphatics. A large number of the studies that investigated emphatics were either articulatory, focusing on describing the configurations of the articulators involved in the production of emphatics, or phonological, concentrating on aspects such as the feature RTR (Retracted Tongue Root), emphasis domain, emphasis spread, and emphasis blockers. Some of the more recent studies on emphasis focused on sociolinguistic aspects of emphasis pertaining in particular to gender distinctions in the production of emphasis.

A considerably increasing number of studies have been examining the acoustic correlates of emphasis. However, thorough investigations of the perceptual mapping of these correlates have been very scarce. Despite the substantial literature on emphasis, many aspects of the phenomenon are still murky due to a number of reasons such as variations from one language/dialect to another, the design of the experiments conducted, the number and dialectal background of the subjects that participate in these studies, limitations on the consonants and vowels used in the data, to mention a few.

While some of the Semitic languages have lost the emphasis distinction, Arabic still retains the full set of emphatics reconstructed from Proto-Semitic at a number of places of articulation (Versteegh, 2001; Watson, 2002). All dialects of Arabic have minimal pairs of coronal obstruents where the difference is only in terms of emphatic vs. plain. The present study uses data obtained from Urban Jordanian Arabic (UJA). It presents an investigation of the acoustic and perceptual correlates of emphasis in UJA.

1.2. Emphasis

Different definitions of emphasis agree that it involves a posterior articulation. Studies that used different dialects highlighted certain aspects of the definition of emphasis. Among these, Walter Lehn provides a satisfactory definition of emphasis that encompasses several aspects of the phenomenon. He says that:

> Emphasis is the cooccurrence of the first and one or more others of the following articulatory features: (1) slight retraction, lateral spreading, and concavity of the tongue and raising of its back (more or less to what has been called velarization), (2) faucal and pharyngeal constriction (pharyngealization), and (3) slight lip protrusion or rounding (labialization), and (4) increased tension of the entire oral and pharyngeal

musculature resulting in the emphatics being noticeably more fortis than the plain segments.

(Lehn, 1963:30-1)

Lehn's definition accounts for more than one type of emphasis at the level of articulation. Lehn justifiably makes a distinction between emphasis and pharyngealization proper. Though most emphatics are pharyngeal, it has been found that some emphatics are labialized in addition to their pharyngealization (Watson, 1999). Other definitions of emphasis are more restricted to pharyngealization. Some Arab grammarians refer to emphasis as *ʔitbãq* (literally, 'covering') and define it as "spreading and raising of the tongue" (Lehn, 1963: 29). Others use the word *ʔistiʕlaaʔ* (literally, 'elevation') and define it as "elevation of the dorsum," *ibid.* Delattre (1971: 129) describes the production of pharyngeals as one in which "the root of the tongue assumes the shape of a bulge and is drawn toward the vertical back wall of the pharynx to form a stricture. This radical bulge generally divides the vocal tract into 2 cavities: one below extending from the stricture to the glottis, the other above extending from the stricture to the lip." This provides a detailed description of the mechanism of the production of pharyngeal sounds but it does not adequately account for the production of emphatics as it involves another secondary yet crucial articulation. Kahn (1975: 39) defines emphasis as a "secondary pharyngeal articulation of certain consonants, usually stops and fricatives." She adds that the articulation of emphasis involves the organs engaged in the production of a given sound in addition to a secondary pharyngeal articulation. This means that any consonant in Arabic, more precisely in Cairene Arabic, the dialect she studies, can be emphatic. Though obstruents are the most common emphatics in Arabic, some studies conducted on Cairene Arabic show that emphasis can be a property of laterals and rhotics, too (*Cf*. Ferguson, 1956). This is also supported by later reports from other studies conducted on other dialects of Arabic. Zavadovsky (1981) cited in Zemánek (1996) reports that in the Mauritanian dialect each consonant can have its emphatic and non-emphatic counterpart.

McCarthy (1994: 38) states that emphasis studied in different dialect regions in the Arab world is always characterized by a "constriction in the upper pharynx". He distinguishes between these emphatics and pharyngealized consonants claiming that while the former ones are purely emphatic, the latter ones should be called uvularized – affected by another set of back segments, i.e., uvulars: /q, χ, ʁ/.

Davis (1995: 465) defines emphasis, which corresponds, as he posits, to pharyngealization, as the phenomenon of producing sounds “with a primary articulation at the dental/alveolar region and with a secondary articulation that involves the constriction of the upper pharynx.” He also provides an account for bilabial emphasis in Arabic, which adds bilabials to the class of possible emphatics, not confining it to the dental/ alveolar place of articulation. Emphasis at the labial region was later reported by Watson (1999: 289) in a dialect of Yemeni Arabic. She says that “emphasis has two articulatory correlates: pharyngealization and labialization,” and reports some examples from Yemeni Arabic though there is a clear lack of minimal pairs at the labial place of articulation. The bilabial consonant mentioned here is the bilabial nasal /m/. This segment does not have an intrinsically emphatic counterpart. There is a set of minimal pairs reported in the literature where /m/ is emphatic in one case and plain in the other – /ma:lak/ vs. /mˤa:lak/, 'your (masc. 2nd person) money, and 'what's wrong with you (masc. 2nd person)?' respectively. Another segment that shows similar behavior is /l/ in sentences like /walla:hu/ and /walˤlˤahu/, 'he appointed him' and 'by God,' respectively. These occurrences are not common in Arabic, and therefore I will not discuss them in detail.

One of the most detailed studies of emphasis has been conducted by Card (1983). She discusses emphasis from the phonological and phonetic perspectives in addition to describing the articulation of emphasis. Rather than giving a brief definition of emphasis, she provides a more detailed description of this phenomenon that I will leave for the next section. More recent investigations on emphasis were provided by Laufer and Baer (1988) who studied emphasis in Hebrew and Arabic, Zawaydeh (1999) who studied gutturals in Arabic, Watson (2002) who found evidence for emphasis in uvulars and bilabials, and Khattab, Al-Tamimi, and Heselwood (2006) who studied the gender differences in the use of /t/ and /tˤ/ in Jordanian Arabic. Their studies also fit better in the next section. In summary, all previous definitions stress that the production of emphatics involves a set of features that engage the pharynx in a mechanism much similar to the production of pharyngeals.

1.3. Urban Jordanian Arabic (UJA)

One of the interesting debates in the literature is concerned with the linguistic situation in Arabic. It is common to engage in discussions about the relation between Modern Standard Arabic and the different dialects, and also the relation between these dialects themselves and the different divisions of dialectal regions, hence the need to give a clear idea about the dialect of Arabic from which the data for this study were collected. The question of 'what dialect of Arabic are you studying?' has for a long time been of interest to linguists. The linguistic situation within the Arab world is easy to describe: each Arab community speaks its own dialect and understands a host of other Arabic dialects including MSA, and to a lesser extent Classical Arabic (CA). Due to the wide distribution of Egyptian movies and sitcoms in the Arab world, Egyptian Arabic seems to be the most widespread dialect of the Arab world. Within each country, there are distinct sub-dialects. Differences between these sub-dialects are more often than not related to dissimilarity in the consonantal rather than the vocalic inventory. These distinctions are usually hard to detect. For example, it is hard for a non-Moroccan speaker of Arabic to distinguish different Moroccan dialects, to which he/she will collectively refer as 'Moroccan Arabic'. Similarly, Jordanian Arabic (JA) is commonly spoken by Jordanians; however, there are different sub-dialects within what is commonly referred to as JA that are hardly known to non-Jordanians. One of the relatively vivid investigations of JA which addresses the linguistic situation in Jordan is Suleiman (1985). He provides an investigation of the linguistic varieties, the classical/colloquial dichotomy referred to as diglossia, that dominate the scene in

Jordanian Arabic, focusing on the linguistic practices of the educated groups in Jordan. He collected data from 40 students at Yarmouk University in Jordan by means of personal interviews and questionnaires. He found that the linguistic situation in Jordan is best described as triglossic consisting of Classical Arabic, Colloquial Arabic and MSA (p. 93). He divides JA into three dialectal regions: the ‘Madani,’ represented in the urban centers, the ‘Fallahi,’ spoken in rural areas, and the ‘Bedouin,’ spoken by the non-sedentary nomads, (p 13). These dialectal regions of JA differed in the consonantal inventory. A more recent description divides JA into four sub-dialects: Urban, Rural, Bedouin and Ghorani, (Zuraiq and Zhang, 2006). UJA is spoken by people living in the major cities, including the capital city, the Rural dialect is spoken by villagers, mostly from the northern villages of Jordan, the Bedouin dialect is spoken by the Bedouins in the north east, middle and south of Jordan. And finally, the Ghorani dialect is spoken by farmers and people living in the Jordan valley. As mentioned earlier, these dialects differ in their consonantal inventories while the vowels are essentially the same. The consonant inventory of UJA is shown in Table 1.

Table 1. Consonant inventory of Urban Jordanian Arabic (Zuraiq and Zhang, 2006)

	Labial	Labio-dental	Inter-dental	Alveolar	Palato-alveolar	Palatal	Velar	Pharyn-geal	Glottal
Plosive	b			t d tˤ dˤ			k g		ʔ
Nasal	m			n					
Trill				r					
Fricative		f	θ ð ðˤ	s z sˤ	ʃ		x ɣ	ħ ʕ	h
Affricate					dʒ				
Approximant				l					
Glide	w					j			

1.4. The articulatory and acoustic correlates of emphasis

As mentioned earlier, emphasis has been mostly studied from a phonological perspective. However, many of the phonological observations might very well map on to the acoustics of emphasis. Sibawayh, cited in Semaan (1968), described the articulation of emphatic sounds as early as the eighth century AD. Sibawayh uses the term *ʔitbãq*, literally 'covering,' to refer to emphasis. He says that emphatic sounds are produced by "the part of the tongue which is the place of their utterance being closely covered in their utterance by what is opposite to it of the palate" Semaan (1968: 45). He adds that in the production of emphatics "you raise it [the tongue] towards the palate." *ibid.* He also says that if it was not for emphasis, then /tˤ/ would be /d/, /sˤ/ would be /s/, /zˤ/ [1] would be /ð/ and /dˤ/ would disappear from the language, (*ibid* p. 46). In other words, Sibawayh suggests that the emphasis distinction creates minimal pairs differing

[1] Semaan uses this phonetic symbol to refer to the emphatic voiced dental fricative.

in the feature [+emphatic] or [-emphatic]. This description pairs the /tˤ/ with the /d/ rather than the /t/, where it should be, having in mind that the emphatic/ plain minimal pairs agree in place and manner of articulation but differ only in emphasis. This account also draws heavily on the physical observation of the speech organs that are brought together in the production of emphatics. It should be noticed here that a clear account of the status of these emphatics remains unavailable. Though Classical Arabic (CA), the variety of Arabic spoken during the early Islamic era, retains the same orthography as Modern Standard Arabic (MSA), it has undergone many changes at the phonetic level. It is due to these and other changes that we now have MSA. A simple match of the orthographic symbols to the same phonetic realizations of MSA is likely misleading.

Another account in the medieval literature on emphatics is sketched by Card (1983). In addition to her account of Sibawayh's study, much similar to what Semaan has presented, she discussed Ibn Sina (980 – 1037) – known in the western literature as Avicenna. Ibn Sina was a physician and his account of these sounds is much affected by his scientific background. As an example, as discussed by Card, (1983: 9), he describes the production of the sounds /tˤ/, /t/, /d/, saying that they have the same place of articulation. "For /tˤ/ the air is restricted by the larger part of the tongue tip and the two sides of the tongue. A depression is formed in the center of the tongue, which resonates as the air is forcibly driven out. The /t/ has similar articulation but only the tongue tip restricts the air." As for the sound /d/, Ibn Sina states that, "there is no covering of the palate," and "the air is not strongly restricted," hinting probably at the energy of voicing in the vocal folds. This, I think, is an insightful description of these three phonemes in Arabic much valued at a time when very few tools, if any, were available to provide more sophisticated descriptions. For other descriptions of emphatic as well as plain sounds of Arabic, Ibn Sina uses terminology such as 'air bubbles' and 'yielding membranes,' *ibid*, which are not as linguistic as those used by Sibawayh, yet his observations are still linguistically valid.

These two accounts that have been presented give us an idea about emphasis but the descriptions of the sounds might not be totally valid to account for the same sounds that are now present in different dialects of Arabic. Sibawayh's and Ibn Sina's descriptions cover the era from the eighth to the tenth century A.D. and possibly for a short time after that. However, in light of the inevitable change that affects many sounds of the world's languages over time, descriptions of certain sounds have to differ by extents compatible with the degree of change.

Modern studies of emphasis have changed their focus from descriptions solely based on observation to more detailed and accurate explanations made possible by available techniques. Marcáis, as discussed by Card (1983: 13) investigated the articulation of emphatics in the 1940s making use of palatograms and radioscopy of the vocal tract. He found that the articulation of emphasis involves "muscular tension and retraction of the prominent articulating organs." "The tongue root approaches the back of the pharynx, with the result that the back of the tongue forms a 'collapsed plateau', dipping away from the palate." The feature that holds for all descriptions of the production of emphatics so far is that they all involve upper pharyngeal constriction. A distinction has to be made here between pharyngeals and pharyngealized segments. The term pharyngeals refers to the sounds whose primary articulator is the pharynx whereas the term pharyngealized, used to describe emphatics, means that the pharynx is the secondary articulator for sounds articulated primarily with other speech organs. Ghazeli (1977) shows the distinction in the production of pharyngeals and pharyngealized segments. Using cinefluographic films, he shows that for pharyngeals such as /ʕ/ and /ħ/ the greatest constriction was located below the epiglottis, while the greatest constriction for emphatics occurs in the upper pharynx. This suggests that the production of these two types of sounds is unrelated – giving no legitimacy for using the two terms interchangeably as some linguists do.

Lehn (1968: 31) has noticed other features of emphasis. In his phonological study, he mentions that features of emphasis do not hold for speakers of different dialects to the same degree. He observed that in Cairene Arabic, emphasis is more characteristic of men than women and that effects of emphasis on adjacent segments, i.e. emphasis spread, are also not similar. He does not, however, provide experimental support to validate his statements that are built on articulatory impressions. If it is true that women emphasize less than men do, we still need to know if this occurs in all environments and in all dialects. These observations are mostly impressionistic. Another characteristic of emphasis that has been frequently observed and has experimental support is that emphatics affect adjacent vowels by dragging them to the low back position, hence lowering their F2 frequencies. With this in mind, Lehn's observation that "all plain consonants occur before plain vowels" *ibid* is straightforward. To that he adds that emphasis never occurs as the only feature of any segment in any environment; "its minimum domain is CV". Lehn is the first one to establish that the minimum emphasis domain is the syllable. He states that the minimum emphasis domain is the syllable and that the maximum domain, later referred to as emphasis spread, is the utterance. Further, he says that emphasis domain is calculated at the syllable level, which means that a whole syllable is either emphatic or plain, (p. 37). For this last argument, Lehn cites examples such as /tˤi:n/ vs. /ti:n/, 'mud' and 'figs', respectively; and /zˤu:r/ vs. /zu:r/, 'perjury' and 'visit' (imperative), respectively. For these pairs, subsequent studies (Card 1983, Davis 1995, and Watson 1999) report that the long vowels block emphasis spread and are phonologically opaque to emphasis. However, vowels blocking emphasis do not violate the minimum emphasis domain requirement. In light of the fact that the present study is devoted to the acoustics of emphasis and perception of emphasis, it remains unknown whether phonological opacity applies to phonetic correlates.

Kahn (1975) compared the production of emphatics among males and females. She found that emphatics in Cairene Arabic do not lower F2 frequency values to the same degree for male and female speakers. Instead, the extent of F2 lowering for adjacent segments, an indication of emphasis, is greater for male speakers than for female speakers. This suggests that male speakers ‘emphasize’ more than female speakers, seemingly an acoustic replication of Lehn’s (1968) phonological observation. Kahn also tested a number of non-Arab speakers of American English who had been trained by an Arab male speaker to produce emphatics and found that there was no significant gender difference in their articulation of emphatic sounds. She concluded that “among Arabs, the magnitude difference in the formant frequencies between men and women was found to be much greater than anatomically predicted by Fant and the direction of sex-related formant differences was opposite to Fant’s predictions.” (p. 38). The finding that differences in F2 frequencies between emphatic and plain segments were smaller for native female than male speakers of Arabic (p.42) should be attributed to sociolinguistic factors. If these patterns were due to anatomical properties, we would expect both American and Cairene female speakers to emphasize less than males. The fact that this was not the case suggests that both male and female speakers *can* emphasize by similar degrees but don’t for sociolinguistic reasons: softening harsh sounds, avoiding course sounds in favor of more ‘feminine’ sounds. That is, female speakers intentionally emphasize less than males. Similar findings have been reported in later research: Royal (1985: 155 - 157) on Gamaliya, a dialect of Egyptian Arabic, and Haeri (1996: 70 - 74) also on Cairene Arabic. However, results contrary to the ones mentioned above have also been reported. Al-Masri & Jongman (2004) found that females had a greater degree of F2 lowering in emphatic segments, meaning that they ‘emphasized’ more than male speakers did.

Davis (1995) examined two dialects of Palestinian Arabic: a northern dialect and a southern dialect. His analysis is phonologically motivated. He considers applications of Grounded Phonology to account for emphasis spread in these two dialects. Davis reports that emphasis spread behaves asymmetrically: leftward emphasis is not blocked for the entire word but rightward emphasis is always blocked by [+high, –back] vowels (p. 468). This goes against what Lehn suggested, namely that the vowels /i:/ and /u:/ always block emphasis spread, and it actually excludes the vowel /u:/ from being opaque.

Davis' findings support the assumption that different dialects show asymmetries in the characteristics of emphasis spread with respect to the so-called opaque segments that block emphasis spread, and the direction of spreading. In more recent phonological accounts put forward by Davis (1995) and Watson (1999), emphasis is realized by the spread of the feature Retracted Tongue Root [RTR] to adjacent segments. This, I think, maps on to the phonetic parameter of low F2. This mapping, however, might very well be non-linear. In other words, the same distance of spread of the feature [RTR] in the underlying representation might not correspond to a comparable lowering of F2 values of the same segments in the same directions.

Card (1983) divides her investigation of emphasis into two parts: phonetic and phonological. Having established a relatively clear account of the phonological attributes of emphasis, I shall focus on the phonetic part of her study. Card studied emphasis in Palestinian Arabic and found evidence for the lowering effect of emphasis on F2 frequency for segments in emphatic environments compared to higher frequencies for corresponding segments in plain environments. In addition to this by-then clear characteristic of emphasis, she found that emphasis spreads phonetically rightward and leftward in the whole word, (p.49). Furthermore, she found that if the emphatic segment is word-initial, then emphasis is likely to spread to an adjacent word. Secondary emphatics, i.e. those that acquire emphasis effects from neighboring segments through spread, do not have F2 frequencies as low as those that have segments with primary emphasis or as high as F2 frequencies of plain segments. Card noticed that emphasis spread is blocked in the presence of the vowels /i:/ and /u:/. The presence of these vowels in a word eliminated the main effect of emphasis, F2 drop. Interestingly, she reports that for one of the stimuli, /tˤi:r/, meaning ‘fly!’, she found a significant F2 drop despite the occurrence of a ‘blocking’ segment (p. 79).

Royal (1985) explored the sociolinguistic factors crucial in linguistic choice. She particularly investigated this choice in terms of the degree pharyngealization. Royal observed a general tendency among Cairene women to have markedly less pharyngealization than Cairene men. But with a closer look at her results, it is evident that this difference is ascribed to conventional choice rather than anatomical constraints. She found that older Gamalyian women, women of Gamalyia – a suburb of Cairo, display stronger pharyngealization than older Gamalyian men (Royal, 1985:165). This led Royal to question any anatomical constraints on the vocal tract configurations for men and women as far as their capability of pharyngealization is regarded. Another observation is that she noticed variability in the degree of pharyngealization among Gamalyian subjects in response to the sex of the listener. In other words, she found that the degree of emphasis varied depending on the gender of the addressee. These findings contradict Kahn's (1975). Similar findings, that is, differences ascribed to social norms rather than anatomical facts, were reported in the other studies mentioned above.

Another study was conducted by Laufer and Baer (1988) on emphasis in Hebrew and Arabic. They collected 300 minutes of video recordings and simultaneous audio recordings for nine Hebrew and Arabic speakers using a fiberscope in the upper pharynx. Their analysis shows that all the emphatic and pharyngeal sounds were made with qualitatively the same pharyngeal constriction but that the pharyngeal constrictions were more extreme for pharyngeal sounds than for oral emphatics. This provides more evidence for the fact that emphatics and pharyngeals should be distinguished, *cf*. McCarthy (1994).

Zawaydeh (1999) studied the phonology and phonetics of gutturals in a number of Arabic dialects. She distinguishes two types of gutturals but reports that they behave similarly. These two types of sounds are uvulars: /q, χ, ʁ/ and emphatics: /dˤ, tˤ, ðˤ, sˤ/. Most of her work is devoted to studying the uvular sounds in terms of their phonological and phonetic behavior. Zawaydeh supports McCarthy's (1994) argument that emphatics are uvularized sounds, neither velarized nor pharyngealized. Previous studies (Ali and Daniloff 1972; Al-Ani 1978) showed that emphatics can be pronounced with a secondary articulation either in the pharynx or at the velum. Zemánek (1996) reports much similar findings.

Zawaydeh presents results on the acoustic characteristics of gutturals. She posits that gutturals can be distinguished as one group consisting of emphatics, uvulars, pharyngeals and laryngeals. Her findings indicate that gutturals show similar but not identical acoustic behavior. For example, she reports that while pharyngeals are characterized by a raising of F1 for adjacent vowels, emphatics show a strong effect of F2 lowering for adjacent vowels. While effects of emphasis and uvularization can be blocked, the segments that cause blocking are not similar for both classes. She also distinguishes pharyngeals /ħ/ and /ʕ/ from emphatics in that pharyngeals do not cause F2 drop for adjacent vowels but only a significant raising for F1. Further, her findings show that F2 lowering spreads to adjacent syllables if it is triggered by emphatics not by pharyngeals. This is evident in UJA in that low vowels after emphatics are pronounced with a back allophone that does not appear after pharyngeals (p. 38 – 9). Zawaydeh also questions whether the spread of emphasis and uvularization is categorical or gradient. In other words, whether the F2 lowering or F2 raising of the vowel in the target syllable and F2 of adjacent vowels drop gradually or categorically. Her findings show that the drop is gradual but some discrepancies are also reported.

More recently, Watson (2002) provides an acoustic account of emphasis. She says that "the oral emphatics are typically marked by a compact acoustic spectrum through lowering of the upper frequency formant (principally F2) due to an enlarged mouth cavity, and a raising of F1 due to a reduced pharyngeal cavity.” (p. 270). She does not mention the effects of opaque vowels or the domain of emphasis.

Khattab, Al-Tamimi, and Heselwood (2006) investigated the gender differences in the production of /t/ and /$t^ʕ$/ in Jordanian Arabic. 10 speakers of JA (5 males and 3 females were from the northern part of Jordan, 2 females were from the capital city of Amman) produced 4 pairs of /t/ and /$t^ʕ$/ in word-initial positions with the vowels /i/ and /a/. They report lower F2 and higher F1 for vowels in emphatic environments compared to their plain counterparts regardless of gender, (p. 151). They also report longer VOT delays in /$t^ʕ$/ than in /t/ only for females. They conclude that females generally have a markedly less emphatic speech compared to males. In other words, VOT latencies were more pronounced in male speech. However, this result, as they later explain (p. 155) is compromised by the fact that the two female speakers that were from Amman are the ones that show less emphasis. This is in line with the findings of Royal (1985) on Gamalyian Arabic.

Another acoustic measure pertaining to emphasis is the locus equation. Locus equations are ‘straight line regression fits to data points formed by plotting F2 transitions along the *y* axis and their corresponding midvowel nuclei along the *x* axis,’ Sussman, McCafrrey, and Matthews (1991). They provide information about the place of articulation for the consonants, and also about the degree of coarticulation. Slopes generated by plotting the F2 Onset by F2 Vowel indicate the degree of coarticulation.

Yeou (1997) investigated locus equations for a set of emphatic consonants: /dˤ/, /tˤ/, /ðˤ/, /sˤ/ in Modern Standard Arabic spoken by native speakers of the Moroccan dialect. He found that locus equations reflected some place distinctions. He also reports that the pharyngealized set of consonants used in the study, which is the same set of primary emphatics used in the present study, emerged as a distinct class, 'having the flattest locus equation slopes of all consonants.' This points to minimal coarticulation between the consonants and the vowels.

Another measurement is the spectral moments (center of gravity, standard deviation, skewness and kurtosis). Norlin (1987) measured spectral moments for Egyptian sibilants /s/ and /sˤ/ in word-initial positions. He used FFT spectra created from a 26.5 ms sample taken after the first third of the sibilant, (p. 16). The target consonants he used /s/ and /sˤ/ were used in one vocalic environment /a:/.Norlin found that /sˤ/ had a significantly lower center of gravity (5974 Hz) compared to /s/ (6345 Hz), (p. 94). Jongman, Wayland, and Wang, (2000) found that a greater positive skewness indicates a concentration of energy in the lower frequencies.

Clearly, back articulation in several dialects of Arabic has triggered much research to find out its phonological, articulatory, acoustic and, to a much smaller extent, perceptual correlates. Many of these studies provide us with findings that help draw a better picture of this back articulation in Arabic. Now we know more about the mechanism of back articulation, spread of certain classes such as emphatics and uvulars, blocking segments, directionality of spread and the importance of locus equations. Despite these valuable findings, many of the studies in this respect suffer from certain limitations. Some are too general to the point that they deal with a relatively great number of back sounds despite the fact that the articulators of these sounds are different. As suggested by Perturbation theory (Chiba and Kajiyama,1942), not all back sounds have similar acoustic effects. Other limitations that are common include using data from different dialect regions, combining a limited number of subjects, and using data from the researcher himself/herself.

1.5. The perceptual correlates of emphasis

Perception of emphasis has received much less attention than the acoustics of emphasis. Obrecht (1968) conducted a study on the perception of emphasis in Lebanese Arabic. He synthesized a /$t^{ʕ}$i:-ti:/ continuum in which he varied F2 in 120 Hz steps from 1080 Hz to 1800 Hz; F3 was fixed at 3000 Hz and F1 was flat for all the experiments. Obrecht found that the perception of emphatics was categorical. The turning point between emphatic and plain occurred at an F2 around 1560 Hz. Stimuli higher were perceived as plain and stimuli lower were perceived as emphatic. He also found that the perception of emphasis depended largely on vowel quality. In a replication of Obrecht's experiments for the /$s^{ʕ}$i:-si:/ distinction in Moroccan Arabic, Yeou (1995) found similar results. He also found that the F1 transition lacks perceptual cues for the plain/ emphatic distinction. Ali and Daniloff (1974) on Iraqi Arabic found that the vocalic portion of the plain/ emphatic words included sufficient cues for listeners to detect the distinction.

Other studies that report on the perception of emphasis viewed the results in sociolinguistic terms related to gender, social selection, and existing linguistic norms (Kahn 1975; Alwan 1983; Wahba 1993; and Al-Wer 2000*b*). Kahn (1975) states that emphatics were equally perceived by native speakers of Arabic regardless of their gender.

Due to the apparent scarcity of studies on the perception of emphasis, our understanding of the characteristics of emphasis remains wanting. The previous studies either focused on the emphatic/plain consonant, not on the vowel, or used the whole word as the unit of perception. While focusing on the consonant gives us a good insight into the nature of the target obstruents involved in emphasis, using the whole word falls short of accounting for the source of the difference. Neither of them accurately investigates the characteristics of the vowel adjacent to the target consonants.

1.6. Statement of the problem

The present study examines the acoustic and perceptual correlates of emphasis in UJA. Many of the previous studies provided phonological accounts of emphasis including emphasis domain, emphasis spread, directionality of emphasis spread, and opaque vowels that delimit the domain of emphasis spread. Although several recent studies explored the acoustic characteristics of emphasis, many aspects of the acoustic signal for emphatic segments are still unclear. The relevance of the target consonants and vowels and their effects on the acoustics and perception of emphasis is still debatable. The present study focuses on the characteristics of the consonants by measuring their duration, spectral moments and locus equations; and also on the vowels by measuring their durations, F1, F2, and F3 at onset, temporal midpoint and offset of the vowel. The present study also tests whether the findings on the acoustics of emphasis map on to perception. That is, whether the perception of emphasis is realized most on the target consonant or on the target vowel, with reference to some characteristics of the consonants (manner) and the vowels (quality).

1.7. Rationale of the study

The current study examines the acoustics and perception of emphasis in UJA to provide a better understanding of this phenomenon in Arabic linguistics. It aims to further previous research on this matter and add deeper insights into the nature of emphasis. Despite the increasing number of acoustic studies conducted on emphasis, several factors contribute to the need for the present study. Much of the previous research had limitations on the number of subjects and the inconsistency of their dialects, the nature of the data used, the limited number of measurements, and in some cases the lack of statistical analyses. With regard to the perception of emphasis, research is very scarce to begin with. The limited number of studies on the perception of emphasis leaves this aspect of emphasis virtually unexplored.

1.8. Objectives of the study

The present study aims at first better clarifying the nature of emphasis in UJA. While many of the previous studies investigated emphasis in different dialects of Arabic, the present one helps complete the picture by using data from a less commonly studied dialect of Arabic. This should be helpful in enriching the different fields of Arabic linguistics and possibly paving the way for much needed future research on Arabic. One of the basic contributions of this study is to provide a better understanding of emphasis through a systematic approach that enables the author to report on the characteristics of the plain and emphatic segments by means of the measurements conducted. The relatively fine control on the consonant types, using the different vowels of UJA, using a relatively large and equal number of male and female subjects and large number of observations should allow for reliable results. In addition to contributing to the research on Arabic linguistics, a better understanding of the characteristics of emphasis at the levels of acoustics and perception will definitely be helpful for pedagogical purposes.

Chapter Two

Acoustic Study – the monosyllables

In this chapter, I present the first part of the acoustic study which deals with the monosyllables. This part aims to introduce the basic findings on the acoustic correlates of emphasis in UJA. Specifically, it aims to answer the following questions:

1. What are the characteristics of the plain/emphatic consonants?
2. Does manner of articulation of the consonants affect emphasis?
3. Are the effects of emphasis equally attested for different vowels?
4. How does emphasis spread within the syllable?
5. Where is emphasis realized most?
6. Does gender affect the degree of emphasis?

In accordance with perturbation theory (Chiba and Kajiyama, 1942), see also (Kent and Read, 24:1992), it is expected that the presence of a constriction in the back part of the vocal tract triggers F2 lowering and may raise F1 and F3. Many previous studies on emphasis unanimously report F2 lowering of the vowel in the same syllable with the target consonant (Al-Ani, 1970, 1978; Kahn, 1975; Ghazeli, 1977; Giannini & Pettorio, 1982; Card, 1983; Bukshaisha, 1985; Laufer & Baer, 1988; Haselwood, 1992; Zawaydeh, 1999; Al-Masri & Jongman, 2004; Khattab, Al-Tamimi & Heselwood, 2006 among others). Fewer studies report F1 raising (Klatt & Stevens, 1969; Al-Ani, 1970, 1978; Ghazeli, 1977; Giannini & Pettorio, 1982; Alwan, 1986; Butcher & Ahmad, 1987;

Laufer & Baer, 1988). And finally, Card (1983) reports no differences between F3 values in plain and emphatic environments. In terms of durations, Obrecht (1968) hinted that F2 consonant-vowel transitions were longer in emphatic positions compared to their plain counterparts. In Egyptian Arabic, Norlin (1987:76) found that there was a slight tendency for plain vowels to be longer than emphatic ones, especially for long vowels. Alioua (1995), however, reported contrasting results, namely that vowels following emphatic consonants had slightly longer durations than their plain counterparts. And finally, Norlin (1987) found lower center of gravity for word-initial emphatic fricatives compared to plain ones. Based on previous literature reviewed in Chapter 1, I make the following hypotheses:

1. Emphatic consonants will be slightly longer than their plain counterparts.

2. Vowel duration is not affected by emphasis.

3. Emphatic consonants will have a lower center of gravity than their plain counterparts. They are also expected to have a greater positive skewness due to the concentration of energy in the lower frequencies.

4. Locus equations will show flatter slopes for emphatic consonants compared to their plain counterparts.

5. F2 will be significantly lower for the vowels adjacent to the emphatic consonant.

6. F2 lowering will be strongest closest to the emphatic consonant.

7. The presence of an emphatic consonant will raise F1 and F3 in adjacent positions.

8. Gender does not affect emphasis; F2 lowering is expected to be similar for males and females.

2.1. Method

2.1.1. Subjects

Eight adult speakers (four males and four females) of UJA aged 20 to 39 years old (average age was 28.5 years) participated in the study. Three males, who were PhD students at the University of Kansas, and their spouses were living on the KU campus; the remaining male and female speakers lived in Fayetteville, AR. All of the subjects spoke the urban dialect of JA. Duration of stay in the US at the time of recording ranged from 3 months to 4 years (average duration of stay was 2.85 years). None of the subjects reported any known speech or hearing impairments.

2.1.2. Materials and Procedure

A list of 96 target CVC stimuli was prepared. The wordlist consisted of 48 pairs of words where the target consonant (the plain or emphatic consonant) was either word-initial or word-final. Each of the UJA vowels was used with each of the target consonants. Thus, four pairs of target consonants: /t/ - /tˁ/, /d/ - /dˁ/, /ð/ - /ðˁ/, and /s/ - /sˁ/were used word-initially and word-finally along with the 6 vowels of UJA: /i:/, /i/, /a:/, /a/, /u:/, and /u/ - yielding 48 words with plain consonants and 48 words with emphatic consonants. The consonant /b/ was used to fill up the remaining C slot. Thus, the study material consisted of CVb and bVC stimuli, see Appendix I. This yielded 48 nonwords (17 plain and 31 emphatic) that were all phonotactically acceptable in UJA. Subjects read the target words in a carrier sentence:/ˈʔiħ.ki *target word* ka.ˈma:n ˈmar.rah/ [Say *target word* again]. Subjects read 3 times from a wordlist that included

12 pages, each having one column. Each column consisted of 12 sentences – the first and last 2 sentences were fillers and did not include target words. Since Arabic short vowels are not written in full letters, diacritics were added to illustrate these vowels where they occurred. If subjects made a mistake while reading, they were instructed to resume reading two lines before the line in which the mistake was made. Speakers read the wordlist three times. Recordings were carried out in an anechoic chamber using a Digital Master DAT recorder (Fostex D-5) and a unidirectional microphone (ElectroVoice RE-20). Recordings were digitized at a 22050 Hz sampling rate using Praat speech analysis software (Boersma and Weenink 2005). Each subject was recorded individually and each recording session took approximately 12 minutes. Measurements taken from the three repetitions were averaged for each subject and the average was used for statistical analysis.

2.1.3. Measurements

For each consonant, duration was measured and spectral moments (center of gravity, standard deviation, skewness and kurtosis) were calculated. Spectral moments were calculated from FFT. All other measurements were taken from wide-band spectrograms. For consonants in word-initial position, duration was measured from the offset of the last segment of the carrier sentence, the vowel /i/, until the offset of the burst for stops or the end of the frication duration for fricatives. For word-final stops, duration was measured from the offset of the preceding vowel in the target word until the offset of the stop burst. For word-final fricatives, the duration was that of the frication. For fricatives, spectral moments were calculated with a 30-ms window centered around the temporal midpoint of the fricative. For stop consonants, spectral moments were calculated at the onset of the burst. As a result, window size for stop consonants varied depending on the duration of the burst, which ranged from 10 to 46 ms. The burst duration was longer, on average, for word-final stops compared to word-initial stops. In both positions, the average burst duration was longer for voiceless stops compared to voiced stops. In very few cases, the burst was very hard to locate. In these cases, the burst was estimated using auditory and visual cues and a window of 10 to 15 ms, depending on the duration of the burst, was placed over the estimated onset to calculate the spectral moment. For the target vowels, duration was measured and F1, F2 and F3 were measured at onset, midpoint and offset of the vowel. The vowel onset is coded as the point in the vowel closest to the onset of the target word and the vowel offset is the point in the vowel closest to the offset of the target word regardless of the position of the target consonant. In other words, in words with final target consonants, the frequency measurements at the vowel offset resemble the point closest to the consonant that triggers emphasis. Locus equations were also calculated for each consonant by fitting a regression line to F2 values measured at the onset and the temporal midpoint of each vowel where the target consonant was word-initial, or measured at the offset and temporal midpoint of the vowel where the target consonant was word-final. Figure 1 shows an example of where the measurements were taken.

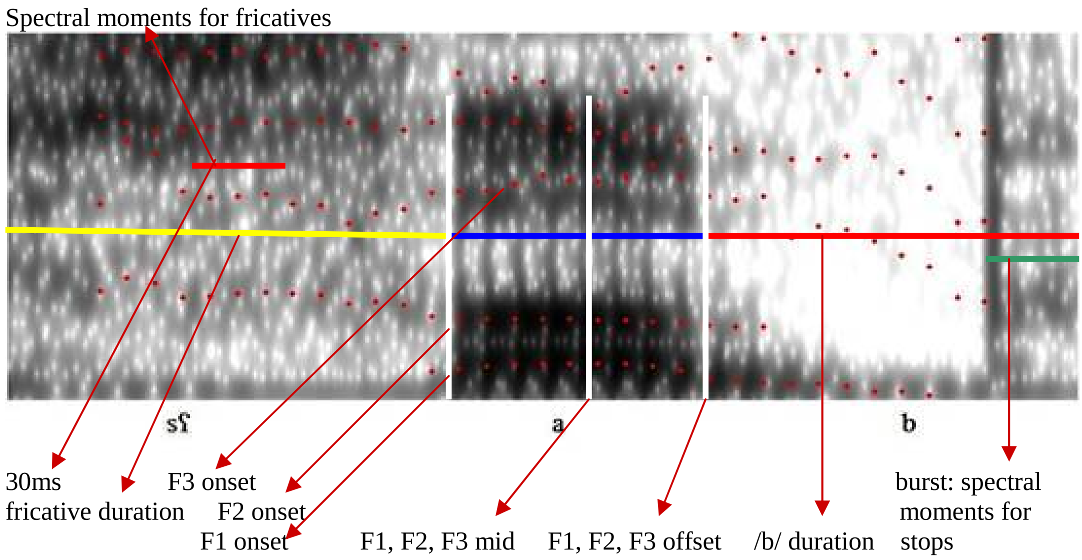

Figure 1: Illustration of the nature and locations of acoustic measurements

2.2. Analysis

To analyze the data, different ANOVA tests were conducted on all measurements. Bonferroni post hoc tests were also used. Twelve dependent variables and eight independent variables were used, see Table 1 below.

Table 1: Dependent and independent variables used in the study

No.	Dependent variables	No.	Independent variables
1	Target consonant duration	1	Consonant-type (plain, emphatic)
2	Duration of /b/	2	Vowel quality (high front, low front, high back)
3	Target consonant center of gravity	3	Vowel length (long, short)
4	Target consonant standard deviation	4	Target consonant position (initial, final)
5	Target consonant skewness	5	Target consonant voicing (voiced, voiceless)
6	Target consonant kurtosis	6	Target consonant manner (stop, fricative)
7	Vowel duration	7	Word type (real word, nonword)
8	Vowel F1 onset	8	Gender (male, female)
9	Vowel F1 midpoint		
10	Vowel F1 offset		
11	Vowel F2 onset		
12	Vowel F2 midpoint		
13	Vowel F2 offset		
14	Vowel F3 onset		
15	Vowel F3 midpoint		
16	Vowel F3 offset		
17	Center of gravity for /b/		
18	Standard deviation for /b/		
19	Skewness for /b/		
20	Kurtosis for /b/		

2.3. Results

In this section, I present the results of the acoustic study for the monosyllables. I will present the results on duration, formant frequencies, spectral moments and locus equations. Since the target consonant appears either word-initially or word-finally, I will divide the results accordingly. In all analyses, interactions between Consonant-type and Gender never showed any significant differences. Except for one analysis, the same applies for Word-type.

2.3.1. Duration

The results on target consonant durations in word-initial and word-final positions show that emphatic consonants were consistently longer than their plain counterparts, [F (1, 766) = 4.747, p = 0.030]. This effect, however, seems to result from word-final target consonants. Word-final emphatics are significantly longer than their plain counterparts, [F (1, 382) = 5.681, p = 0.018], whereas word-initial plain and emphatic consonants are not different in terms of duration, [F (1, 382) = 0.287, p = 0.592]. See Figure 2. The presence of an asterisk (*) indicates significant differences.

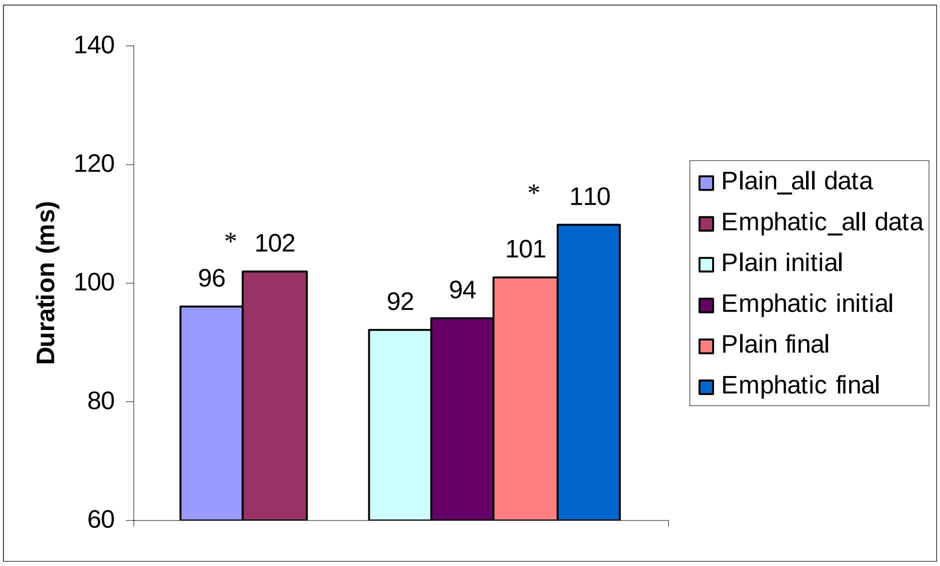

Figure 2: Target consonant durations

When the target consonants are further divided by manner, results show that this durational difference applies only to word-final stops. While word-final fricatives were not significantly different, [F (1, 190) = 0.665, p = 0.416], word-final emphatic stops were significantly longer than their plain counterparts, [F (1, 190) = 5.894, p = 0.016], see Figure 3 below.

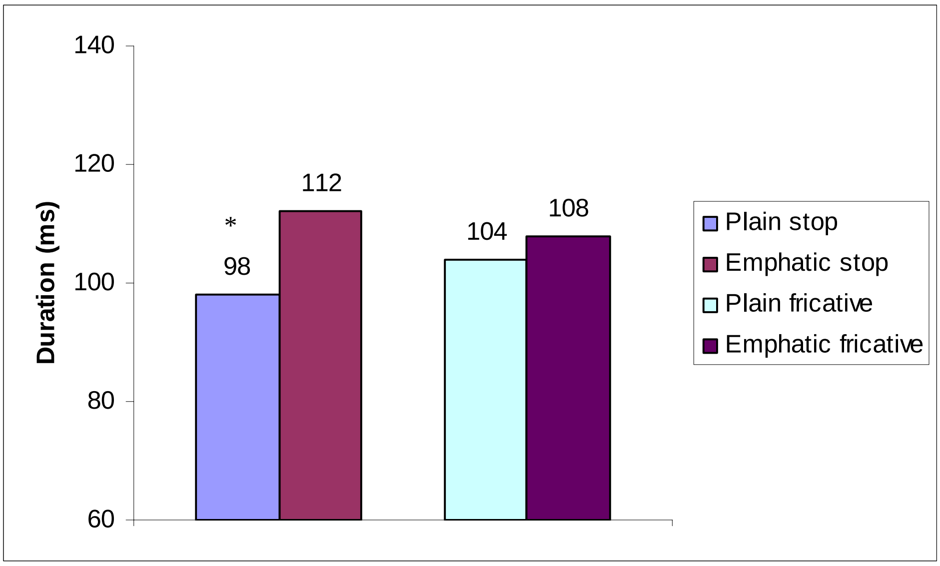

Figure 3: Target consonant duration in word-final positions by manner

No other significant main effects or interactions were found.

While the duration measurements show significant differences for the target consonants, vowel durations were not affected by emphasis. Mean vowel duration was 132 ms for vowels in plain environments and 134 ms for vowels in emphatic environments. No significant main effects or interactions were found.

All target words either started or ended with /b/. An investigation of durational differences of this consonant in the presence or absence of an emphatic segment yielded no significant differences. For all tokens, /b/ duration was 84 ms and 85 ms in plain and emphatic environments, respectively. Similar results for duration are maintained in words with initial emphatics: 88 ms in plain environments and 89 in emphatic environments. The same results are also obtained in words with final emphatics: /b/ duration is 80 ms in words with plain consonants and 81 ms in words with emphatic consonants. No significant main effects or interactions were found.

2.3.2. Formant frequency

In this section, I report on the three vowel formant frequencies, F1, F2 and F3 in three positions: vowel onset, midpoint and offset.

2.3.2.1. F1

Overall, vowels in emphatic environments have a higher F1 onset compared to vowels in plain environments. Including measurements from all data, F1 onset is 397 Hz in emphatic positions and 369 Hz in plain positions. This difference is significant, [$F(1, 766) = 26.402$, $p < 0.001$]. This difference holds for words where the emphatic is word-initial, F1 onset is 403 Hz in emphatic environments and 364 Hz in plain environments, [$F(1, 382) = 25.196$, $p < 0.001$]. The same comparison also yields significance in word-final emphatics, F1 onset is 390 Hz for vowels in emphatic positions, and 372 Hz for vowels in plain positions: [F (1, 382) = 5.194, p = 0.023], see Figure 4 below.

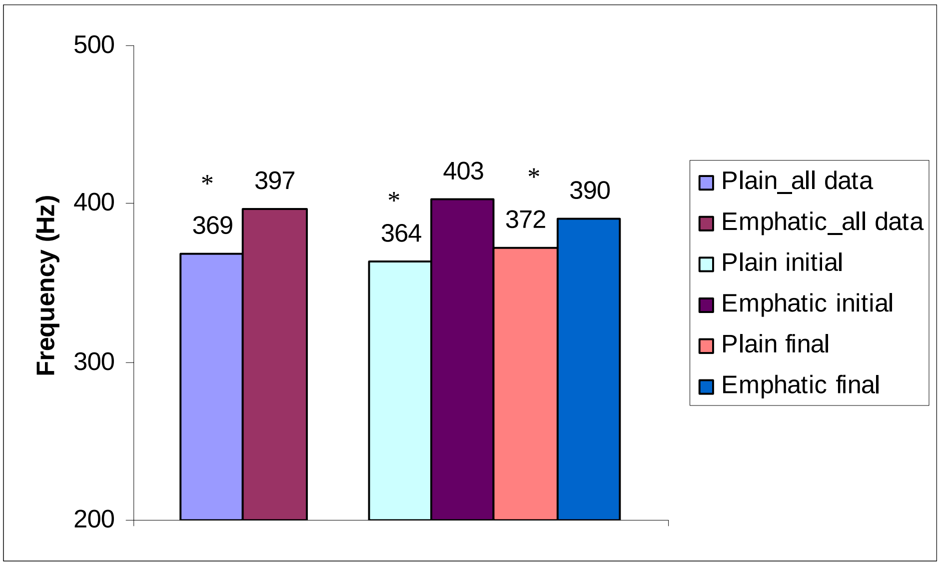

Figure 4: F1 at vowel onset

A Consonant-type by Position interaction reveals a trend. Though it does not show significance, [F (1, 767) = 3.599, p = 0.058], there is a tendency for F1 at vowel onset to rise by a larger extent in words with initial target consonants compared to words with final target consonants: 364 Hz to 403 Hz for words with initial target consonants compared to 372 Hz to 390 Hz for words with final target consonants; magnitudes of rise are 39 Hz and 18 Hz, respectively. No other significant main effects or interactions were found.

F1 at midpoint also shows significant differences. Across all data, vowels in the same syllable with the emphatic target consonants have a significantly higher F1 at midpoint than vowels in the same syllable with plain target consonants: 508 Hz and 480 Hz, respectively, [F (1, 766) = 5.448, p = 0.020]. However, when the data are divided by position, this difference is no longer significant. F1 midpoint for vowels in words with initial emphatics is 509 Hz, and 483 Hz for their plain counterparts, [F (1, 382) = 2.315, p = 0.129]. In words with emphatics in final position, F1 midpoint is 507 Hz in emphatic environments, and 477 Hz in plain environments, [F (1, 382) = 3.160, p = 0.076]. See Figure 5 below.

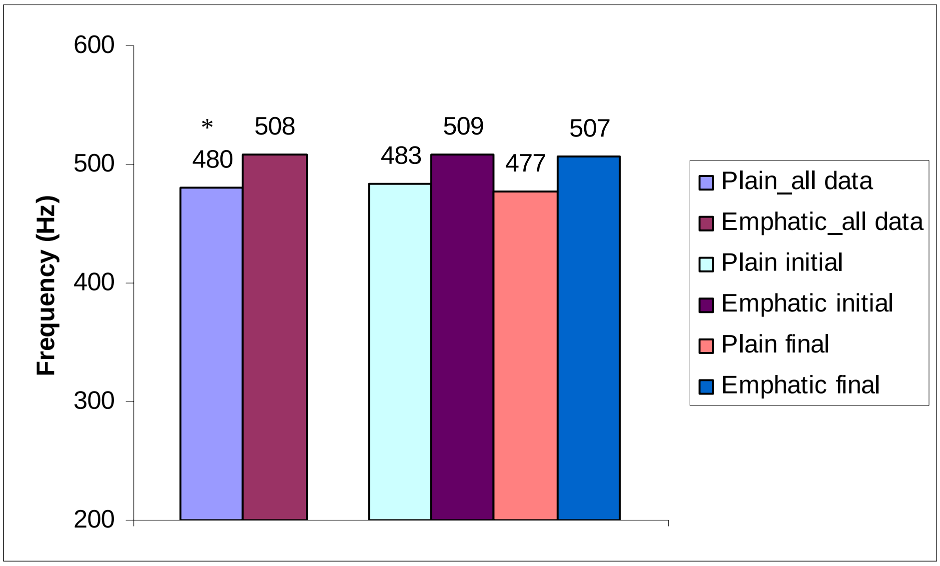

Figure 5: F1 at vowel midpoint

No other significant main effects or interactions were found.

At offset positions, F1 also shows significant differences. F1 offset is higher in emphatic positions than in their plain counterparts, 409 Hz and 381 Hz, respectively: [F

(1, 766) = 19.768, p < 0.001]. This difference is lost in words with initial target consonants but is maintained in word-final target consonants. F1 offset is 409 Hz in emphatic environments and 395 Hz in plain environments in words with initial emphatics. This difference is not significant, [F (1, 382) = 2.071, p = 0.151]. In words where the target consonant is word-final, F1 offset is 409 Hz in emphatic environments and 366 Hz in their plain counterparts, [F (1, 382) = 26.181, p < 0.001]. See Figure 6.

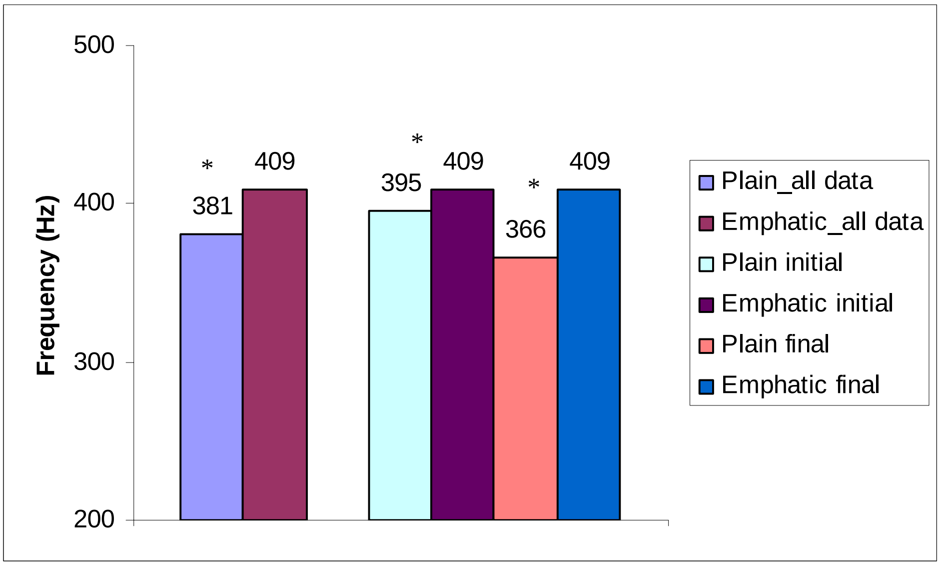

Figure 6: F1 at vowel offset

A Consonant-type by Position interaction shows that while words with final target consonants have a significantly higher F1 offset in emphatic environments (409 Hz) compared to plain environments (366 Hz), words with initial target consonants lack this distinction for F1 offset in emphatic positions (409 Hz) and in their plain counterparts

(395 Hz) [F (1, 767) = 5.365, p < 0.021]. See Figure 7 below. No other significant main effects or interactions were found.

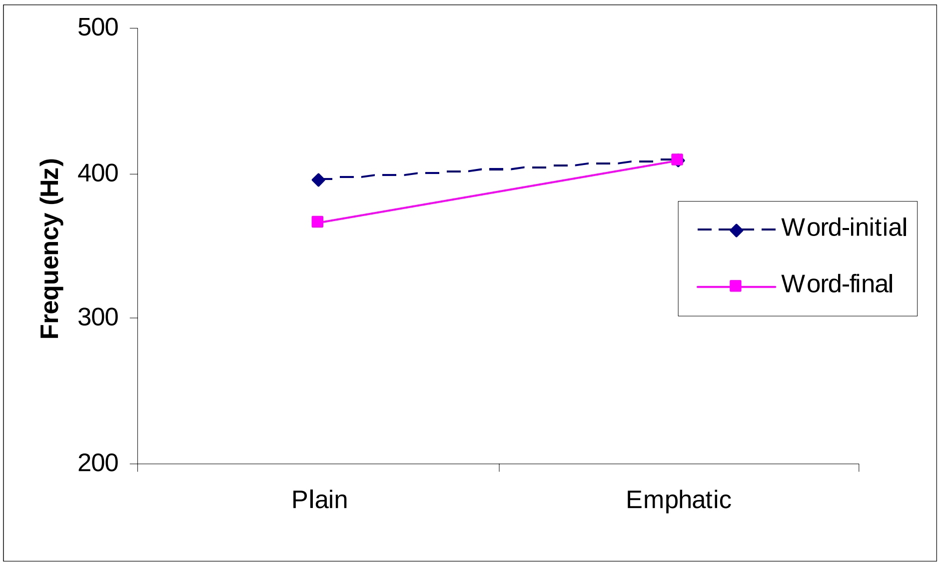

Figure 7: Consonant-type by Position interaction for F1 Offset

Since the F1 measurements were taken at three positions, it is worthwhile to look at the effects of emphasis across the three points of the vowel: onset, midpoint and offset. In words with initial target consonants, F1 is significantly higher in emphatic environments. This difference is significant only at the onset of the vowel – the point closest to the consonant that triggers emphasis. The effect diminishes as the measurement is taken further away from the target consonant, see Figure 8. Arrows stand for the direction of significant differences; absence of the arrows indicates absence of significant differences.

Similarly, in words with final target consonants, vowel F1 at the point closest to the target consonant (F1 offset in this case) is significantly higher in the emphatic environment. The effect diminishes at the vowel midpoint, though it shows a trend, and is significantly higher at the point further away from the target consonant, (F1 onset in this case). See Figure 9.

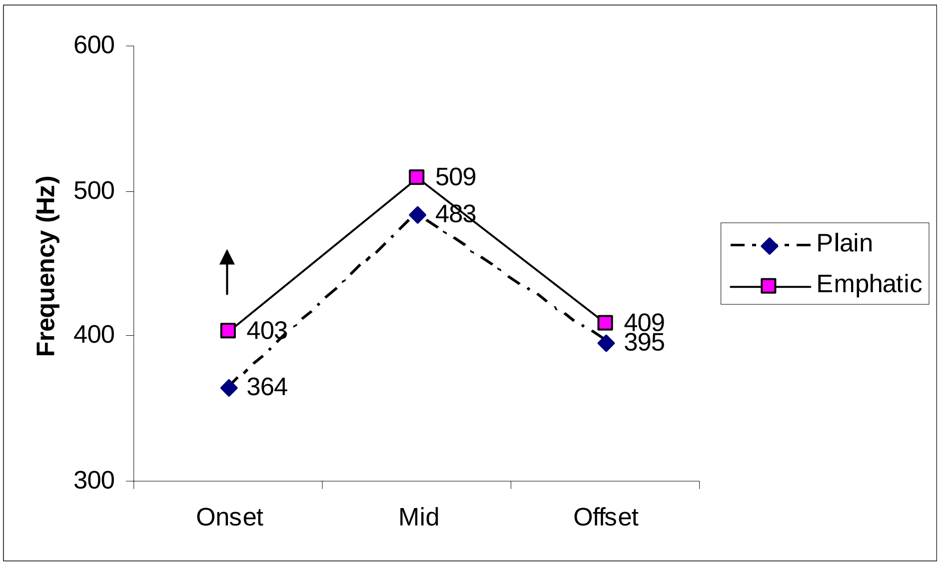

Figure 8: Vowel F1 in words with initial target consonants

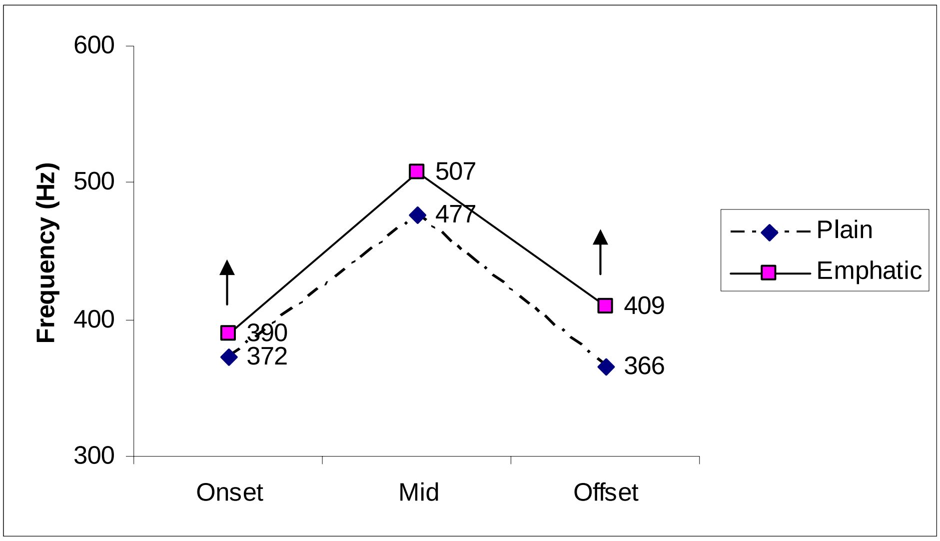

Figure 9: Vowel F1 in words with final target consonants

2.3.2.2. F2

Measurements for F2 across all data show that F2 is consistently lower in emphatic than in plain environments. F2 measured at the onset of the vowel in the same syllable with the target consonant shows significant lowering in the emphatic environment. Average F2 onset is 1332 Hz in emphatic environments and 1704 Hz in plain environments. This difference is significant, [$F(1, 766) = 212.738$, $p < 0.001$]. This difference is significant in both word-initial and word-final emphatics. In words with initial target consonants, F2 onset for vowels is 1332 Hz in emphatic environments and 1838 Hz in plain environments. This effect is significant, [$F(1, 382) = 342.174$, $p < 0.001$]. In words with final target consonants, F2 onset is 1341 Hz and 1569 Hz in emphatic and plain environments, respectively. This is also significant, [$F(1, 382) = 31.746$, $p < 0.001$]. See Figure 10.

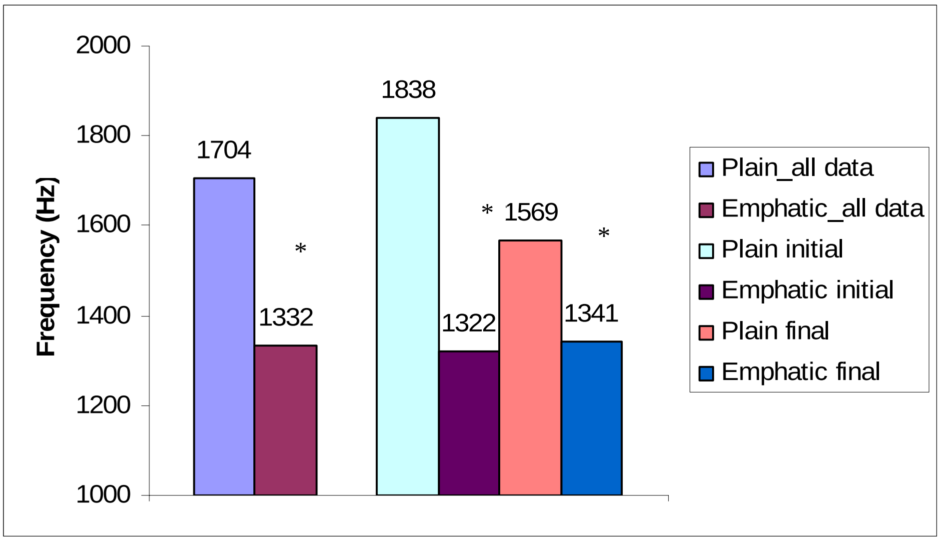

Figure 10: F2 at vowel onset

An interaction of Consonant-type by Position reveals significant differences [$F(1, 767) = 34.161$, $p < 0.001$]. The drop in F2 onset is significantly greater in words with initial emphatics (516 Hz) compared to words with final emphatics (228 Hz). Figure 11 shows this result.

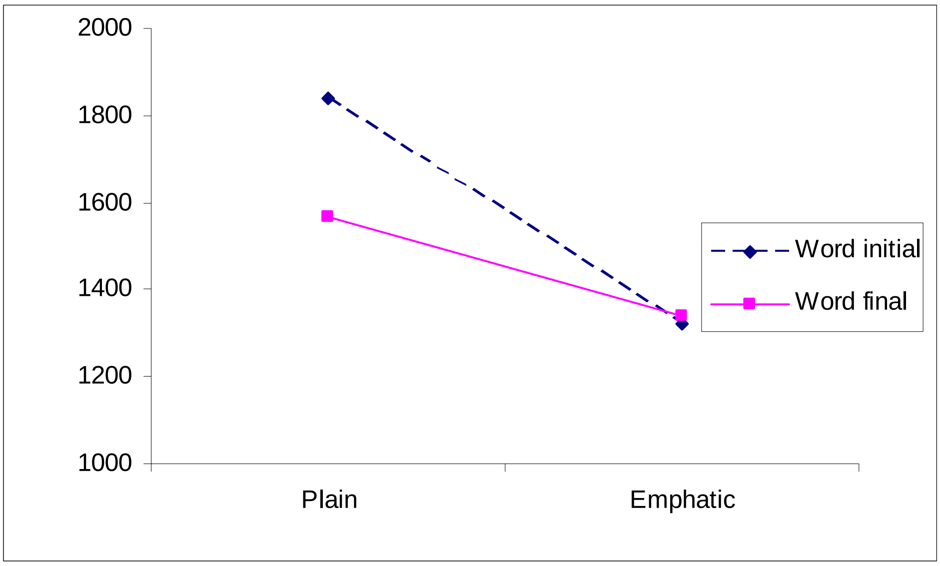

Figure 11: Consonant-type by Position for vowel F2 onset

In addition, a Consonant-type by Vowel Quality interaction reveals significant differences, [F (1, 767) = 15.544, p < 0.001]. While the effect of emphasis is similar for the front vowels /i:/ and /i/ and /a:/ and /a/, the F2 decrease for the back vowels /u:/ and /u/ is much smaller. Table 2 below shows these results. The same results are obtained for words with initial target consonants, [F (1, 383) = 13.043, p < 0.001], and for words with final target consonants, [F (1, 383) = 13.097, p < 0.001]. See Table 3 below. No other significant main effects or interactions were found.

Table 2: F2 onset by vowel quality

	Plain (Hz)	Emphatic(Hz)	Plain-emphatic	% difference
High front	2069	1627	442	21
Low front	1666	1221	445	27
High back	1376	1146	230	17

Table 3: F2 onset by vowel quality in word-initial and word-final target consonants

	Plain (Hz)		Emphatic (Hz)		% difference	
	Initial	Final	Initial	Final	Initial	Final
High front	2131	2007	1486	1769	30	12
Low front	1769	1564	1240	1202	30	23
High back	1616	1137	1241	1052	23	7

Vowel F2 at midpoint shows a significant drop in emphatic environments. Vowels in emphatic environments have an F2 midpoint value of 1428 Hz compared to 1678 Hz for their plain counterparts, [$F(1, 766) = 19.768$, $p < 0.001$]. In words with initial target consonants, F2 midpoint is still lower in emphatic environments, 1427 Hz compared to their plain counterparts, 1680 Hz, [$F(1, 382) = 26.784$, $p < 0.001$]. The same effect is also detected for words with final target consonants. F2 midpoint in words with final target consonants is 1428 Hz in emphatic positions and 1676 Hz in plain positions, [$F(1, 382) = 21.837$, $p < 0.001$]. See Figure 12 below.

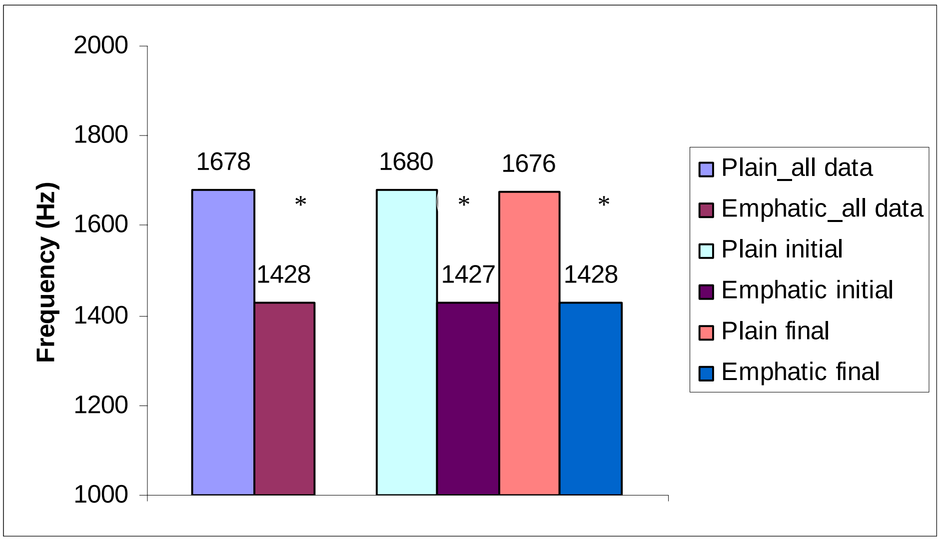

Figure 12: F2 at vowel midpoint

No other significant main effects or interactions were found.

A significant Consonant-type by Vowel Length interaction reveals differences between vowels in the two different conditions. Independent of emphasis, long vowels (164 ms) are longer than short vowels (102 ms). This difference is significant: [$F(1, 766) = 784.735$, $p < 0.001$]. In short vowels, F2 midpoint is 1648 Hz in plain environments and 1321 Hz in emphatic environments, a drop of 327 Hz. In long vowels, F2 midpoint is 1708 for vowels in plain environment and 1534 Hz in emphatic environments, a drop of 174 Hz. This difference in lowering is significant: [$F(1, 767) = 4.621$, $p = 0.032$]. See Figure 13 below.

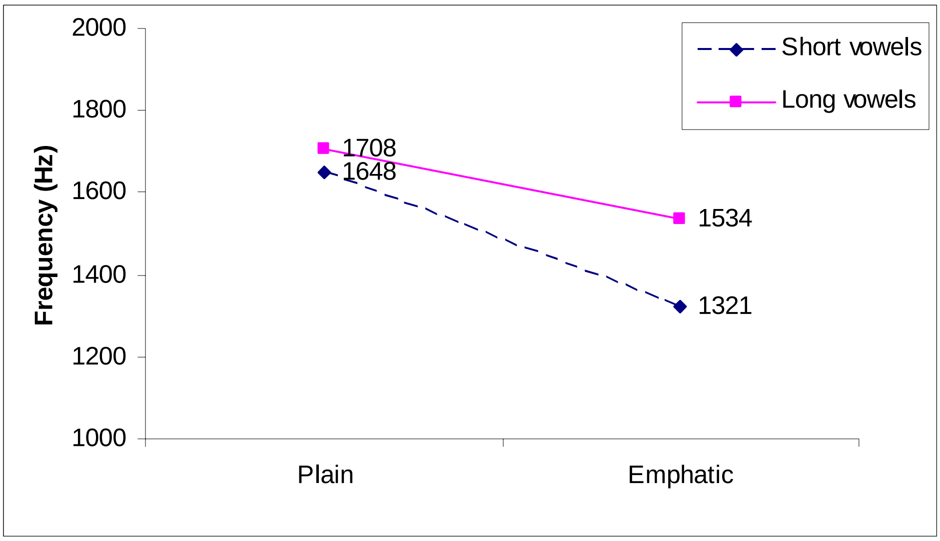

Figure 13: Consonant-type by Vowel length for vowel F2 midpoint

However, this difference in F2 midpoint is not attested for words with initial target consonants, [$F(1, 383) = 2.468$, $p = 0.117$], nor for words with final target consonants, [$F(1, 383) = 2.156$, $p = 0.143$].

F2 midpoint is affected by vowel quality. Overall, low front vowels show the highest degree of lowering for F2 midpoint between plain and emphatic environments, followed by high front vowels. The least degree of lowering is detected for high back vowels. These differences are significant, [$F(1, 767) = 14.770$, $p < 0.001$].Table 4 below shows these values.

Table 4: F2 midpoint by vowel quality

	Plain (Hz)	Emphatic (Hz)	Plain - emphatic	% difference
High front	2168	1959	209	10
Low front	1669	1254	415	25
High back	1196	1070	126	11

The same effect is attested for words with initial target consonants, [F (1, 383) = 7.220, p < 0.001], and also for words with final target consonants, [F (1, 383) = 9.159, p < 0.001]. Table 5 below shows these results.

Table 5: F2 midpoint by vowel quality in word-initial and word-final target consonants

	Plain (Hz)		Emphatic (Hz)		% difference	
	Initial	Final	Initial	Final	Initial	Final
High front	2131	2206	1969	1949	8	12
Low front	1668	1670	1256	1253	25	25
High back	1240	1151	1056	1083	15	6

F2 offset is also significantly lower in emphatic environments. Across all data, F2 offset drops from 1615 Hz in plain environments to 1302 in emphatic ones, [F (1, 766) = 164.548, p < 0.001]. F2 offset values demonstrate the same effects in words with initial target consonants and words with final target consonants. In word-initial positions, F2 offset is 1486 Hz in plain environments and 1321 Hz in their emphatic counterparts, F (1, 382) = 19.613, p < 0.001]. In words with final target consonants, F2 offset is 1744 Hz in plain environments and 1282 Hz in their emphatic counterparts, F (1, 382) = 258.281, p < 0.001]. Figure 14 shows these results.

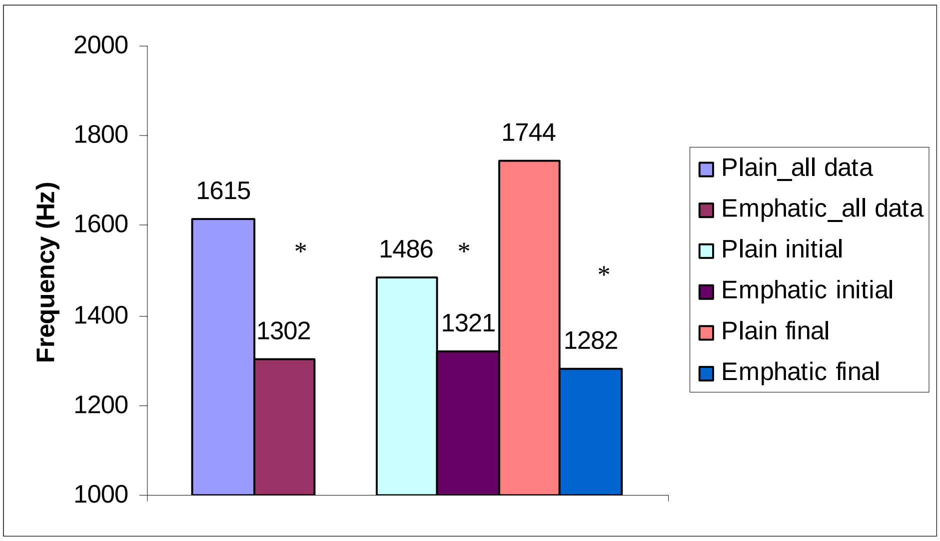

Figure 14: F2 at vowel offset

An interaction between Consonant-type and Position of the target consonant reveals significant results. F2 offset in words with final target consonants drops by 462 Hz, (1744 in plain environments and 1282 in emphatic ones). In words with initial target consonants, F2 offset drops only by 165 Hz, (1486 Hz in plain environments compared to 1321 Hz in their emphatic counterparts). This difference proves significant: [F (1, 767) = 39.683, p < 0.001]. Another interaction between Consonant-type and Vowel Quality reveals significant differences for F2 offset. High front vowels have the largest F2 offset drop, followed by low front vowels and finally by high back vowels. These differences are significant, [F (2, 767) = 9.223, p < 0.001]. Table 6 shows these results.

Table 6: F2 offset by vowel quality

	Plain (Hz)	Emphatic (Hz)	Plain - emphatic	% difference
High front	1948	1569	379	19
Low front	1551	1191	360	23
High back	1346	1145	201	15

The same effects hold for words with initial emphatics where low front vowels show the largest drop, followed by high front vowels and then high back vowels. These differences are significant, [$F (2, 383) = 8.981$, $p < 0.001$]. In words with final emphatics, high front vowels drop by the largest amount, followed by low front vowels and finally by high back vowels, [$F (2, 383) = 7.587$, $p < 0.001$]. Table 7 below shows these findings.

Table 7: F2 offset by vowel quality in word-initial and word-final target consonants

	Plain (Hz)		Emphatic (Hz)		% difference	
	Initial	Final	Initial	Final	Initial	Final
High front	1875	2021	1702	1437	9	39
Low front	1448	1654	1168	1214	19	27
High back	1135	1558	1092	1196	4	23

No other significant main effects or interactions were found.

Plotting the results for F2 with regard to the point at which the measurements were taken reveals interesting observations. The closer the measurement is taken to the emphatic consonant, the larger the F2 drop in emphatic environments. In Figure 15, this F2 drop is greatest at vowel onset, the point closest to the target consonant, and decreases as the measurement point moves away from the target consonant. The mirror image is observed in Figure 16 since the target consonant is word-final.

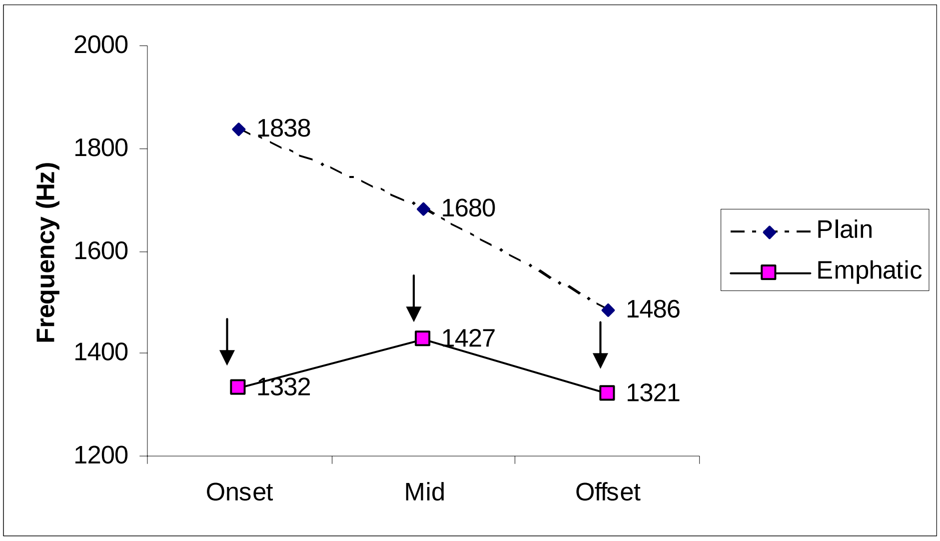

Figure 15: Vowel F2 in words with initial target consonants

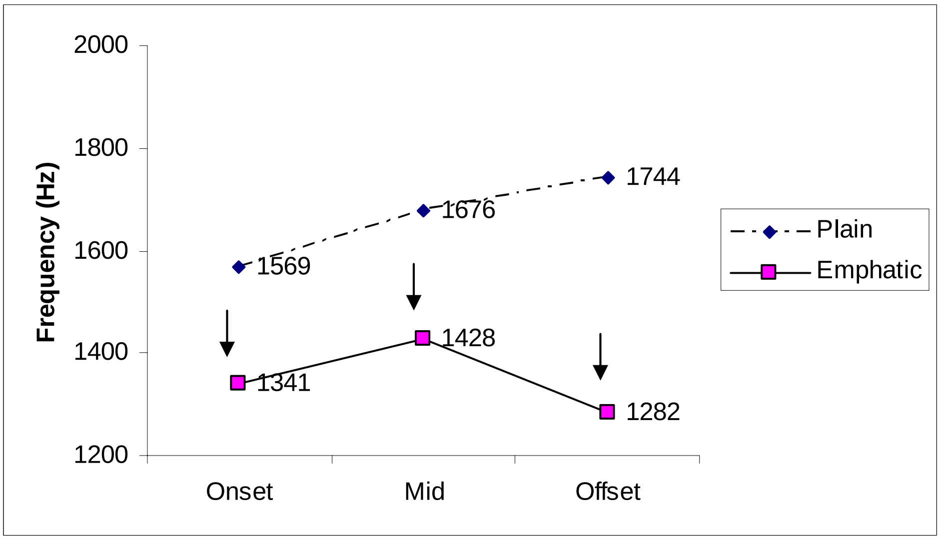

Figure 16: Vowel F2 in words with final target consonants

2.3.2.3. F3

Overall, F3 in emphatic environments rises in all three positions: onset, midpoint and offset, compared to plain ones. Across all data, F3 onset is 2811 Hz in plain environments compared to 2880 Hz in emphatic environments. This difference is significant, [$F(1, 766) = 11.469$, $p = 0.001$]. The same difference is attested for words with initial target consonants: F3 onset is 2895 Hz in plain environments and 3005 Hz in emphatic environments, [$F(1, 382) = 15.892$ $p < 0.001$]. However, F3 onset does not show significant differences in words with final target positions. It is 2727 Hz in plain environments compared to 2756 Hz in emphatic environments, [$F(1, 382) = 1.233$, $p = 0.268$]. Figure 17 shows these values.

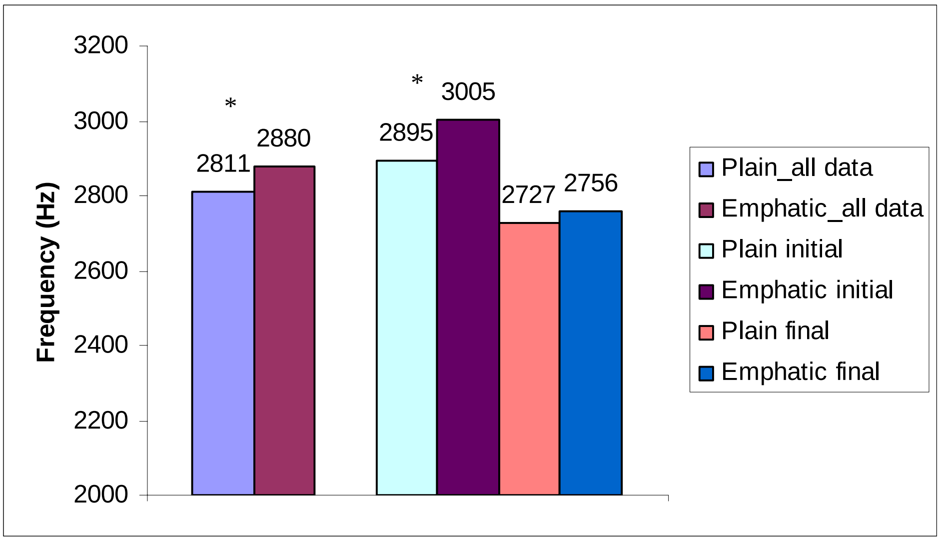

Figure 17: F3 at vowel onset

An interaction between Consonant-type and Word-type reveals significant differences for F3 onset. In real words, F3 onset is higher in emphatic positions (2928 Hz) than in plain positions (2810 Hz) by 118 Hz. In nonwords, this difference in F3 onset is only 28 Hz: 2840 Hz for F3 onset in emphatic nonwords compared to 2812 Hz in their plain counterparts. This difference is significant. See Figure 18.

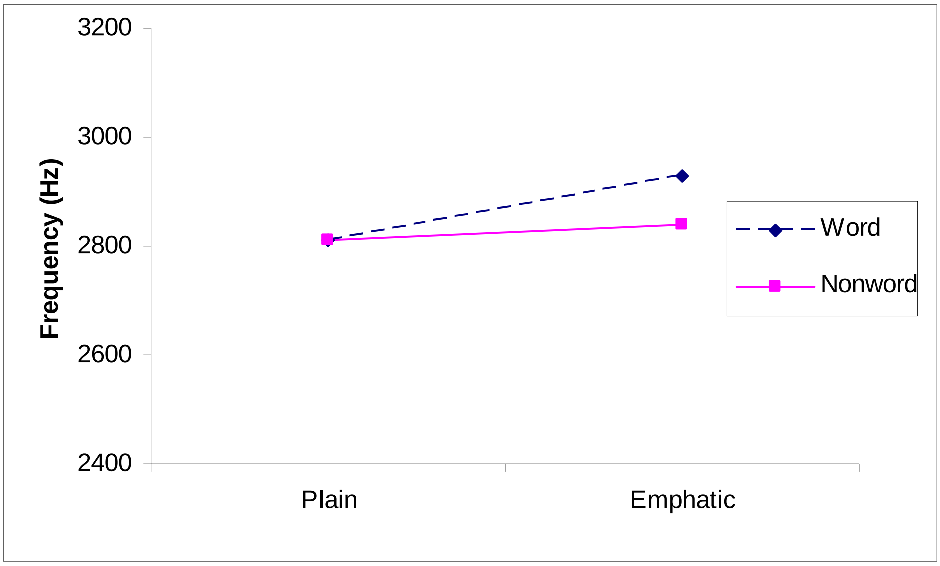

Figure 18: Consonant-type by Word-type for vowel F3 onset

No other significant main effects or interactions were found.

F3 at vowel midpoint is higher in emphatic environments. When all data are included, vowels in emphatic positions have an F3 midpoint of 2937 Hz compared to 2870 Hz in plain positions; [F (1, 766) = 8.610, p = 0.003]. In words with initial target consonants, F3 midpoint is still higher in emphatic environments, 2945 Hz, compared to 2869 Hz in their plain counterparts, [F (1, 382) = 5.373, p = 0.021]. In words with final target consonants, F3 midpoint is 2929 Hz in emphatic environments and 2870 Hz in their plain counterparts. Though F3 midpoint is still higher in emphatic positions, this effect is not significant, [F (1, 382) = 3.331, p = 0.069]. Figure 19 shows these results.

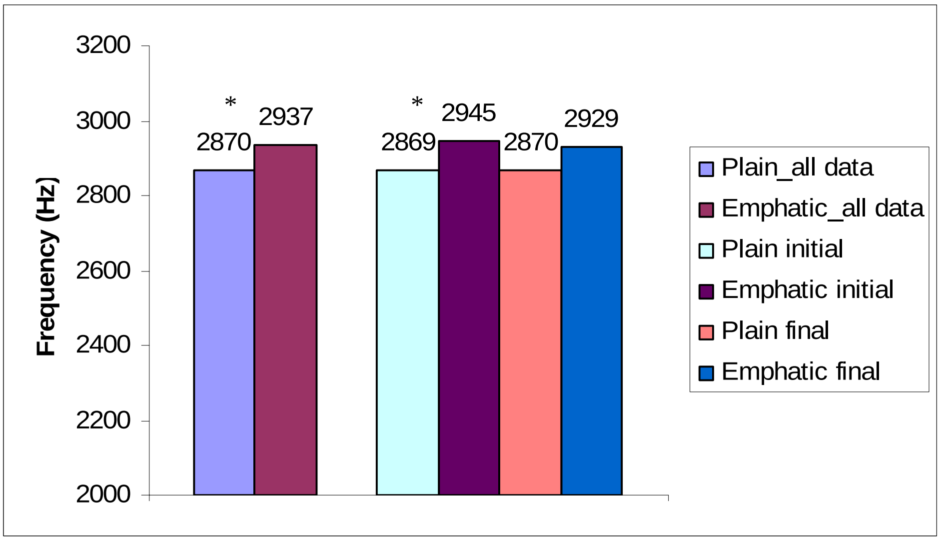

Figure 19: F3 at vowel midpoint

A Consonant-type by Vowel Quality interaction for F3 midpoint proves significant: low front vowels have a higher F3 midpoint in emphatic positions than in plain ones while high front vowels have a *lower* F3 midpoint in emphatic positions compared to plain ones, [F (2, 767) = 5.367, p = 0.005]. However, F3 midpoint in high back vowels does not show significant differences. Table 8 below shows F3 midpoint values. The minus symbol represents the direction of difference – namely that the value is larger in emphatic positions.

Table 8: F3 midpoint by vowel quality

	Plain (Hz)	Emphatic (Hz)	Plain - emphatic	% difference
High front	2971	2958	13	0.5
Low front	2821	2871	-50	-1
High back	2816	2981	-165	-1

When data are split by position of the target consonant, this interaction is not observed for words with initial target consonants. There is no significant interaction between consonant-type and vowel quality for F3 midpoint in words with initial target consonants, [F (1, 383) = 1.249, p = 0.288]. The magnitude of drop for F3 midpoint is significantly different for high front vowels compared to low front vowels, where F3 rises in emphatic positions, whereas high back vowels do not show significant differences. Table 9 shows these values.

Table 9: F3 midpoint by vowel quality in word-initial and word-final target consonants

	Plain (Hz)		Emphatic (Hz)		% difference	
	Initial	Final	Initial	Final	Initial	Final
High front	2953	2990	2968	2948	-1	0.2
Low front	2825	2818	2897	2845	-1	-1
High back	2830	2801	2970	2992	-1	-1

No other significant main effects or interactions were found.

Across all data, F3 offset is higher in emphatic positions. F3 offset is 2917 Hz for vowels in emphatic positions, and 2838 Hz for vowels in plain positions, [F (1, 766) = 12.467, p < 0.001]. For words with initial target consonants, F3 offset is 2812 Hz in emphatic positions, and 2752 Hz in plain positions. This effect shows a trend but is not significant, [F (1, 3.652) = 8.610, p = 0.057]. For words with word-final target consonants, F3 offset is 3021 Hz in emphatic positions compared to 2923 Hz in their plain counterparts. This difference is significant, [F (1, 382) = 11.535, p = 0.001]. Figure 20 plots these results.

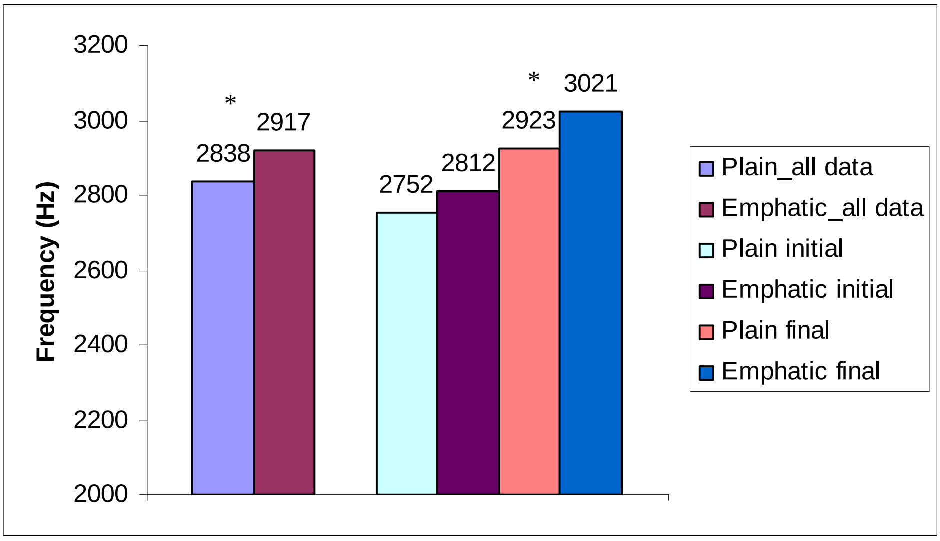

Figure 20: F3 at vowel offset

No other significant main effects or interactions were found.

When looking at the change in F3 measured at different positions of the vowel, results are compatible with what is reported for F1 and F2 above. The closer the measurement is taken to the consonant that triggers emphasis, the greater the rise. As the measurement is taken further away, this rise either declines on disappears. See Figure 21 and Figure 22.

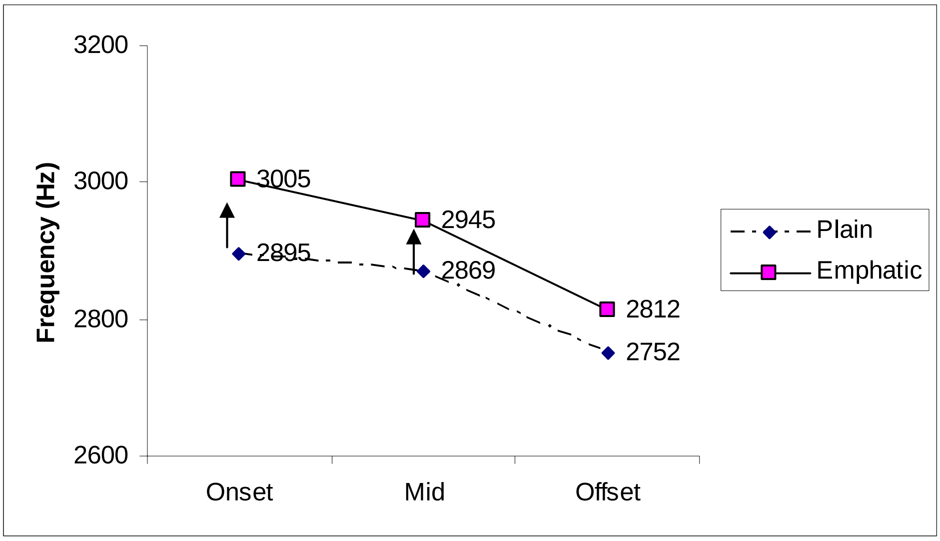

Figure 21: Vowel F3 in words with initial target consonants

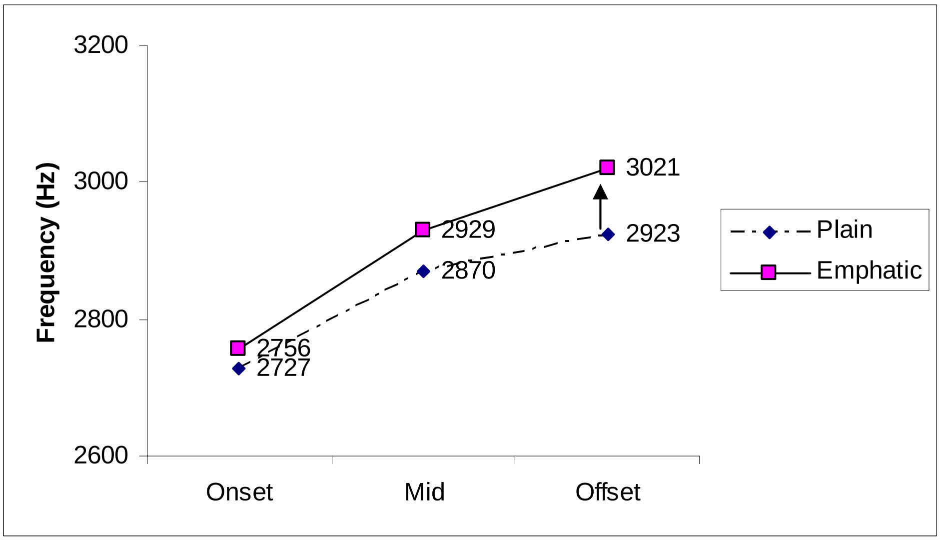

Figure 22: Vowel F3 in words with final target consonants

2.3.3. Spectral moments

2.3.3.1. Target consonants

Overall, none of the spectral moments for plain and emphatic consonants show significant differences. Center of gravity was 6840 for plain consonants and 6740 for emphatic consonants, [F (1, 766) = 0.999, p = 0.318]. The same results are obtained for word-initial emphatics – center of gravity is not different between plain and emphatic consonants. A Consonant by Manner interaction reveals significant differences. In word-final target consonants, plain stops have a higher center of gravity (6793 Hz) compared to their emphatic counterparts (6485 Hz), whereas plain fricatives have a lower center of gravity (7906 Hz) compared to their emphatic counterparts (7945 Hz). This difference is significant, [F (1, 383) = 4.082, p = 0.044]. See Figure 23 below. No other significant main effects or interactions were found.

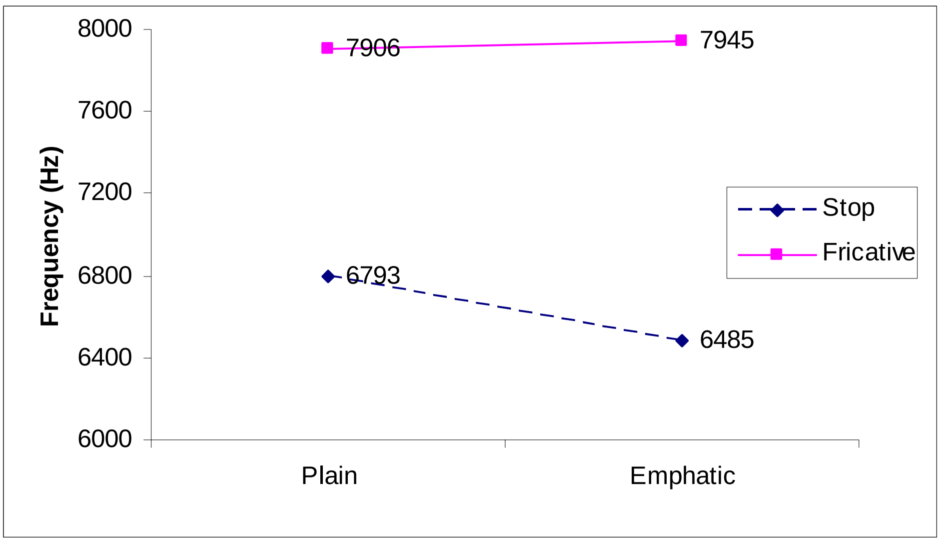

Figure 23: Consonant-type by Manner of articulation for Center of gravity in words with final target consonants

For standard deviation, no significant main effects or interactions were found. Mean variance was 2330 Hz for plain consonants and 2359 Hz for emphatic consonants, [F (1, 766) = 0.255, p = 0.613].

No significant main effects or interactions were found for skewness. Plain consonants had a skewness value of 3.464 and -0.4711 for their emphatic counterparts, [F (1, 766) = 1.000, p = 0.318].

Finally, for kurtosis, no significant main effects or interactions were found. Plain target consonants have a kurtosis value of 0.3696 and 0.5755 for their emphatic counterparts, [F (1, 766) = 2.214, p = 0.137].

2.3.3.2. /b/ consonant

Overall, spectral moments for /b/ yielded no significant main effects or interactions. Table 10 shows these results.

Table 10: Spectral moments for /b/

Measurement	Plain	Emphatic
Center of gravity (Hz)	5418	5405
Standard deviation (Hz)	3258	3277
Skewness	0.0067	0.0035
Kurtosis	-0.9954	-0.9946

Similar results are obtained for words with initial target consonants and words with final target consonants as well, see Table 11.

Table 11: Spectral moments for /b/ in word-initial and word-final target consonants

Measurement	Plain		Emphatic	
	Initial	Final	Initial	Final
Center of gravity (Hz)	5922	4941	5952	4859
Standard deviation (Hz)	3029	3488	3035	3520
Skewness	-0.1431	0.1566	-0.1764	0.1834
Kurtosis	-0.9582	-1.0326	-0.9580	-1.0289

2.3.4. Locus equations

Locus equations were calculated for each target consonant. A linear regression was conducted with F2 onset as the dependent variable and F2 vowel as the independent variable to obtain the slope and the *y*-intercept values. A one-way ANOVA shows that emphatic target consonants have a lower mean slope (0.464) than their plain counterparts (0.640). This difference is significant, [$F(1, 14) = 5.586$, $p = 0.033$]. This effect is attested for words with initial target consonants: slope value is 0.310 for emphatic consonants, and 0.576 for their plain counterparts, [$F(1, 6) = 11.223$, $p = 0.015$]. The same effect is also evident for words with final target consonant: slope value is 0.618 for emphatic consonants and 0.708 for their plain counterparts, [$F(1, 6) = 7.153$, $p = 0.037$]. See Figure 24. Figure 25 shows the scatter plots for all the data.

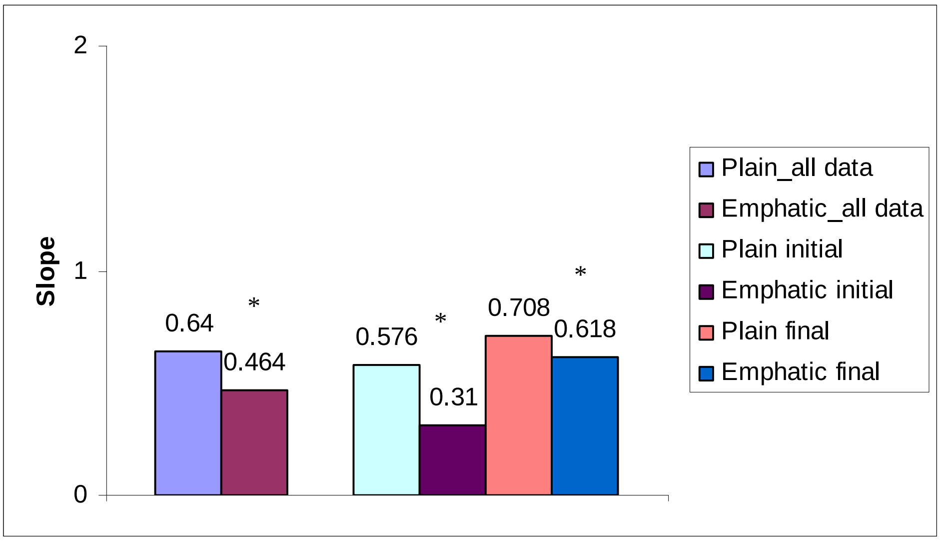

Figure 24: Slope values

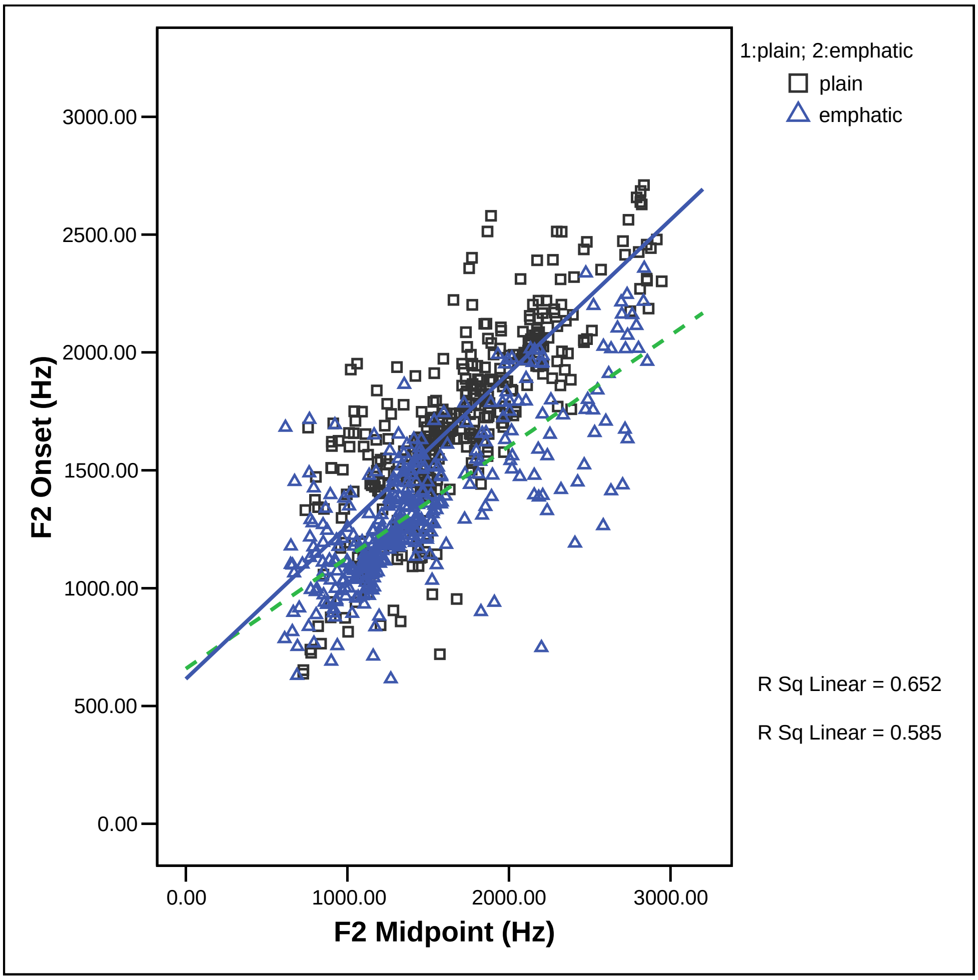

Figure 25: scatter plot, all data

Analysis of *y*-intercept values did not reveal significant differences. For all data, mean *y*-intercept was 630 Hz for plain and 668 Hz for emphatic consonants, [F (1, 14) = 0.075, p = 0.788]. The same results were obtained for words with initial target consonants. *y*-intercept value was 872 Hz for plain consonants, and 878 Hz for their emphatic counterparts, [F (1, 6) = 0.002 , p = 0.962]. Similarly, words with final target consonants show no difference in y-intercept values. Plain consonants have a *y*-

intercept of 388 Hz and their emphatic counterparts have a *y*-intercept of 457 Hz, [$F(1, 6) = 3.252$, $p = 0.121$]. Figure 26 below shows these results.

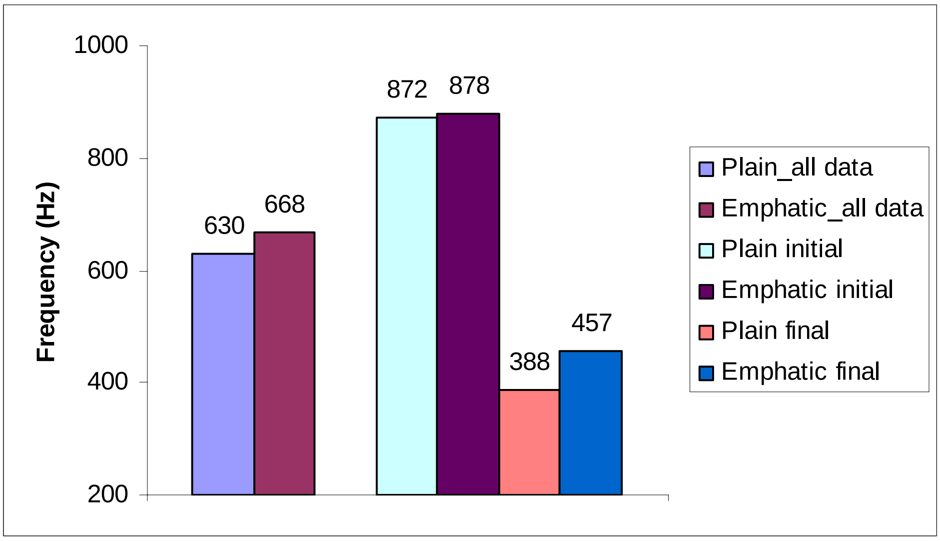

Figure 26: *y*-intercept value

2.4. Results Summary

Tables 12 and Table 13 summarize the findings of the acoustic study. This arrow (🡅) represents an increase in emphatic positions, the other one (🡇) represents a decrease in the emphatic position, and an arrow with a (t) represents a trend in the direction of the arrow. The number of arrows in one box indicates the magnitude of the raise or drop. Variables that did not show significant differences are excluded from these two tables.

Table 12: Main findings

	All	Initial	Final
C duration	🡅		🡅
F1 onset	🡅	🡅	🡅
F1 midpoint	🡅		t🡅
F1 offset	🡅		🡅
F2 onset	🡇	🡇	🡇
F2 midpoint	🡇	🡇	🡇
F2 offset	🡇	🡇	🡇
F3 onset	🡅	🡅	
F3 midpoint	🡅	🡅	
F3 offset	🡅	t🡅	🡅

Table 13: Summary of interactions: from left to right: I: Initial; F: Final; S: Stop; F: Fricative; VD: Voiced; VS: Voiceless; S: Short; L: Long; W: Word; N: Nonword; M: Male; F: Female.

	Position		Manner		Voicing		V length		V quality			Word-type		Gender	
	I	F	S	F	VD	VS	S	L	/i/ /i:/	/a/ /a:/	/u/ /u:/	W	N	M	F
C duration		↑	↑												
/b/ duration												↑			
F1 onset	t↑														
F1 midpoint		t↑													
F2 onset	↓								↓↓	↓↓	↓				
F2 midpoint							↓		↓↓	↓↓↓	↓				
F2 offset		↓							↓↓↓	↓↓	↓				
F3 onset												↑			
F3 midpoint									↓	↑					
C gravity			↑[2]	↓[3]											

2.5. Discussion

The present results show that emphatic stops in word-final position are consistently longer than their plain counterparts. Preliminary results (Al-Masri and Jongman, 2004) indicated an effect of position of the target consonant – namely, that word-initial target emphatics tend to have longer durations than their plain counterparts. However, this tendency might have been influenced by the fact that it was obtained from data with

[2] Only in word-final position
[3] Only in word-final position

different word lengths. The results obtained here suggest that stops are more sensitive to emphasis than fricatives in terms of duration. This might be due to the fact that, in general, fricative durations are longer than stop durations, which means that stops are more likely capable of showing slight durational differences compared to fricatives. Besides, this supports Zawaydeh's (1999) finding about the directionality of emphasis in UJA, namely that it is more prominent leftward than rightward. The lack of such findings for the other segments, the vowel and the /b/ consonant, might be due to the fact that durational differences in emphasis are not likely to spread in either direction. While durational differences are observed on the target consonants under certain conditions, they are not expected to spread to adjacent segments. Ultimately, back articulation, which is characteristic of emphasis, is not closely related to duration.

As for formant frequencies, different results are reported. The overall means do not seem to be incongruent with previous findings, (Obrecht, 1968; Alosh 1987; Zawaydeh 1999). However, the present results are more detailed since all formant frequencies were measured at three positions of the vowel: onset, midpoint and offset. F1 onset is consistently higher in emphatic than in plain positions. There is a trend for F1 to rise by a larger amount in words with initial target consonants compared to words with final consonants. F1 at the steady state of the vowel is still higher in emphatic positions compared to plain ones for all data. This difference is lost for word-initial emphatics and is only obtained as a trend for word-final emphatics. The lack of significance for F1 rise in the steady state of the vowel for word-initial target consonants, and the presence of a slight trend for words with final target consonants support the previous findings in this study for the prominence of leftward spread of emphasis within monosyllables. For F1 at offset positions, a mirror image of F1 onset is presented. Overall, F1 offset is higher in emphatic positions. Also, the magnitude of rise for F1 offset is clearer for word-final target consonants. From the findings for F1 onset and F1 offset, we can conclude that emphasis is gradient within the monosyllable: the closer the vowel and the segment that triggers emphasis, the more pronounced the rise in F1.

Most of the previous studies report on F2. F2 is lower in emphatic positions than in plain ones at the three measurements points. F2 onset is significantly lower for all data and when the target consonant is word-initial and word-final as well. The difference between F2 onset values in emphatic positions is significantly more pronounced in word-initial than in word-final positions. Another detailed finding is that the drop is not similar for different vowels. It is evident that the drop is larger for high front and low front vowels compared to high back vowels. Seemingly, there is more room for this drop in front vowels than in back vowels. Additional interesting results are observed for F2 midpoint. Consistently, F2 midpoint is lower in emphatic environments. Interestingly, no interaction with position of the target consonant is observed here now that the measurements are taken equidistant from the consonant that triggers emphasis. Interactions with vowel quality are also more salient here. Low front vowels show the largest F2 midpoint drop, followed by high front vowels and finally high back vowels. As for vowel duration, in line with previous findings, (Card, 1983; Zawaydeh, 1999), short vowels show a larger F2 midpoint drop in emphatic positions than their long counterparts. This also points to the gradient nature of emphasis spread.

F2 offset shows a significant drop in emphatic than in plain positions. This drop is reported for all data and for words with initial and final target consonants as well. As expected, a mirror effect is obtained here: F2 offset drop is larger in words with final target consonants compared to words with initial consonants due to the fact that the temporal interval between the emphatic segment and the vowel offset is shorter in offset positions than in initial positions. High front vowels here show a larger F2 offset drop than low front vowels, which, in turn, show a larger drop compared to high back vowels. Evidently, emphatic consonants exert more influence on front vowels compared to back vowels. This may be because back vowels already have lower F2 and higher F1 values compared to front vowels. Therefore, there is less room for each formant to change under emphasis compared to the room available for front vowels.

F3 is higher in emphatic than in plain positions. F3 onset is higher in emphatic positions when all data are included in the measurements. This effect carries on to words with initial target consonants but not to words with final target consonants. There is an unexpected interaction with word-type where F3 onset rises by a larger degree in words compared to nonwords. F3 midpoint is also higher in emphatic positions than in plain ones for all data and also for words with initial target consonants. However, a puzzling interaction with vowel quality is observed for F3 midpoint. While emphasis causes F3 midpoint to rise, it does so for low front vowels and high back vowels. While the difference is significant in low front vowels, it is not significant in high back vowels. Surprisingly, emphasis causes F3 midpoint to decrease in high front vowels. F3 does not rise at the midpoint position for words with final target consonants. In offset positions, F3 rises in emphatic positions for all data, for words with final target consonants, and shows a trend for words with initial target consonants. This effect is in harmony with the findings on the directionality of emphasis spread within the monosyllables.

While durations and formants show a host of significant distinctions in the acoustic signal between plain and emphatic segments and environments, spectral moments fail to show similar differences. The only significant finding that can be reported is the interaction of manner with the center of gravity for the target consonants: while emphatic stops have a higher center of gravity than their plain counterparts, fricatives have a lower center of gravity compared to their plain counterparts. All other spectral measurements on the target consonant and on the /b/ consonant as well fail to yield significant differences.

As for the findings on locus equations, emphatic consonants have flatter slopes compared to their plain counterparts. This finding it true for stops and fricatives and also regardless of position of the target consonant. This suggests that emphatics are more stable in terms of their resistance to effects of adjacent vowels. This is in line with what Yeou (1997) found for the same set of consonants in Modern Standard Arabic spoken by native speakers of the Moroccan dialect. He found that the same set of emphatics emerged as a distinct class with the flattest slope values, which indicates minimal coarticulation between the consonants and the vowels. Using data from Cairene Arabic produced by three male speakers, Sussman, Hoemeke and Ahmed, (1993) found that /d/ and /dˤ/ had similar slopes but significantly differed in their *y*-intercept values. They show that *y*-intercept was 1307 Hz for /d/ and 933 Hz for /dˤ/. The present study found no significant differences in slope values or in *y*-intercept values for /d/ and /dˤ/. While slope turns out to be a factor in defining emphatics as a separate class of sounds, *y*-intercept fails to yield significant differences between plain and emphatic consonants. Emphatics consistently had a higher *y*-intercept compared to their plain counterparts, but this difference was not significant.

Chapter Three

Acoustic Study – the bisyllables

This chapter presents the acoustic findings on the bisyllables. In Chapter 2, analyses on the monosyllables provided a first idea of emphasis spread by comparing words with the target consonant in initial and final position. To get a better understanding of the nature and domain/extent of spread, investigation of longer words will give us an idea about emphasis spread to adjacent syllables. This chapter provides a first look at this issue. Since spectral measures for the consonants in monosyllables did not really reveal differences between plain and emphatic tokens, analysis of bisyllabic words will focus on spectral measures of the vowels only. More precisely, this chapter aims to answer the following questions:

1. Are the results obtained for monosyllables identical to those obtained for the syllable which has the target consonant (the target syllable)?

2. Does emphasis spread beyond the target syllable?

3. Is emphasis spread attested for duration (for consonants and vowels) and/or vowel formant frequency (F1, F2, F3)?

4. Does spreading to the right and left of the target syllable pattern similarly?

5. What is the effect of vowel quality on emphasis spread?

6. Is emphasis spread influenced by gender of the speaker?

Despite several limitations, see Section 1.7. above, previous research addresses some of these questions. For example, Card (1983) found that emphasis, as an effect of F2 lowering, spreads beyond the target syllable unless in the presence of a ‘blocking vowel,’ which she defines as one of the three long vowels /i, a, u/. Davis (1995) found that in Palestinian Arabic, leftward emphasis was not blocked whereas rightward emphasis was blocked by [+ high, - back] vowels. Based on these and similar previous findings, see Section 1.4. above – and in accordance with the present findings on the monosyllables, see Chapter Two, I can make the following hypotheses:

1. Emphatic consonants will be slightly longer than their plain counterparts only in target syllables. Durational differences will disappear in adjacent syllables.

2. Vowel duration will not be affected by emphasis, neither in target syllables nor in adjacent ones.

3.Vowel F1 and F3 values will rise, especially when measurements are taken closest to the vowel in the same syllable with the emphatic target consonant. Vowel F2 will decrease in the target vowel and in adjacent vowels as well

4. No gender interactions will be obtained.

5. No word/nonword differences will be obtained.

3. 1. Method

3.1.1. Subjects

Eight adult speakers (four males and four females) of UJA aged 16 to 26 years old (average age was 20.6 years) participated in the study. Five of them (four males and one female) were recruited from the Yarmouk University, Irbid, Jordan. The three other females were recruited from the local community of Irbid: two of them were high school students and one was a university graduate. All of the subjects spoke UJA. None of them ever left Jordan. Four of the university students were majoring in religious studies, one was majoring in psychology and one had a degree in English language and literature. None of the subjects reported any known speech or hearing impairments. They were paid $10 for their participation

3.1.2. Materials and Procedure

A long list of target words was prepared as part of a larger project. The wordlist in question consisted of 80 target CV.CVC pairs (plain-emphatic). It included the four emphatic consonants and their plain counterparts along with the six UJA vowels. It was designed as follows: 24 pairs with the target consonant in word-initial position, and the adjacent syllable was /-bat/ - yielding pairs such as /sabat/-/$s^{ʕ}$abat/, /sibat/-/$s^{ʕ}$ibat/, /subat/-/$s^{ʕ}$ubat/ etc.; another 24 pairs with the target consonant in a word-final position and the adjacent syllable was /ta-/ - yielding pairs such as /tabas/-/$tabas^{ʕ}$/, /tabis/-/$tabis^{ʕ}$/, /tabus/-/$tabus^{ʕ}$/, etc.; and 32 pairs with the target consonant in word-medial position. In this subset, all the target consonants were used, the filler consonant was /k/ and only two UJA vowel pairs were used: long and short /a/ and /i/ - yielding pairs such as /kasak/-/$kas^{ʕ}$ak/, /kasik/-/$kas^{ʕ}$ik/, /kasaak/-/$kas^{ʕ}$aak/, etc. Thus, the study material consisted of CV.bat, ta.bVC, and kV.CVk stimuli, see Appendix II. This design yielded many nonwords that were all phonotactically acceptable in UJA. Subjects read the target words in a carrier sentence: /'ʔiħ.ki *target word* ka.'maan 'mar.rah/ [Say *target word* again]. The wordlist included 12 pages, each having one column, and each column consisted of 12 sentences – the first and last two sentences were fillers and did not include target words. The best two of these three repetitions were used for analysis. Choice was made based on the correct completion of the wordlist with the minimum amount of mistakes. Since Arabic short vowels are not written in full letters, diacritics were added to illustrate these vowels where they occurred. Speakers read the wordlist three times. Recordings were carried out in a sound-proofed booth using a portable solid-state recorder (Marantz PMD 671) and a unidirectional microphone (ElectroVoice N/D767a). Each subject was recorded individually and each recording session took approximately 70 minutes. Recordings were digitized at a 22050 Hz sampling rate. Using Praat speech analysis software (Boersma and Weenink 2005), a script was written to carry out automatic segmentation of the stimuli in order to isolate the target words. Due to the relatively long duration of the recording sessions, some subjects occasionally made mistakes in reading parts of the wordlist. In these instances, they were instructed to repeat two lines before and after the line in which they made these occasional mistakes. During the segmentation process through which the target sound files were obtained, these lines which included possible mistakes were disposed of.

3.1.3. Measurements

The same method in Section 2.1.3 above was adopted here. However, slight changes were applied due to the huge amount of data used in this section. The measurement procedure this time was automatic. The cursors were placed by hand, using a waveform and a spectrogram, at a number of locations in the speech signal. For stop consonants, cursors were placed at the offset of the previous segment (the beginning of closure), at the release of the burst, and at the onset of the following vowel. For fricatives, cursors were placed at the onset and offset of the frication noise. For vowels, cursors were placed at the start of F1 and the offset of F2. When the burst was very hard to locate, it was estimated using auditory and visual cues. For the frequency values of the target vowels, F1, F2 and F3 were measured at onset, midpoint and offset of the vowel. While the cursors for the onset and offset points where easy to locate, the cursor for the vowel midpoint was automatically derived. A script was written which took the measurements for each segment and wrote them to an Excel file. Figure 1 below shows the placement of the cursor at different points for an example target word: /sabat/

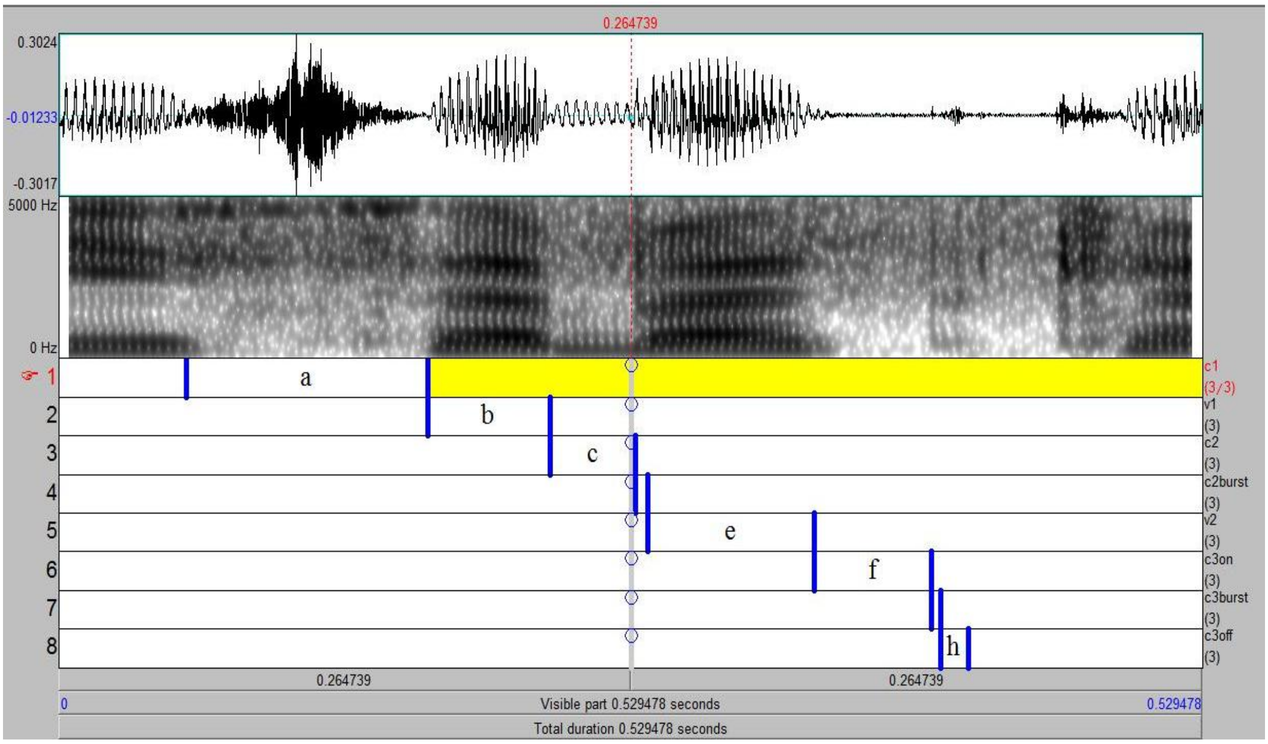

Figure 1: Sample measurements conducted for one stimulus word: /sabat/: (a) represents the initial consonant; (b) the first vowel; (c) the closure of the second consonant; (d) the second consonant burst; (e) the second vowel; (f) the closure of the third consonant; (g) the third consonant burst; (h) the third consonant post-burst release.

For consonants in medial positions, the cursors where placed at the offset of the previous vowel, where the three first formants ceased to line up, and at the onset of the following vowel. For word-final consonants, the cursors were placed at the offset of the previous vowel and at the beginning of the burst before the onset of the next stop consonant of the carrier sentence. During this stage, different cues were utilized using both the waveform and the spectrogram. Vowel formant frequency measurements were based on LPC analysis using a 20-ms window.

3.2. Analysis

Different ANOVA tests were conducted on all measurements to analyze the data and obtain the main findings. Multivariate analyses for different dependent variables were also conducted to test interactions between the degree of emphasis and other independent variables. Bonferroni post hoc tests were used for independent variables with more than two levels, namely for vowel quality. Due to the fact that this chapter deals with bisyllables, several dependent and independent variables were used, see Table 1 below. The measurements mentioned in this table were made for each segment in the word. Dependent variables are mentioned here in groups, that is; DV 1 refers to durations of each consonant, and so on.

Table 1: Dependent and independent variables used in the study

No.	**Dependent variables**	**No.**	**Independent variables**
1	Consonant duration	1	Consonant-type (plain, emphatic)
2	Vowel duration	2	Vowel quality (high front, low front, high back)
3	Word duration	3	Adjacent vowel quality
4	Vowel F1 (onset, midpoint, offset)	4	Vowel length (long, short)
5	Vowel F2 (onset, midpoint, offset)	5	Adjacent vowel length
6	Vowel F3 (onset, midpoint, offset)	6	Target consonant position (initial, medial, final)
		7	Target consonant voicing (voiced, voiceless)
		8	Target consonant manner (stop, fricative)
		9	Speaker gender (male, female)

3.3. Results

In this section, I will report the main effects and the interactions for consonant and vowel durations and for vowel formant frequencies. While all main effects and interactions will be tested, I will focus on reporting those effects that show significant differences between plain and emphatic environments.

3.3.1. Duration

Plain and emphatic target consonant durations were exactly equal (when rounded) at 93 ms, [F (1, 1782) = 0.118, p = 0.731]. A similar result was obtained for target consonants in word-initial position where plain target consonants were 89 ms and emphatic ones were 90 ms, [F (1, 374) = 0.036, p = 0.849]. The same also held for target consonants in word-medial position where plain and emphatic target consonants were 89 ms, [F (1, 1014) = 0.085, p = 0.771]. Word-final target consonant durations were also not different. Plain target consonants in word-final position were 106 ms and their emphatic counterparts were 111 ms, [F (1, 390) = 0.637, p = 0.425].

Except for one condition, other consonants in the stimuli did not show any significant differences. That is to say, emphasis spread did not show on consonants in adjacent positions. The only consonants which showed significant durational differences were initial consonants in words where the target consonant was in word-final position. In these stimuli, initial consonants in words with final plain targets were longer than their counterparts in words with final emphatic targets, 83 ms and 78 ms, respectively. This difference is significant, [F (1, 390) = 7.473, p = 0.007]. No interactions with target consonant duration in word-initial positions were obtained.

As for vowels, measurements were taken in relation to the three possible target consonant positions. Similar to target consonants, results on vowel durations did not show significant differences. No significant durational differences were established for vowels when the target consonant was in word-initial or word-final positions. However, vowel durational differences were established when the target consonant was in word medial position. Vowels in the same syllable with the emphatic consonant where the target consonant was in word-medial position were significantly longer than their counterparts in plain environments, 122 ms, and 114 ms, respectively. This difference is significant: [F (1, 1014) = 4.779, p = 0.029]. There were no significant interactions between target consonant manner, vowel length, and vowel quality.

3.3.2. Formant Frequency

Results on vowel formant frequencies are reported in this section in target and in adjacent positions for F1, F2, and F3 at vowel onset, midpoint and offset. Main findings will be reported first, then interactions between the degree of emphasis and other independent variables. Where statistical analyses fail to show significant interactions, results will not be reported.

3.3.2.1. F1

Since the target consonants appear in three different positions: word-initial, word-medial and word-final, the results will be reported accordingly.

3.3.2.1.1. F1 target consonant word-initial

Under this condition, F1 for vowels in the same syllable with the target consonant, e.g. [u] in [sˤubat], was measured at three points in the vowel: onset, midpoint and offset. Results show significant differences. In onset positions, F1 for vowels in plain environments was 406 Hz, and 480 Hz for vowels in emphatic environments, [$F (1, 374) = 52.364$, $p < 0.001$]. The same significance was captured at vowel midpoint positions, [$F (1, 374) = 8.15$, $p =0.004$], and at vowel offset positions, [$F (1, 374) = 7.524$, $p = 0006$]. Figure 2 shows these results:

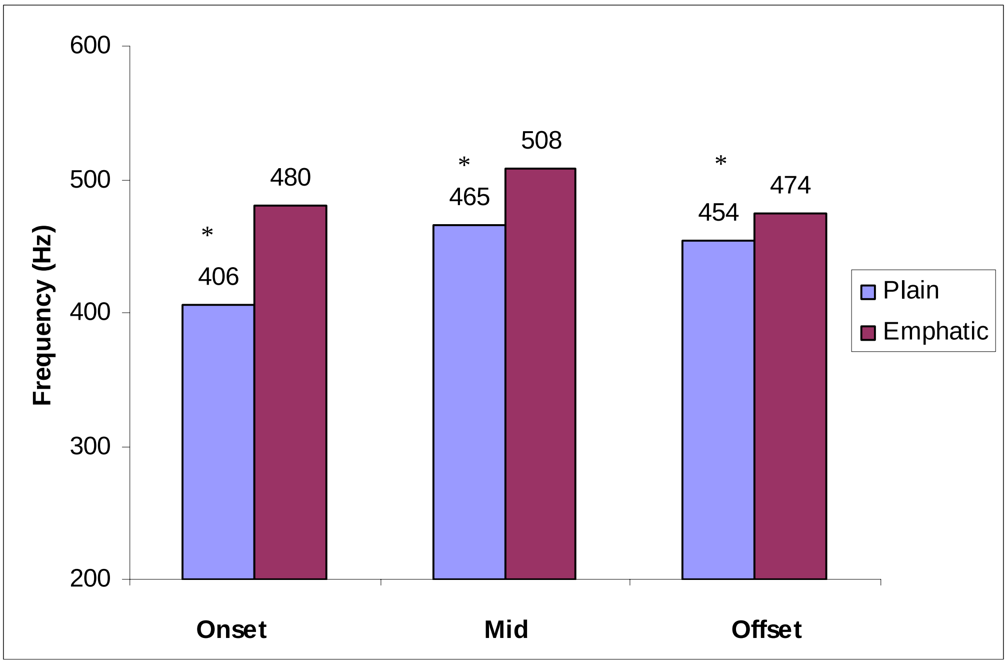

Figure 2: F1 values in word-initial positions at onset, midpoint and offset positions for the vowel in the same syllable with the target consonant.

A Consonant-type by Gender interaction shows that in emphatic environments, F1 at onset position rises by 97 Hz for males and by 51 Hz for females. This difference is significant,

[F (2, 372) = 5.19, p = 0.023]. Figure 3 shows these results.

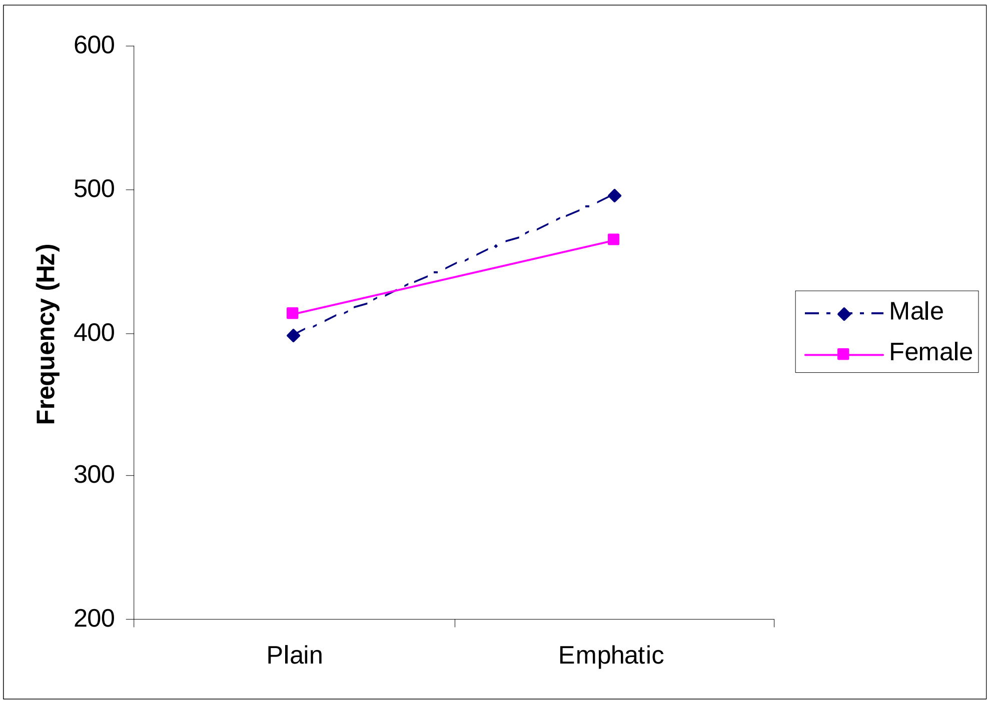

Figure 3: Consonant-type by Gender interaction for F1 Onset

A similar result is obtained for vowel F1 at offset positions; a Consonant-type by Gender interaction is obtained where vowel F1 in emphatic environments rises by 52 Hz for males and by 8 Hz for females. This difference is significant, [$F(2, 372) = 4.42$, $p = 0.036$]; see Figure 4. No other interactions were obtained.

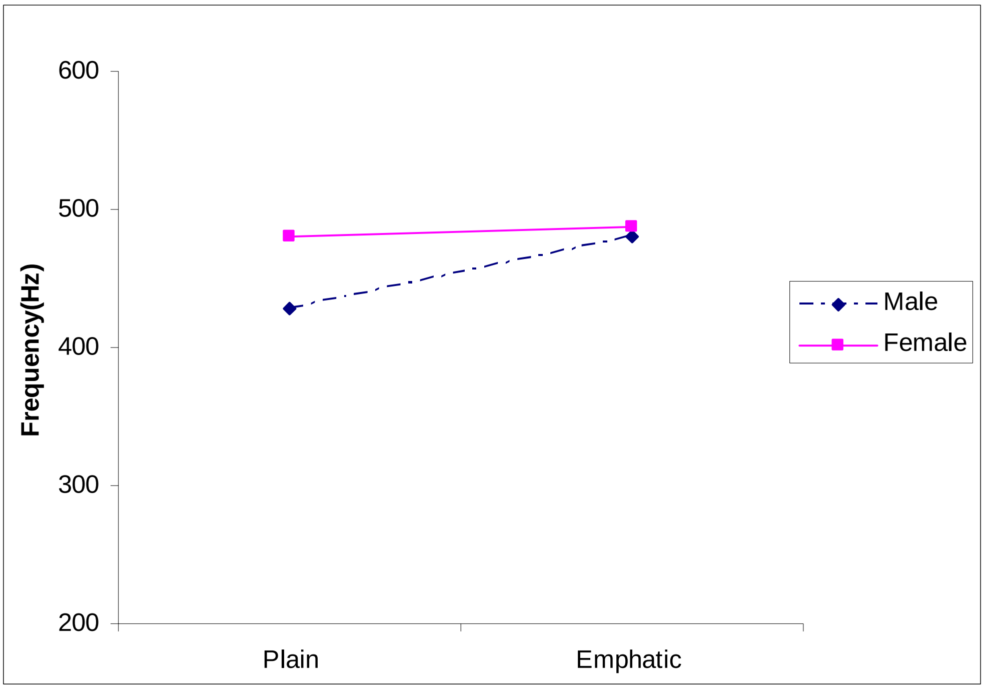

Figure 4: Consonant-type by Gender interaction for F1 Offset

Examining adjacency, e.g. [a] in [sˤubat], F1 for the vowel in the right-adjacent syllable was measured at three points: onset, midpoint and offset.

Except when F1 is measured in onset position, the differences shown here proved insignificant. In onset position, F1 was significantly higher in emphatic environments, [F (1, 374) = 15. 503, p < 0.001]. No significant results were obtained for F1 measurements for vowels in adjacent positions when these measurements were taken at midpoint, [F (1, 374) = 1.245, p =0.265], or at offset, [F (1, 374) = 0.158, p =0.691]. Figure 5 plots these results:

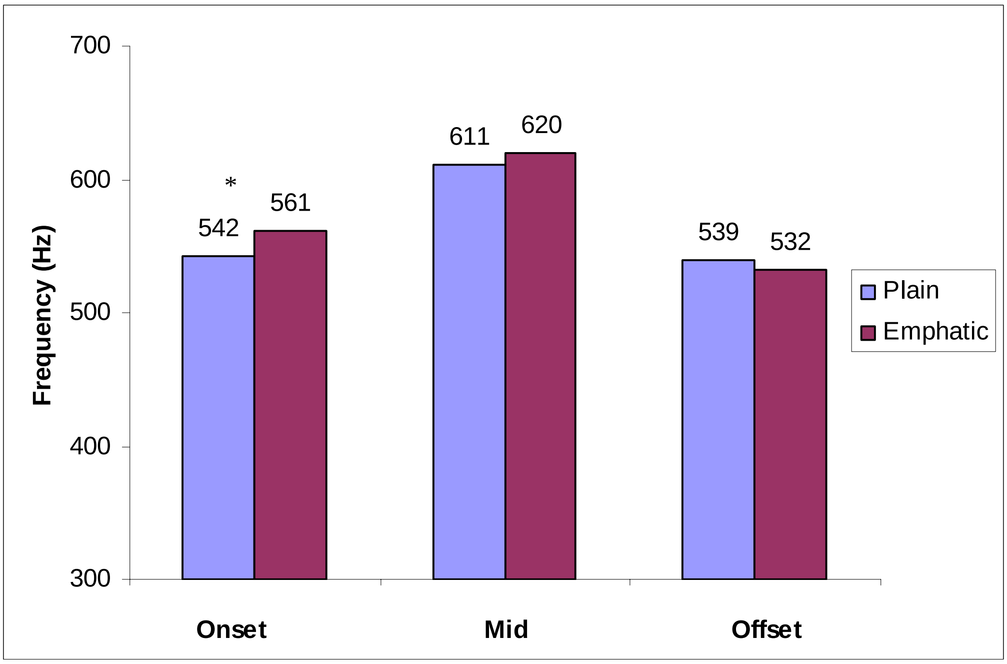

Figure 5: F1 values in word-initial positions at onset, midpoint and offset positions for the vowel right-adjacent to the syllable with the target consonant.

A significant Consonant-type by Gender interaction is obtained for the vowel in the right-adjacent position when the measurement is taken at onset position: F1 in emphatic environments rises by 29 Hz for males and only by 10 Hz for females. This difference is significant, [F (2, 372) = 4.79, p = 0.029]; see Figure 6. No other significant interactions were obtained.

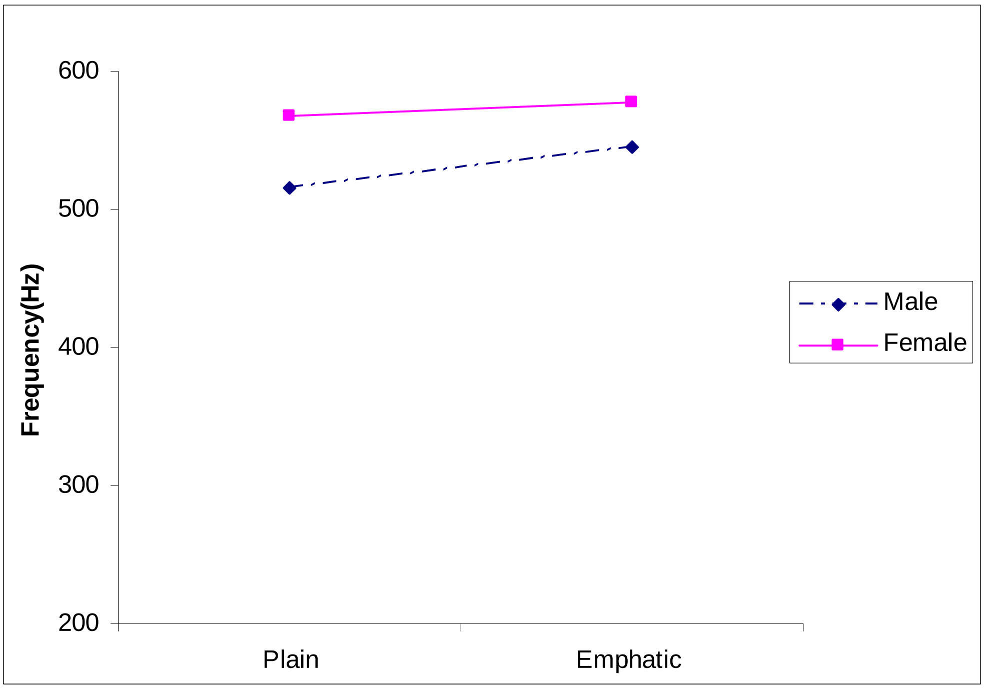

Figure 6: Consonant-type by Gender interaction for F1 Onset for the vowel in the right-adjacent position.

3.3.2.1.2. F1 target consonant word-medial

The stimuli used for this condition had only variations of two vowels: /i/ and /a/. For vowels in word medial positions in the same syllable with the target consonant, e.g. [i] in [katˤik], F1 was measured at three points in the vowel: onset, midpoint and offset. The results show that F1 values at onset and mid positions were significantly higher in emphatic environments compared to their plain counterparts, [F (1, 1014) = 68.897, p < 0.001], and [F (1, 1014) = 7.882, p = 0.005], respectively. F1 values at offset position for the target vowel did not show significant differences, [F (1, 1014) = 2.300, p = 0.130]. Figure 7 below shows these results.

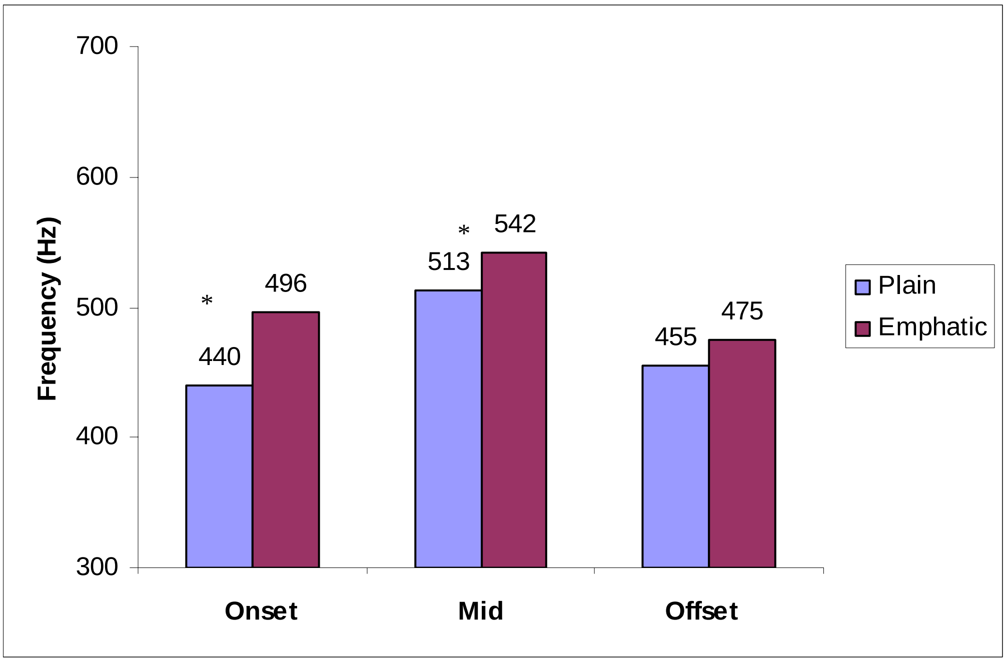

Figure 7: F1 values at onset, midpoint and offset positions for the vowel in the same syllable with the word-medial target consonant.

No Consonant-type by Vowel Quality interactions were obtained for the target vowels themselves, i.e. the vowels in the same syllable with the target consonant. However, some interactions for the adjacent vowel were found. A Consonant-type by Vowel Quality interaction was obtained for F1 Onset of the vowel to the left of the target one. When the target vowel was /a/, F1 Onset for the left adjacent vowel rose by 71 Hz in emphatic position compared to only 46 Hz when the target vowel was /i/. This difference is significant, [F (1, 1011) = 8.05, p = 0.005]. Figure 8 below displays these results.

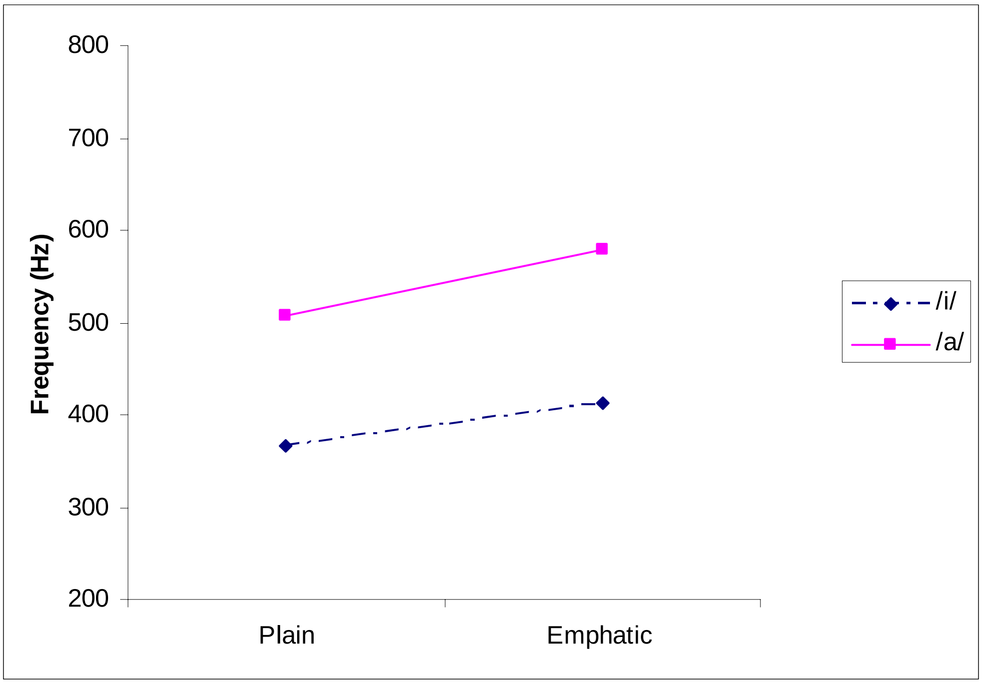

Figure 8: Consonant-type by Vowel Quality interaction for F1 Onset of the vowel to the left of the target one.

Another interaction, a Consonant-type by Adjacent Vowel Quality was obtained for F1 Onset, e.g. for /a/ in [kat^{ʕ}ik]. Results show that in emphatic environments, F1 Onset rises by (44 Hz) for /a/ and by 22 Hz for /i/. This difference is significant, [F (1, 1011) = 17.77, p < 0.001]. Figure 9 below plots these results.

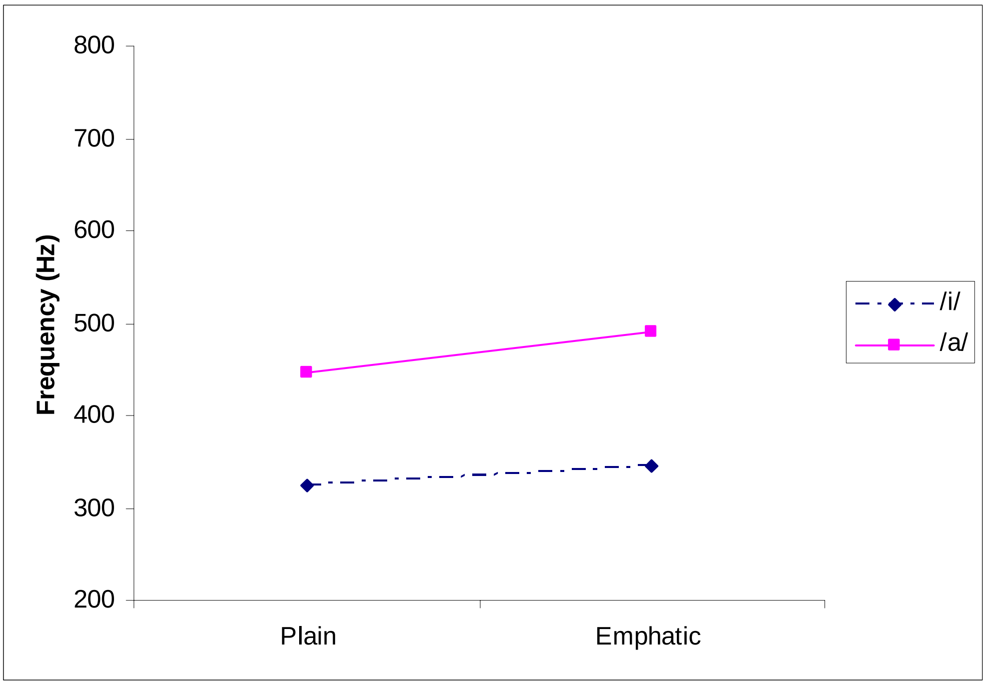

Figure 9: Consonant-type by Adjacent Vowel Quality interaction for F1 Onset of the vowel to the left to the target one.

A similar result was obtained when the measurement was taken at the vowel midpoint. A Consonant-type by Adjacent Vowel Quality was obtained for F1 Mid, e.g. for /a/ in [katˤik]. Results show that in emphatic environments, F1 Mid rises by 73 Hz for /a/ and by 43 Hz for /i/. This difference is significant, [F (1, 1011) = 8.49, p = 0.004]. Figure 10 below plots these results.

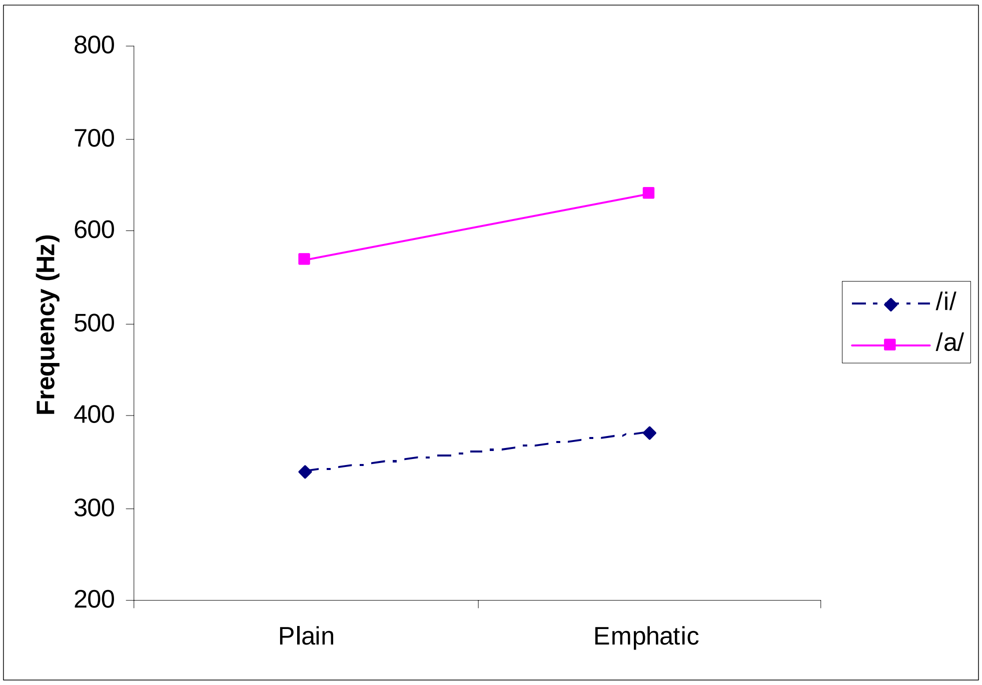

Figure 10: Consonant-type by Adjacent Vowel Quality interaction for F1 Mid of the vowel to the left of the target one.

Similarly, a Consonant-type by Adjacent Vowel Quality interaction was obtained for F1 Offset, e.g. for /a/ in [katˤik]. Results show that in emphatic environments, F1 Offset rises by 82 Hz for /a/ and by 56 Hz for /i/. This difference is significant, [$F(1, 1011) = 3.88$, $p = 0.049$]. Figure 11 below plots these results.

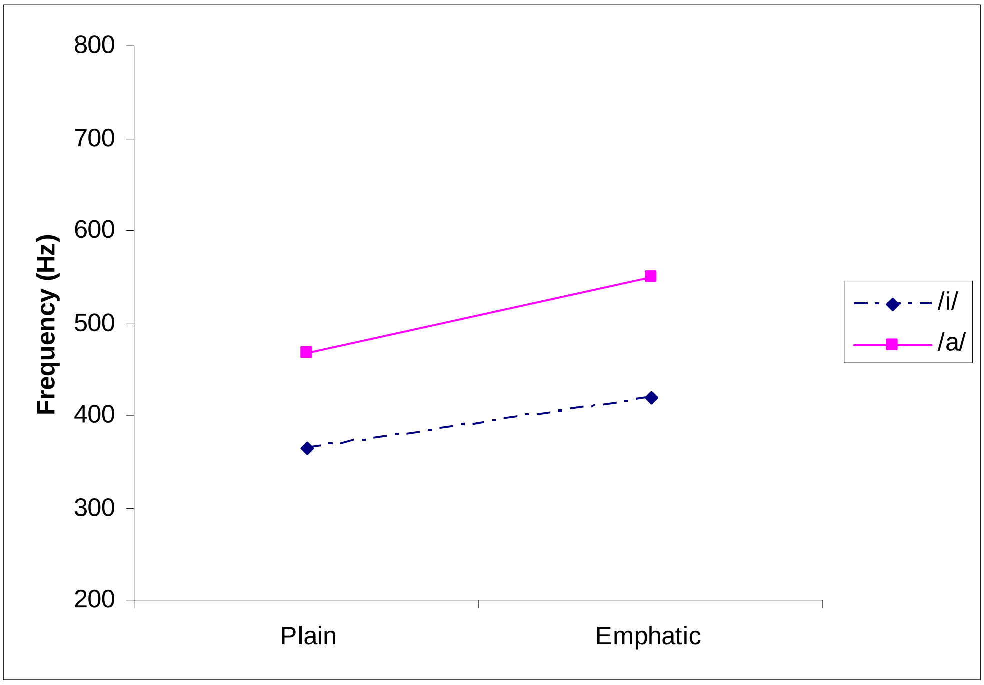

Figure 11: Consonant-type by Adjacent Vowel Quality interaction for F1 Offset of the vowel to the left of the target one.

Additionally, a Consonant-type by Gender interaction was also obtained for F1 Onset of the vowel left to the target one. F1 Onset for males rises by 74 Hz in emphatic environments compared to only 36 Hz for females. This difference is significant, [F (1, 1011) = 8.43, p = 0.004]. Figure 12 below displays this result.

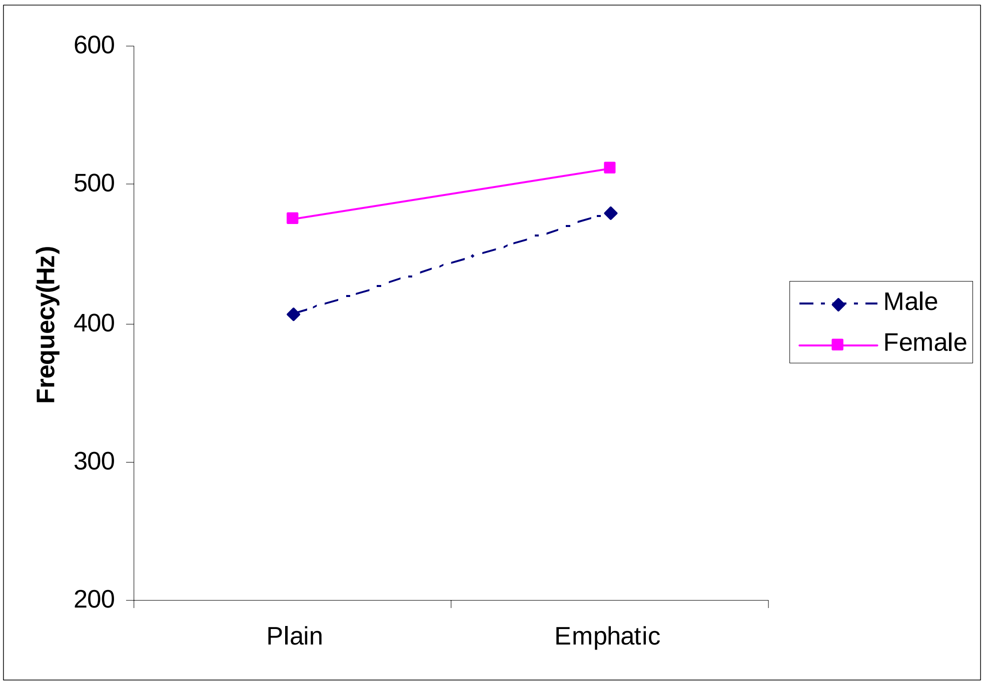

Figure 12: Consonant-type by Gender interaction for F1 Onset of the vowel to the left of the target one.

When F1 measurements were taken at the middle of the left adjacent vowel, similar results were obtained. A Consonant-type by Vowel Quality interaction was obtained for F1 Mid of the vowel to the left of the target one. When the target vowel was /a/, F1 Mid for the left adjacent vowel rose by 47 Hz in emphatic position compared to only 24 Hz when the target vowel was /i/. This difference is significant, [$F(1, 1011) = 3.97$, $p = 0.046$]. Figure 13 below displays these results.

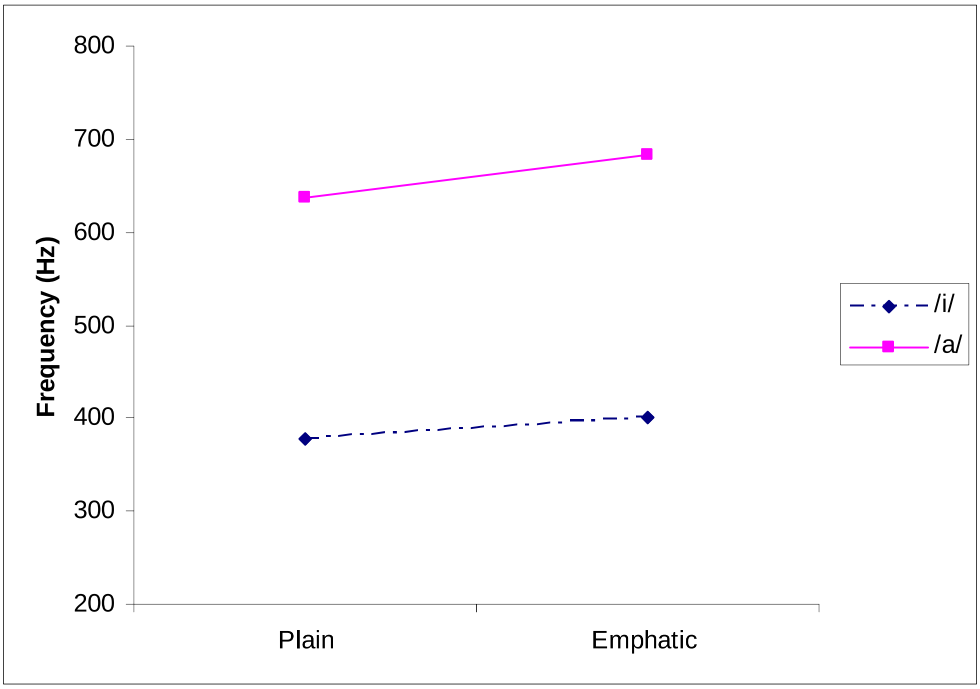

Figure 13: Consonant-type by Vowel Quality interaction for F1 Mid of the vowel to the left of the target one.

Interestingly, when examining leftward adjacency, e.g. [a] in [kat^{ʕ}ik], F1 shows a significant rise when measurements were taken at onset, mid and offset positions. At onset positions, F1 was significantly higher in emphatic environments compared to its counterpart in plain environments, [$F (1, 1014) = 47.631$, $p < 0.001$]. The same applied to F1 values when the measurement was taken at midpoint, [$F (1, 1014) = 43.878$, $p < 0.001$] and at offset, [$F (1, 1014) = 87.760$, $p < 0.001$]. Figure 14 shows these results.

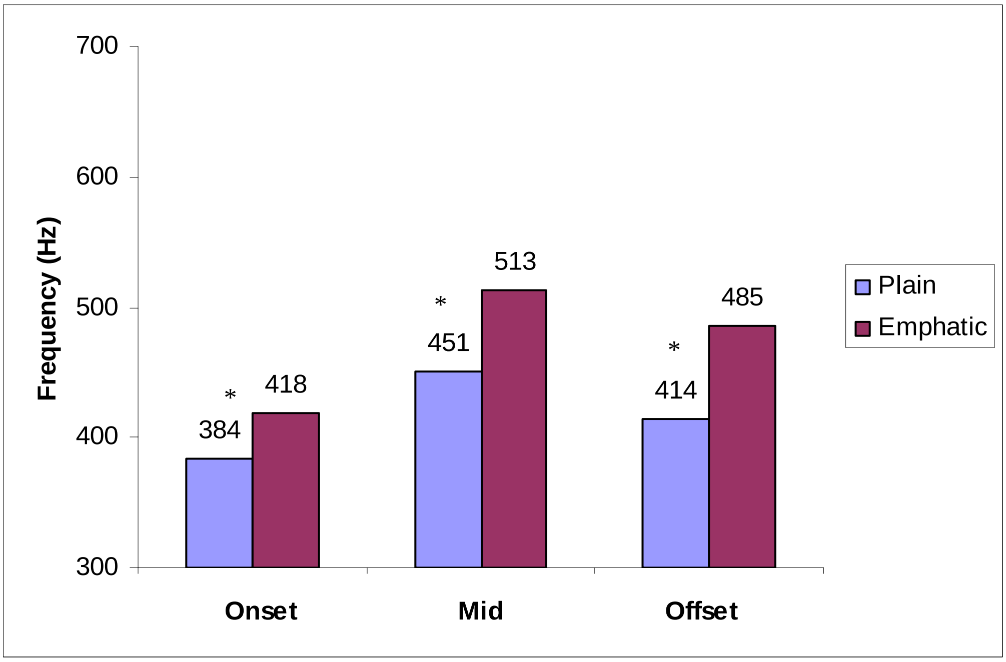

Figure 14: F1 values in word-medial positions at onset, midpoint and offset positions for the vowel left-adjacent to the syllable with the target consonant.

3.3.2.1.3. target consonant word-final

For vowels in word final positions in the same syllable with the target consonant, e.g. [i] in [tabis^{ʕ}], F1 was measured at three points in the vowel: onset, midpoint and offset. Results show that target vowel F1 was significantly higher in emphatic environment compared to its plain counterpart at two positions: onset and offset of the vowel. Differences obtained when the measurements were taken at vowel midpoint were not significant. For onset positions, [F (1, 389) = 5.137, p = 0.024]; for mid vowel positions, [F (1, 389) = 2.975, p = 0.085]; and for vowel offset, [F (1, 389) = 20.402, p < 0.001]. Figure 15 below shows these results.

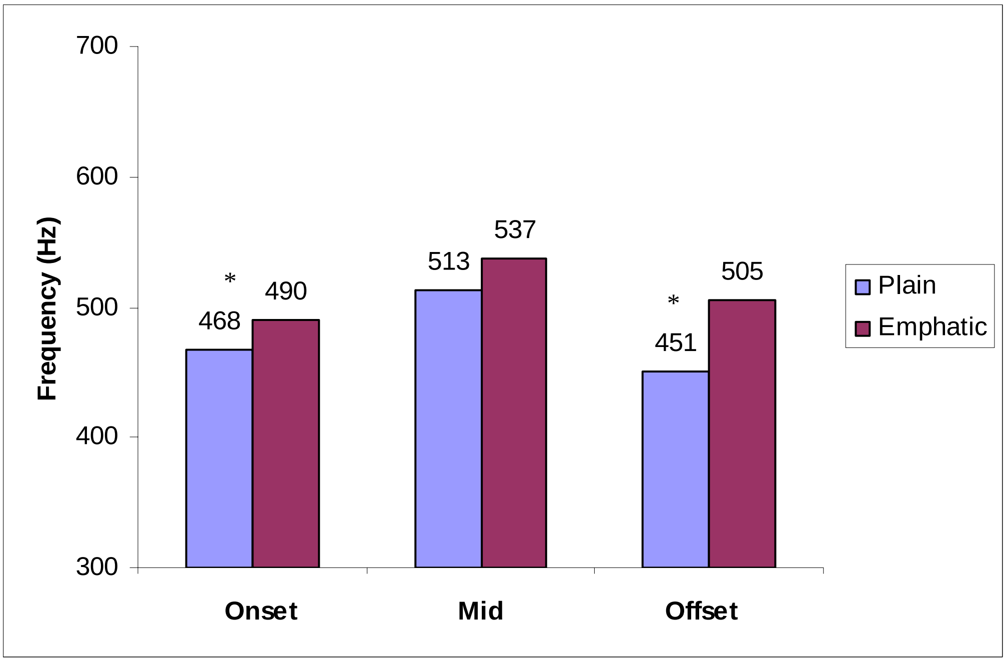

Figure 15: F1 values in word-final positions at onset, midpoint and offset positions for the vowel in the same syllable with the target consonant.

F1 for the vowel in the left adjacent positions, e. g. [a] in [tabisˤ], was significantly higher in emphatic environments compared to plain ones when measurements were taken at three positions: onset, [F (1, 389) = 72.503, p = 0.00], vowel midpoint, [F (1, 389) = 40.933, p = 0.00], and vowel offset, [F (1, 389) = 44.162, p = 0.00]. Figure 16 below shows these results.

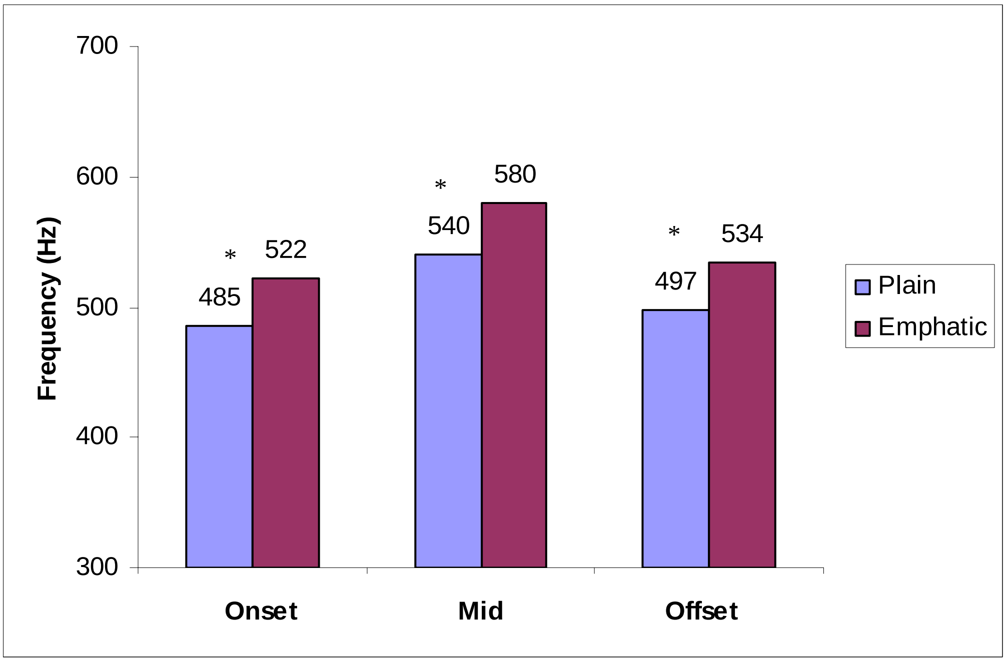

Figure 16: F1 values in word-final positions at onset, midpoint and offset positions for the vowel left-adjacent to the syllable with the target consonant.

A significant Consonant-type by Gender interaction was obtained for F1 of the left adjacent vowel when the measurement was taken at the offset. F1 in emphatic environments rises for males by 79 Hz compared to females 30 Hz. This difference is significant, [$F (2, 387) = 4.17$, $p = 0.042$]; see Figure 17 below.

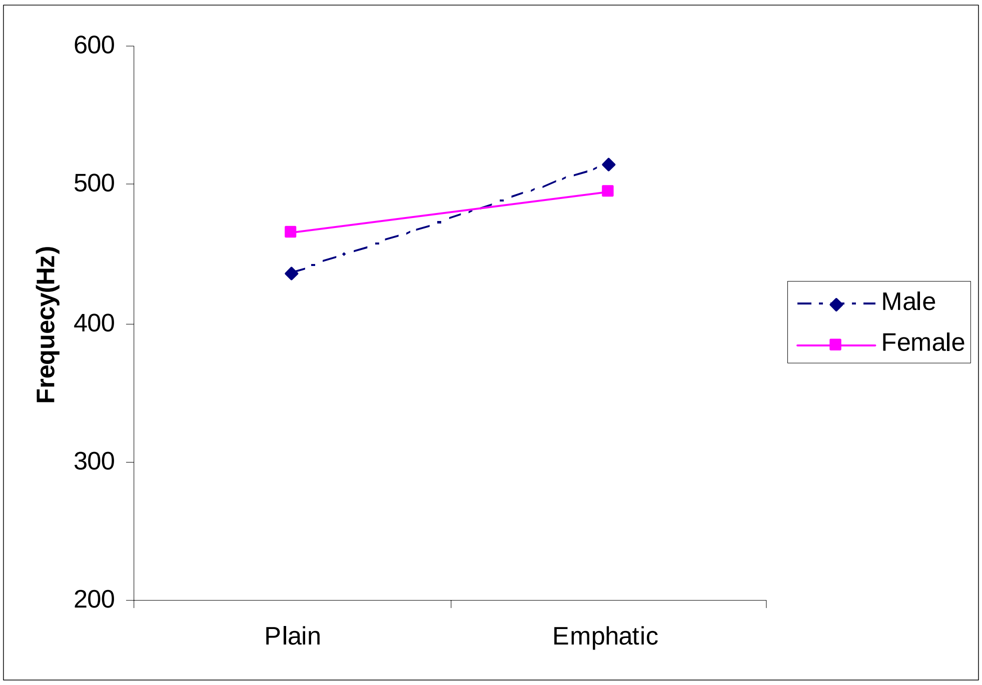

Figure 17: Consonant-type by Gender interaction for F1 Offset for the vowel in the left adjacent position.

3.3.2.2. F2

Since the target consonants appear in three different positions: word-initial, word-medial and word-final, the results will be reported accordingly.

3.3.2.2.1. target consonant word-initial

For vowels in the same position with the target consonant, e.g. [u] in [sˤubat], F2 was measured at three points: onset, midpoint and offset. Where target consonants appear in word-initial positions, the results show that F2 values for vowels in emphatic environments drop significantly. However, the drop is only significant when F2 is measured at onset position. F2 in vowel onset position is significantly lower in emphatic environments compared to plain ones, [F (1, 374) = 32.261, p <0.001]. When measured at vowel midpoint, differences were not significant, [F (1, 374) = 2.789, p = 0.096]; and similarly for vowel offset, [F (1, 374) = 0.862, p = 0.354]. Figure 18 below shows the results:

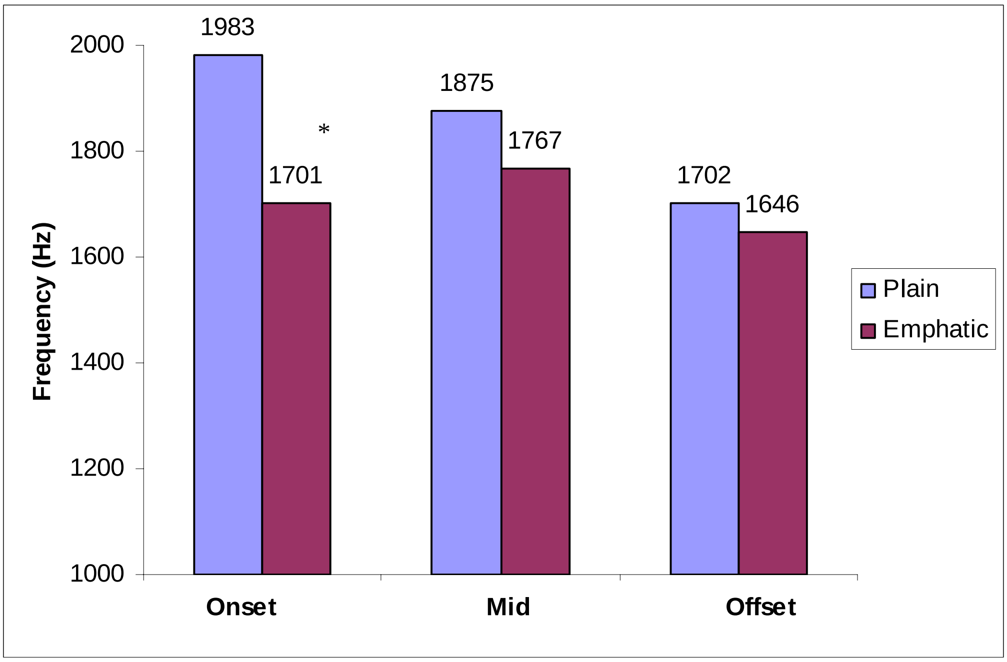

Figure 18: F2 values in word-initial positions at onset, midpoint and offset positions for the vowel in the same syllable with the target consonant.

A Consonant-type by Vowel Quality interaction was obtained for F2 in word-initial positions. In emphatic environments, F2 for the vowel in word-initial target positions dropped by 437 Hz for /i/, 421 Hz for /a/ and only by 32 Hz for /u/. This difference is significant, [F(2, 370) = 14.21, p<0.001]. Figure 19 shows these results:

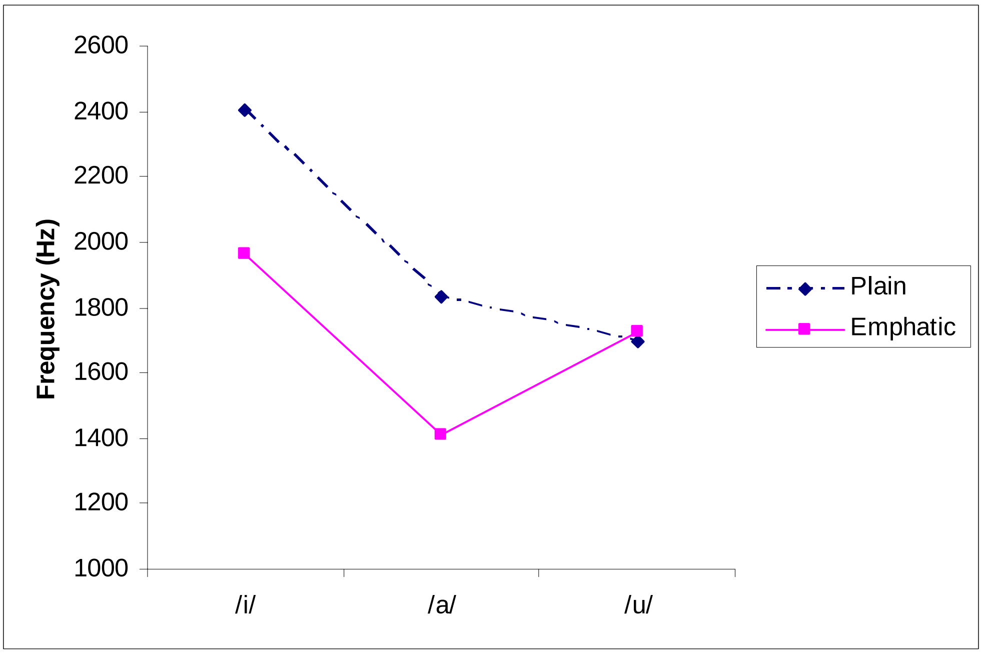

Figure 19: Consonant-type by Vowel Quality interaction for F2 Onset in target positions.

A Consonant-type by Gender interaction is also obtained for F2 in word-initial positions. In emphatic environments, F2 drops by 458 Hz for females and by 105 Hz for males, [$F(2, 372) = 13.31$, $p<0.001$], Figure 20 below shows these results:

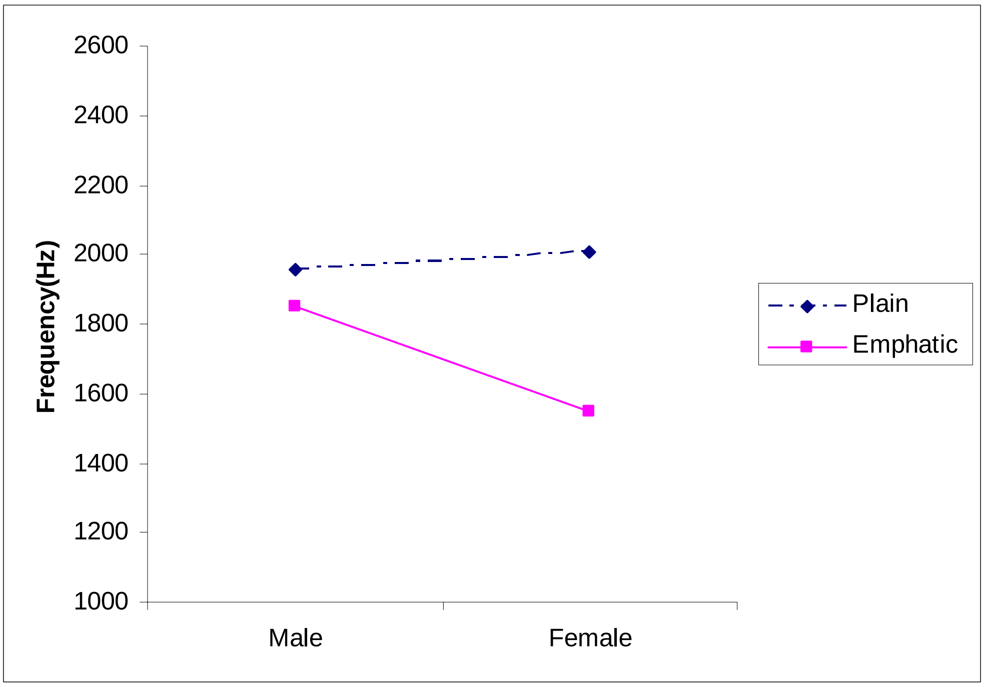

Figure 20: Consonant-type by Gender interaction for F2 Onset in target positions.

Results show that F2 for vowels in right adjacent positions, e.g., [a] in [$s^{ʕ}$ubat], was significantly lower in emphatic environments compared to plain ones. In onset position, the F2 drop for vowels in emphatic positions was significant, [$F(1, 374) = 32.512$, $p < 0.001$]. A similar result was obtained when the measurement was taken at midpoint, [$F(1, 374) = 50.212$, $p < 0.001$], and when the measurement was taken at vowel offset, [$F(1, 374) = 13.453$, $p < 0.001$]. Figure 21 plots these results:

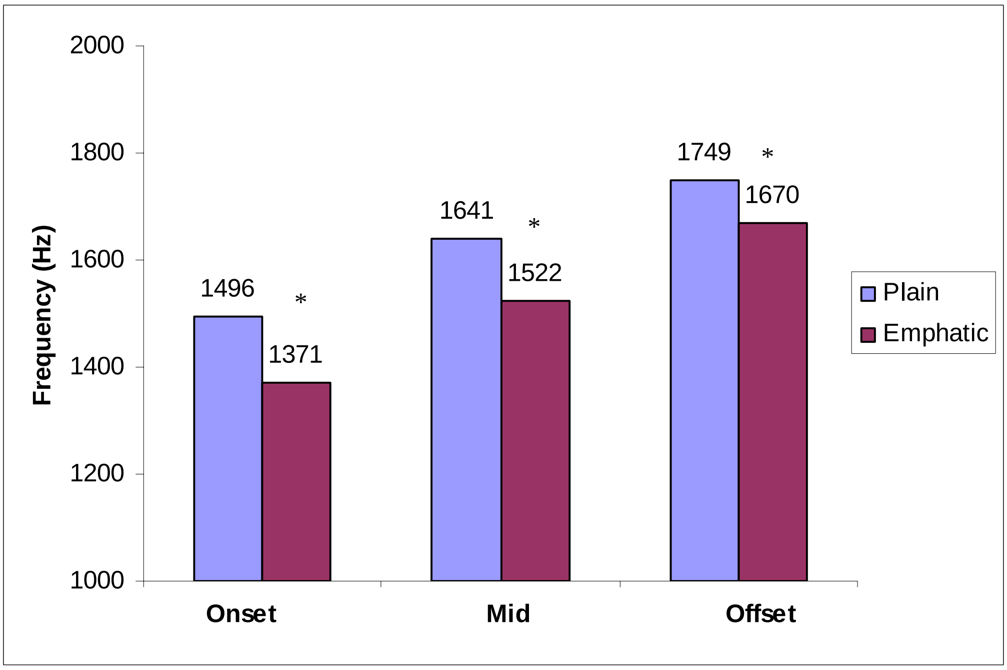

Figure 21: F2 values at onset, midpoint and offset positions for the vowel right-adjacent to the syllable with the word-initial target consonant.

3.3.2.2.2. target consonant word-medial

For vowels in word medial positions in the same syllable with the target consonant, e.g. [i] in [katˤik], results show that F2 drops significantly in emphatic positions when measurements were taken at vowel onset, [$F(1, 1014) = 340.498$, $p < 0.001$]; vowel midpoint, [$F(1, 1014) = 104.776$, $p < 0.001$]; and vowel offset, [$F(1, 1014) = 70.116$, $p < 0.001$]. Figure 22 below shows these results.

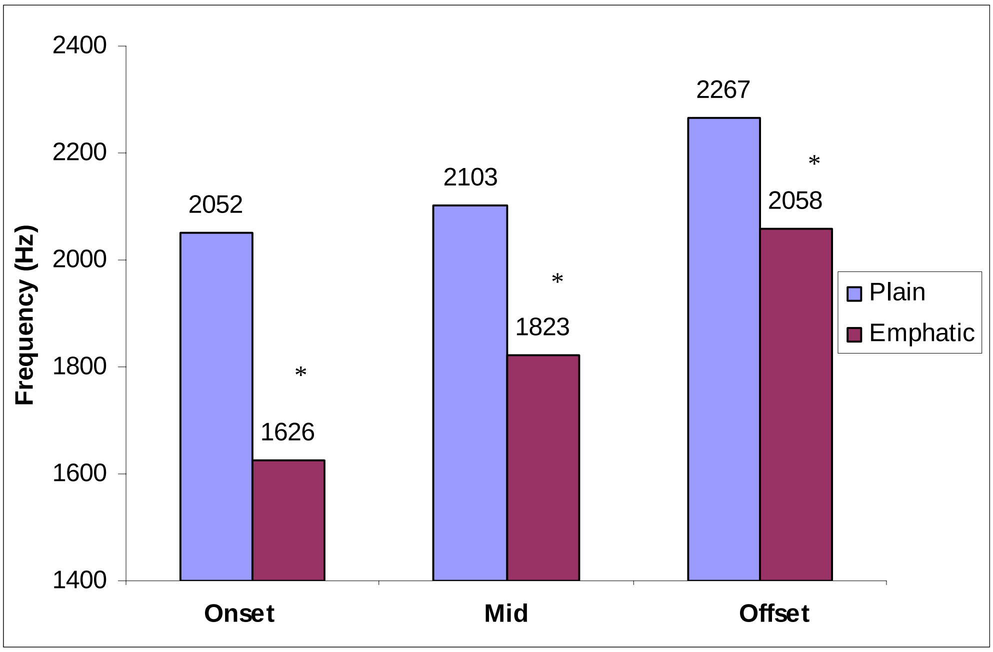

Figure 22: F2 values at onset, midpoint and offset positions for the vowel in the same syllable with the word-medial target consonant.

A Consonant-type by Vowel Quality interaction is obtained where F2 in emphatic environments drops by 349 Hz for /a/ and only by 92 Hz for /i/, [$F(1, 1011) = 65.42$, $p < 0.001$]. Figure 23 plots these results:

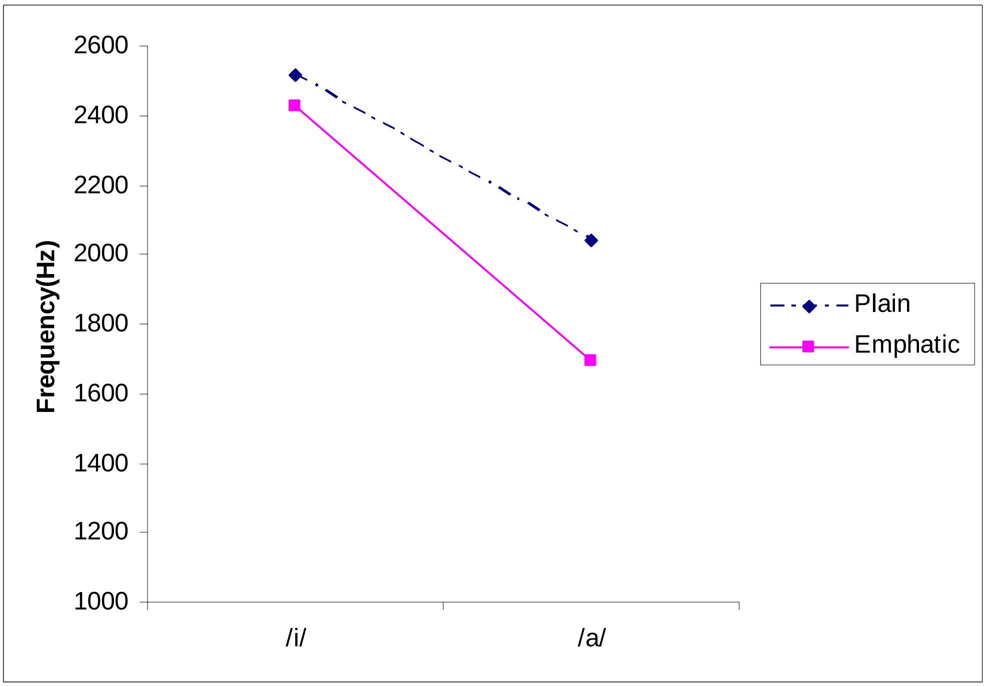

Figure 23: Consonant-type by Vowel Quality interaction for F2 Mid in target positions.

A Consonant-type by Gender interaction is also obtained where F2 for females drops in emphatic environments by 264 Hz, and by 156 Hz for males. This is a significant difference, [$F(1, 1011) = 4.74$, $p=0.030$]. Figure 24 shows the results:

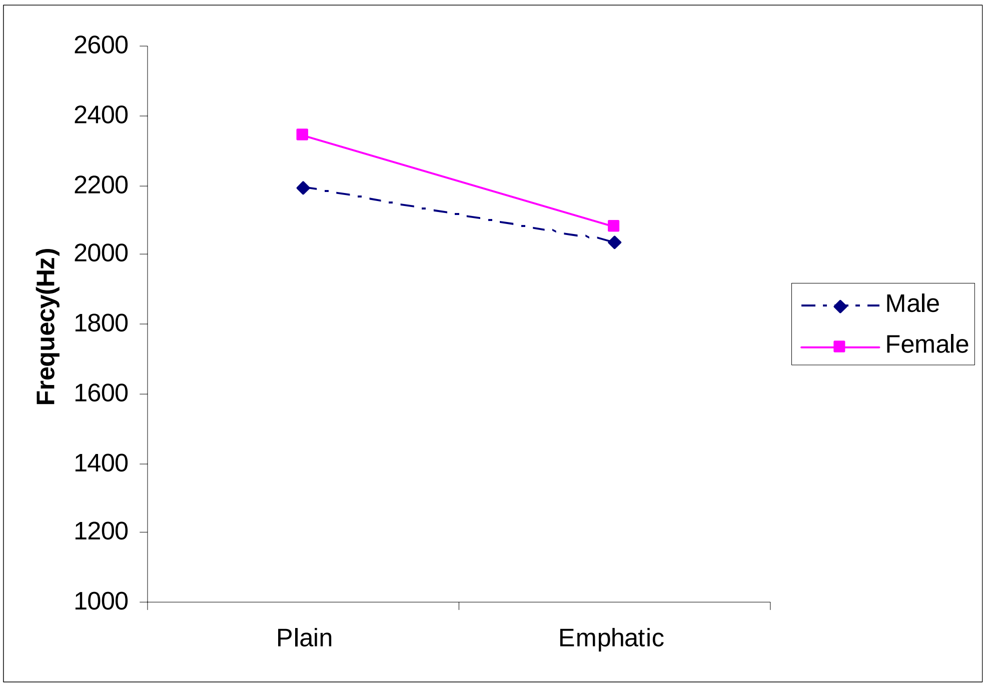

Figure 24: Consonant-type by Gender interaction for F2 Mid in target positions.

A Consonant-type by Adjacent Vowel Quality interaction is also obtained for F2 in word-medial positions for the vowels adjacent to the target one where F2 drops by 408 Hz for the vowel /a/ and by 113 Hz for the vowel /i/. This is a significant difference, [$F(1, 1011) = 92.94$, $p<0.001$]. Figure 25 below shows the results:

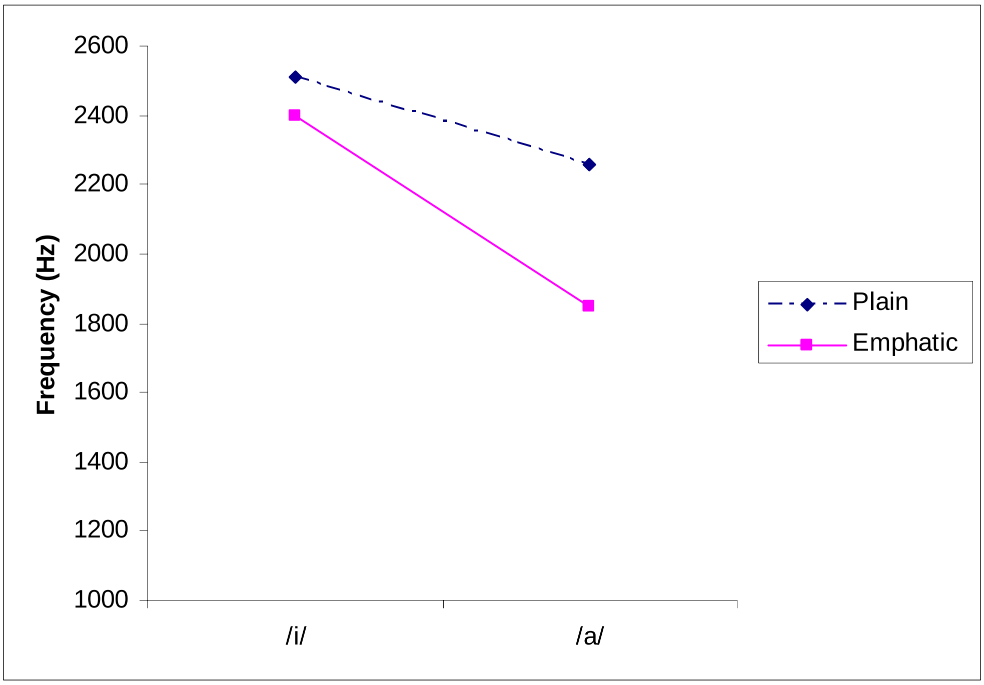

Figure 25: Consonant-type by Adjacent Vowel Quality interaction for F2 Onset in adjacent positions.

In adjacent positions, a Consonant-type by Gender interaction is also obtained where F2 in emphatic environments drops by 323 Hz for females and by 204 Hz for males. This difference proves significant, [F (1, 1011) =11.00 , p=0.001]. See Figure 26.

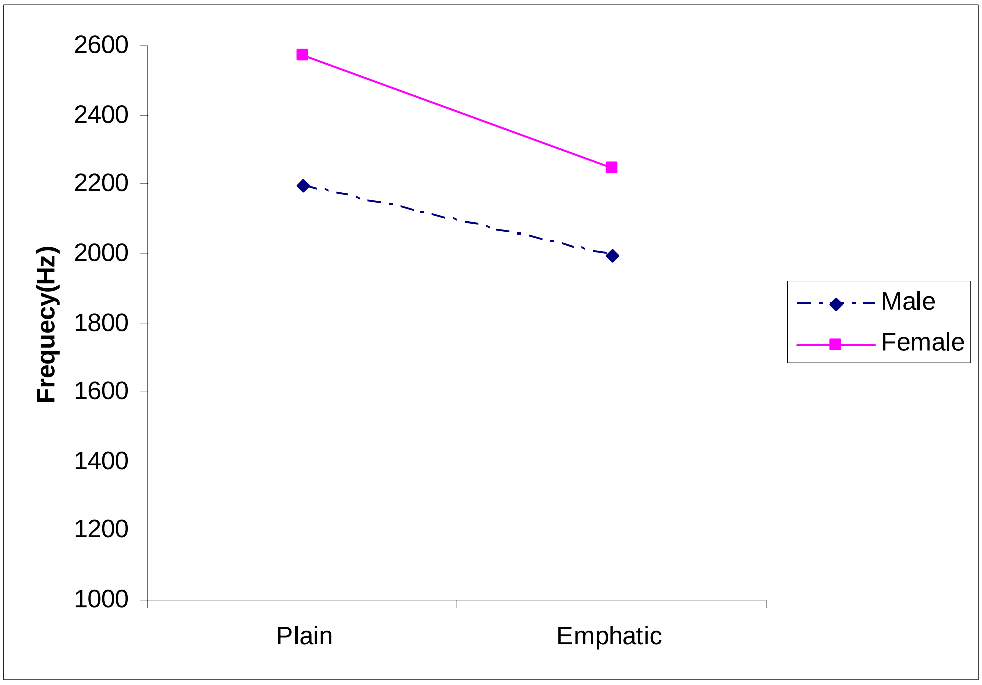

Figure 26: Consonant-type by Gender interaction for F2 Onset in adjacent positions.

For vowels in left adjacent positions, e.g., [a] in [kat^{ʕ}ik], F2 drops significantly in emphatic positions when measurements were taken at vowel onset, [F (1, 1014) = 166.839, p < 0.001]; vowel midpoint, [F (1, 1014) = 207.395, p < 0.001]; and vowel offset, [F (1, 1014) = 464.616, p < 0.001]. Figure 27 below shows these results.

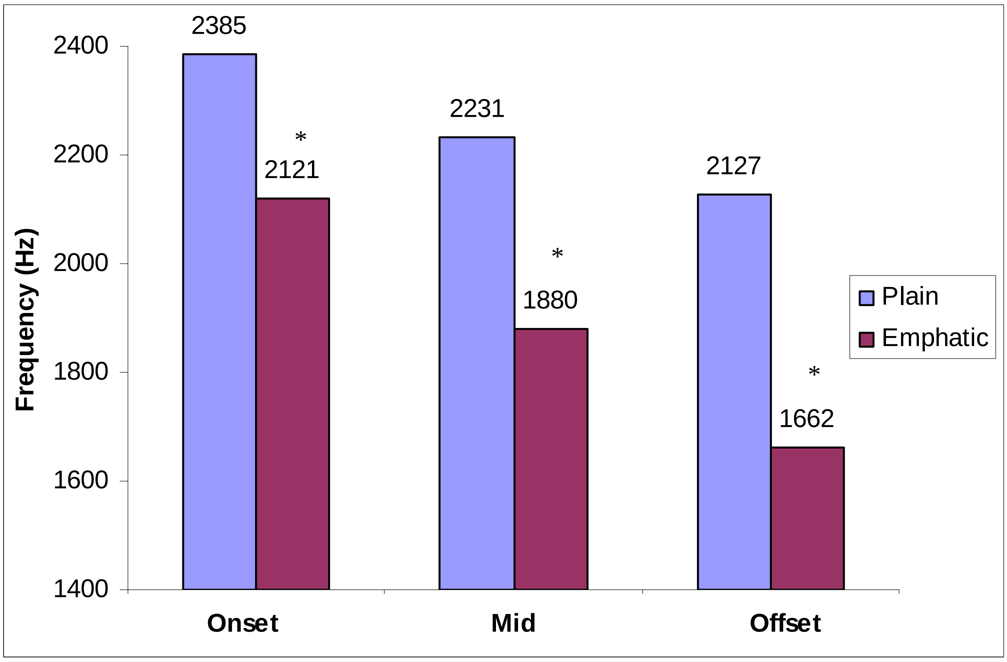

Figure 27: F2 values at onset, midpoint and offset positions for the vowel left-adjacent to the syllable with the word-medial target consonant.

3.3.2.2.3. target consonant word-final

For vowels in word final positions in the same syllable with the target consonant, e.g. [i] in [tabis^{ʕ}], F2 was measured at three points in the vowel: onset, midpoint and offset. At all measurement points, F2 drops significantly in emphatic environments compared to the plain counterparts. At onset positions, [F (1, 389) = 7.389, p = 0.007]; at mid positions, [F (1, 389) = 8.105, p = 0.005]; and at offset positions, [F (1, 389) = 29.169, $p < 0.001$]. Figure 28 shows these results.

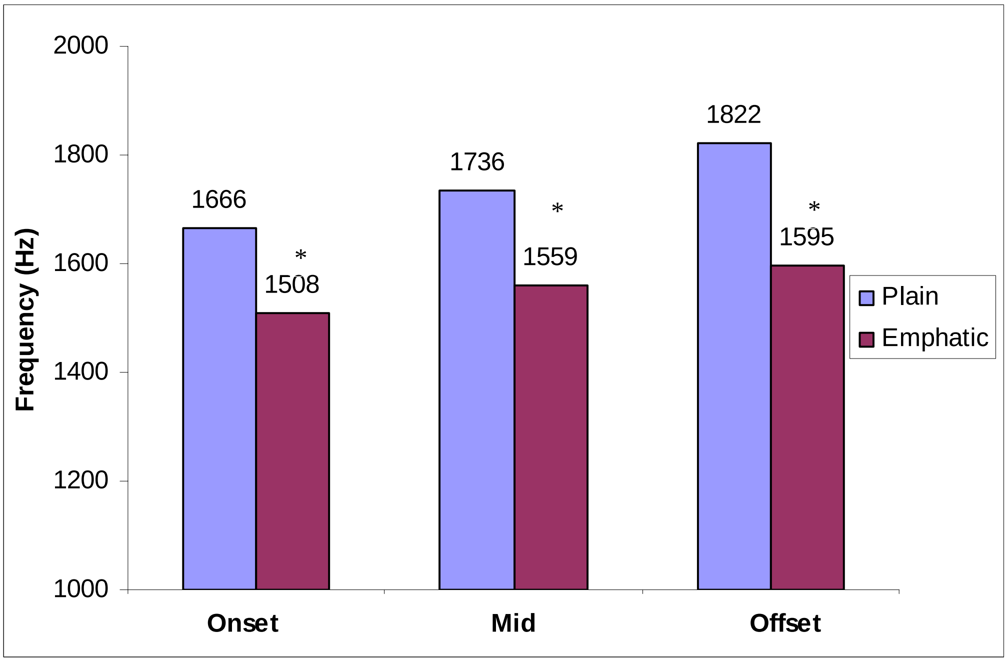

Figure 28: F2 values in word-final positions at onset, midpoint and offset positions for the vowel in the same syllable with the target consonant.

F2 for the vowel in the left-adjacent positions, e.g. [a] in [tabisˤ], was significantly lower in emphatic environments compared to plain ones. At onset positions, [$F (1, 389) = 100.231$, $p < 0.001$]; at mid positions, [$F (1, 389) = 84.499$, $p < 0.001$]; and at offset positions, [$F (1, 389) = 55.099$, $p < 0.001$]. Figure 29 shows these results.

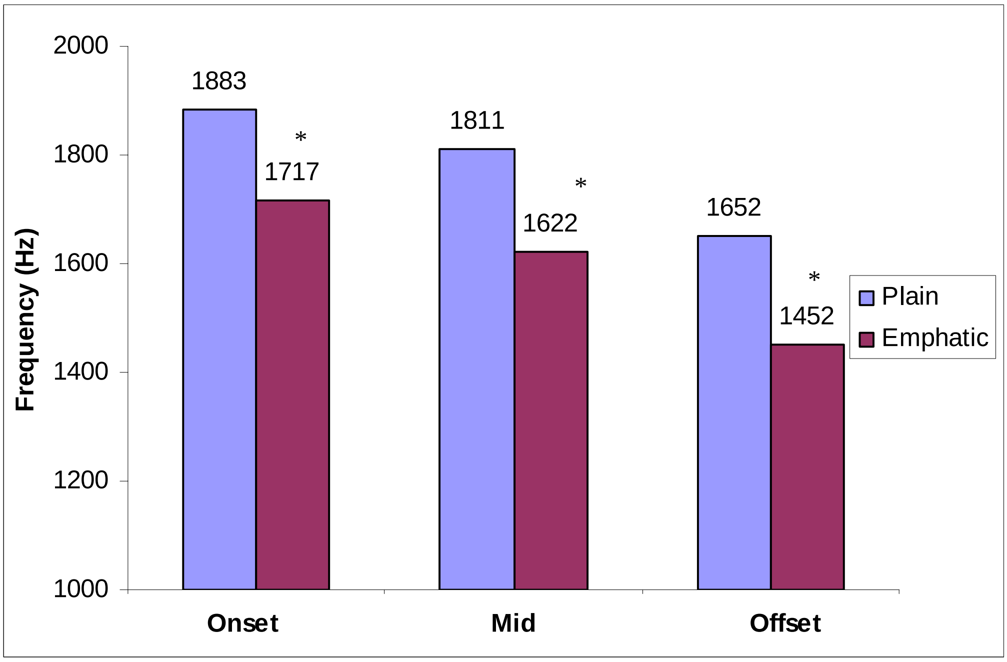

Figure 29: F2 values at onset, midpoint and offset positions for the vowel left-adjacent to the syllable with the word-final target consonant.

3.3.2.3. F3

Since the target consonants appear in three different positions: word-initial, word-medial and word-final, the results will be reported accordingly.

3.3.2.3.1. target consonant word-initial

For vowels in the same position with the target consonant, e.g. [u] in [$s^ʕ$ubat], F3 was measured at three points: onset, midpoint and offset. The results show that F3 is higher for vowels in emphatic environments. This increase is significant regardless of the position in the vowel at which the measurement was taken. In onset position, F3 rises significantly in emphatic environments, [$F(1, 374) = 18.819$, $p < 0.001$]. When the measurement is taken at vowel midpoint, a similar result is revealed, [$F(1, 374) = 4.732$, $p = 0.030$]. And the same is true for measurements taken at vowel offset positions, [$F(1, 374) = 16.143$, $p < 0.001$]. Figure 30 plots these results:

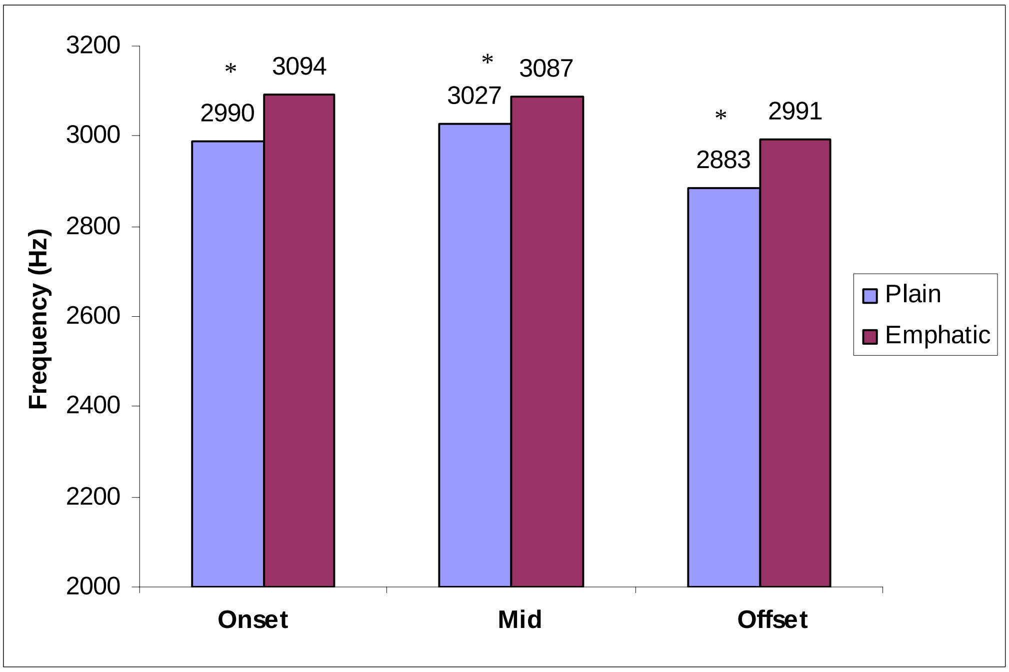

Figure 30: F3 values in word-initial positions at onset, midpoint and offset positions for the vowel in the same syllable with the target consonant.

For F3 measurements for vowels in right adjacent positions, e.g. [a] in [sˤubat], the results show that F3 was significantly higher in emphatic environments compared to plain ones only when the measurements were taken at onset and midpoint positions, not at offset positions.

Vowel F3 in onset position is significantly higher in emphatic compared to plain environments, [F (1, 374) = 13.328, p < 0.001]. A similar result is obtained for vowel F3 at midpoint, [F (1, 374) = 8.376, p = 0.004]. However, no significant difference was obtained for vowel F3 in offset position, [F (1, 374) = 2.972, p = 0.086]. Figure 31 plots these results:

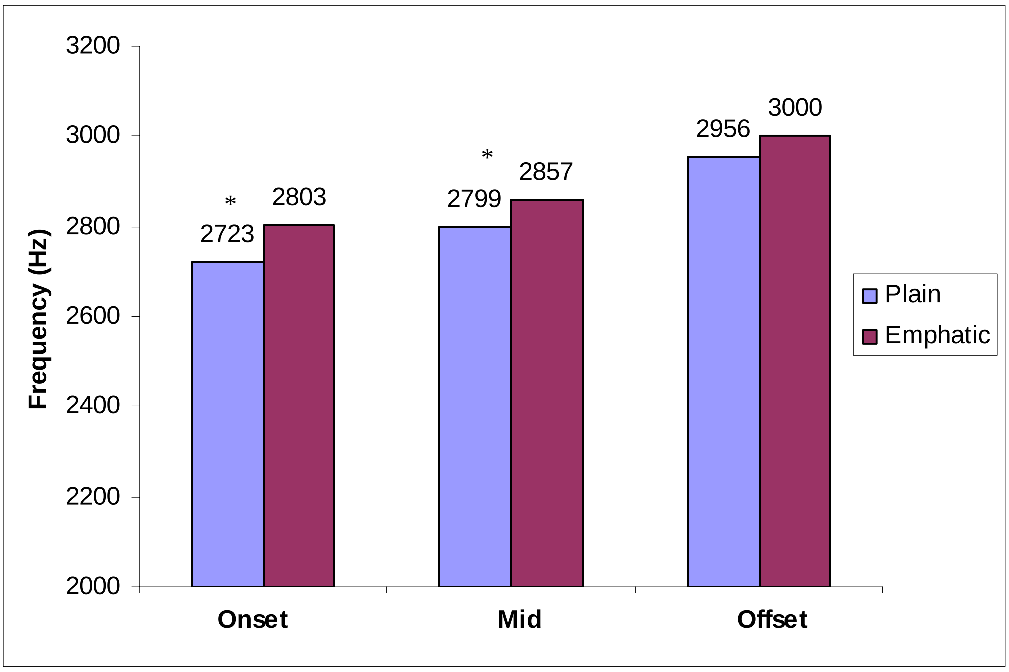

Figure 31: F3 values at onset, midpoint and offset positions for the vowel right adjacent to the syllable with the target consonant.

3.3.2.3.2. target consonant word-medial

For vowels in word medial positions in the same syllable with the target consonant, e.g. [i] in [katˤik], results show that F3 rises significantly in emphatic environments when measurements are taken at onset and offset positions but not at vowel midpoint. At onset positions, [F (1, 1014) = 32.793, p < 0.001]; at vowel midpoint, [F (1, 1014) = 2.400, p = 0.122]; and at vowel offset, [F (1, 1014) = 4.267, p = 0.039]. Figure 32 below plots these results.

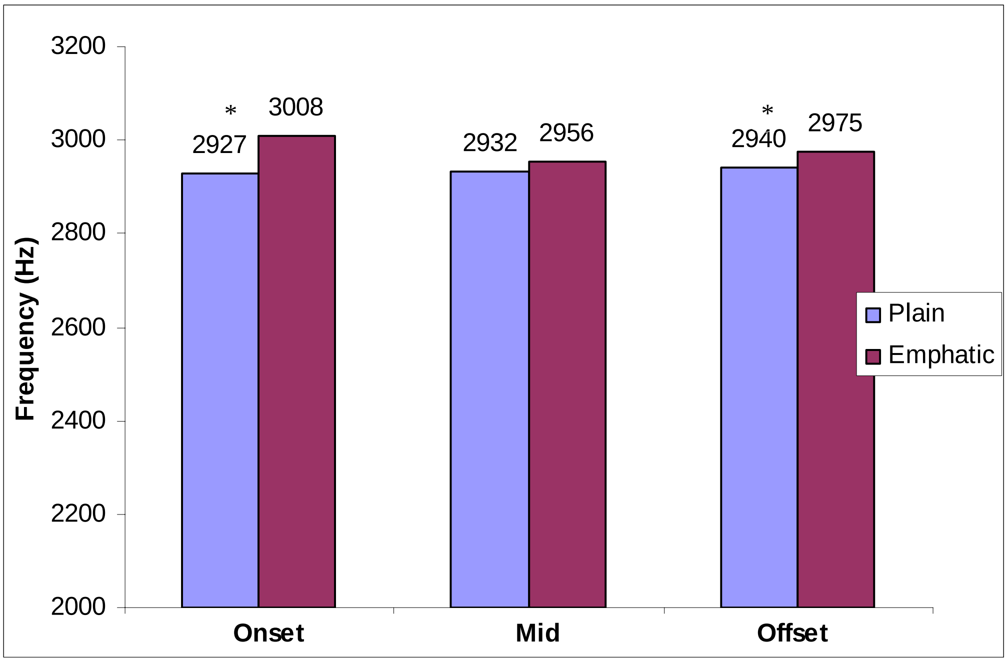

Figure 32: F3 values at onset, midpoint and offset positions for the vowel in the same syllable with the word-medial target consonant.

Surprisingly, for vowels in left adjacent positions, e.g., [a] in [katˤik], F3 drops significantly in emphatic environments when measurements were taken at onset and midpoint positions, but expectedly rises when measurements were taken at offset positions. F3 onset and midpoint for the left adjacent vowel were significantly lower in emphatic environments, [F (1, 1014) = 27.801, p < 0.001], and [F (1, 1014) = 6.439, p = 0.011], respectively. F3 offset for the left adjacent vowel was significantly higher in emphatic environments, [$F(1, 1014) = 21.142$, $p < 0.001$]. Figure 33 below shows these results.

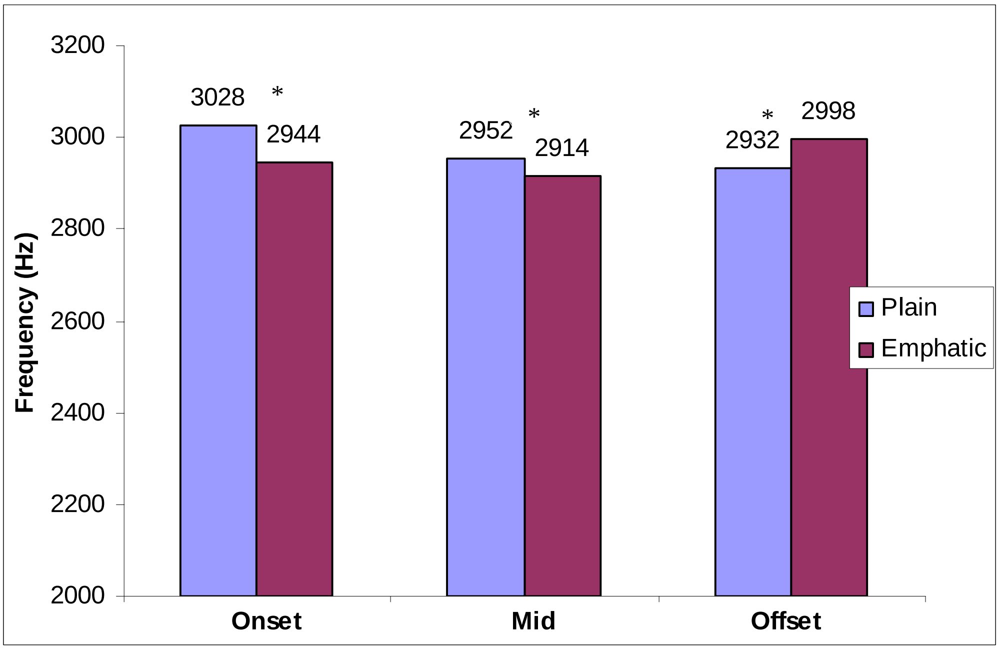

Figure 33: F3 values at onset, midpoint and offset positions for the vowel left-adjacent to the syllable with the target consonant.

3.3.2.3.3. target consonant word-final

For vowels in word final positions in the same syllable with the target consonant, e.g. [i] in [tabisˤ], F3 was measured at three points in the vowel: onset, midpoint and offset. At all measurement points, vowel F3 significantly rises in emphatic environments compared to plain counterparts. F3 is higher in emphatic environments when measurements were taken at onset positions, [$F(1, 389) = 15.857$, $p = 0.00$]; at midpoint, [F (1, 389) = 12.830, p = 0.00]; and at offset, [F (1, 389) = 56.965, p = 0.00]. Figure 34 below displays these results.

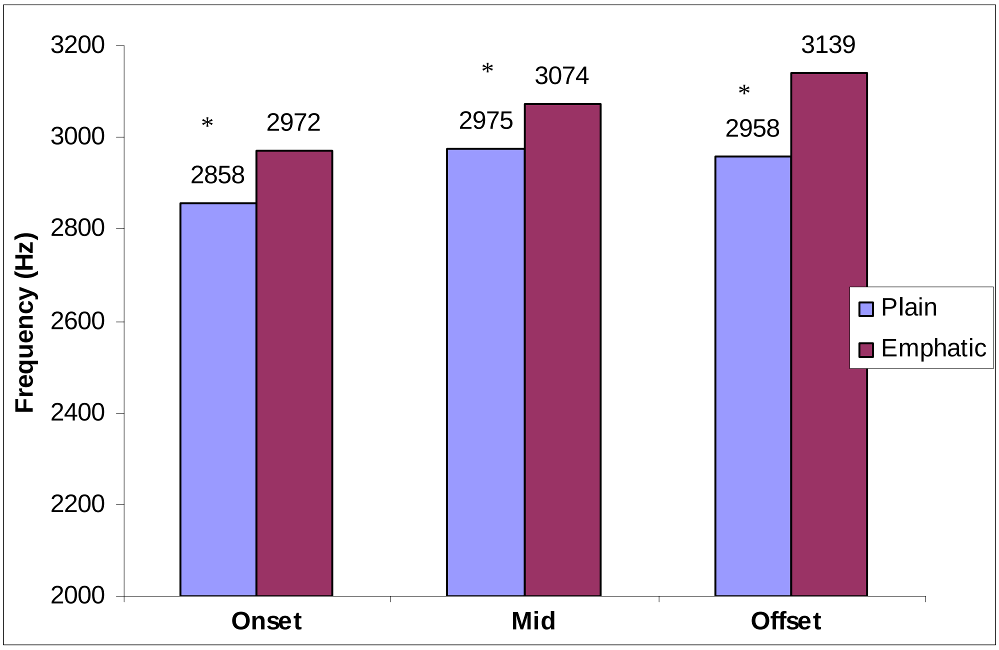

Figure 34: F3 values at onset, midpoint and offset positions for the vowel in the same syllable with the word-final target consonant.

F3 for the vowel in the left-adjacent positions, e.g. [a] in [tabis^{ʕ}], was significantly higher in emphatic environments compared to plain ones. However, this result was obtained when measurements were taken at vowel midpoint and offset positions but not at vowel onset positions. At onset positions, vowel F3 did not show significant differences, [F (1, 389) = 3.249, p = 0.072]. At vowel midpoint, F3 was significantly higher in emphatic environments, [F (1, 389) = 6.061, p = 0.014], and similar results were obtained when measurements were conducted at vowel offset positions, [F (1, 389) = 14.876, p = 0.00]. Figure 35 below shows these results.

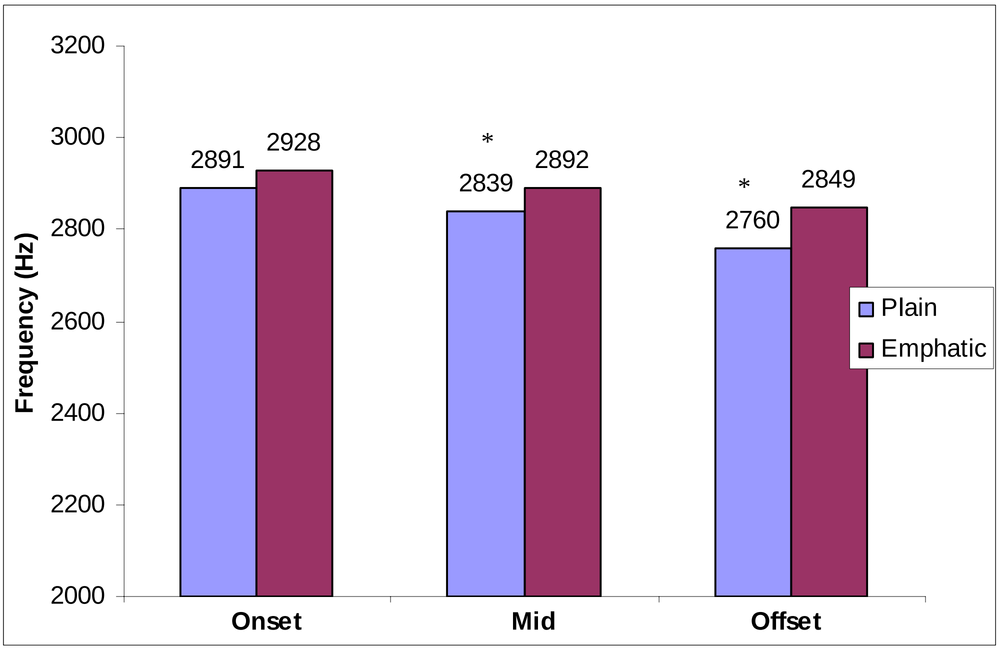

Figure 35: F3 values at onset, midpoint and offset positions for the vowel left-adjacent to the syllable with the target consonant.

3.4. Results Summary

Tables 2, 3, and 4 below summarize the main results on the bisyllables. Since segment durations did not show any consistent effects, we will focus on spectral measures here and in the subsequent discussion. This arrow (↑) represents an increase in formant frequency in emphatic position, the other one (↓) represents a decrease in formant frequency in emphatic position. The numbers in each table under Difference show the magnitude of the increase or decrease (in Hz).Wherever numbers are shown in parentheses, the difference was not significant.

Table 3: Emphasis in words with initial target consonants.

sa.bat		Vowel 1	Difference (Hz)		Vowel 2	Difference
	F1 onset	↑	74	F1 onset	↑	19
	F1 mid	↑	43	F1 mid	↑	(9)
	F1 offset	↑	20	F1 offset	↓	(7)
	F2 onset	↓	282	F2 onset	↓	125
	F2 mid	↓	(108)	F2 mid	↓	119
	F2 offset	↓	(56)	F2 offset	↓	79
	F3 onset	↑	104	F3 onset	↑	80
	F3 mid	↑	60	F3 mid	↑	58
	F3 offset	↑	108	F3 offset	↑	(44)

Table 4: Emphasis in words with medial target consonants.

ka.**s**ak		Vowel 1	Difference (Hz)		Vowel 2	Difference
	F1 onset	↑	34	F1 onset	↑	56
	F1 mid	↑	62	F1 mid	↑	29
	F1 offset	↑	71	F1 offset	↑	(20)
	F2 onset	↓	264	F2 onset	↓	426
	F2 mid	↓	351	F2 mid	↓	280
	F2 offset	↓	465	F2 offset	↓	209
	F3 onset	↓	84	F3 onset	↑	81
	F3 mid	↓	38	F3 mid	↑	(24)
	F3 offset	↑	66	F3 offset	↑	35

Table 5: Emphasis in words with final target consonants.

ta.ba**s**		Vowel 2	Difference (Hz)		Vowel 1	Difference
	F1 onset	↑	22	F1 onset	↑	37
	F1 mid	↑	(24)	F1 mid	↑	40
	F1 offset	↑	54	F1 offset	↑	37
	F2 onset	↓	158	F2 onset	↓	166
	F2 mid	↓	177	F2 mid	↓	189
	F2 offset	↓	227	F2 offset	↓	200
	F3 onset	↑	114	F3 onset	↑	(37)
	F3 mid	↑	99	F3 mid	↑	53
	F3 offset	↑	181	F3 offset	↑	89

3.5. Discussion

In line with previous studies and similar to the present results for the monosyllables, the main findings indicate a significant increase for vowel F1 and F3 values in emphatic target positions and a significant decrease for vowel F2. However, results are more complex for bisyllables. In words with initial target consonants, e.g. [sˤa.bat], F1 significantly rises for the target vowel in all measurement positions but this difference fades away in the right-adjacent vowel when measurements are taken at midpoint and offset positions. For words with a medial target consonant, e.g., [ka.sˤak], F1 values for the vowel in the same syllable with the target consonant rises at onset and midpoint but no significant differences were obtained for target vowel offset. Interestingly, for the vowel in the left-adjacent position, i.e. crossing a syllable, F1 rises at the three measurement points. As for words with target consonants in final positions, i.e. [ta.basˤ], F1 rises at all three measurement points for the target vowel and continues to rise for F1 onset and offset positions, not for F1 midpoint. These results suggest that for the most part, F1 increases in emphatic positions when the vowel is in the same syllable with the target consonant. The same effect seems to spread leftwards more easily than rightward. Card (1983) mentions leftward emphasis spread – as observed through F2 lowering – being more attested compared to rightward emphasis. However, her results are based on monosyllables. In the present study, leftward emphasis spread crosses the syllable boundary compared to rightward emphasis spread, which seems to be confined to the target syllable.

F2 shows a significant drop in emphatic environments. In words with initial target consonants, F2 drops significantly at vowel onset but the drop is insignificant at vowel midpoint and offset. The drop is attested in vowels right-adjacent to the target consonant at all measurement points. This only occurs in words with initial target consonants. In words with medial and final target consonants, F2 drops significantly in emphatic positions at the three measurement points and for the two vowels: the target and the left-adjacent ones. In accordance with our previous observations, F2 drops in the target positions and left of the syllable with the target vowel. This gives more evidence that leftward emphasis spread is more prominent in UJA.

F3 shows a significant increase in emphatic environments. In words with initial targets, vowels in the same syllable show a significant increase. This effect spreads to the vowel in the right-adjacent syllable when measurements are taken at vowel onset and midpoint, not at vowel offset. In words with medial target consonants, F3 rises in target positions when the measurements are taken at vowel onset and offset but not at vowel midpoint. For the vowel left of the target syllable, F3 surprisingly drops at vowel onset and midpoint but rises significantly at vowel offset. In words with final target consonants, F3 rises in the vowel in the same syllable with the target consonant when the measurements are taken at vowel midpoint and offset, but not at vowel onset. However, F3 significantly increases in left-adjacent vowels at the three measurement points.

Despite only a few odd findings in the results, mentioned above, there is a clear effect of emphasis on vowels whereby F1 and F3 increase while F2 drops in emphatic positions; and where leftward emphasis spread – as an effect of F1/F3 increase and F2 drop – is more obvious compared to rightward emphasis spread such that the former spans across the syllable boundary. This shows that anticipatory coarticulation is more common than preservatory coarticulation. Emphasis spread is asymmetrical in nature and "pharyngealization (like velarization) is anchored on the onset phase of the primary articulation and for that reason tends to spread in an anticipatory manner, affecting the formants of preceding segment(s) more than the formants of following segment(s)," Watson (1999: 293). See also Laver 1994; Davis 1995; Ladefoged and Maddieson 1996 for similar discussions on the prevalence of anticipatory coarticulation. Watson, supported by Ladefoged and Maddieson (1996), ascribes this asymmetrical nature of emphasis spread to secondary articulation, (1999: 298). She explains that in emphasis, "the pharynx narrows prior to the hold phase of the primary articulation; thus, pharyngealization is anchored more on the onset of the primary articulation, which results in the anticipatory nature of spread of pharyngealization".

The analyses in this chapter give room to a wider range of interactions that can enable us to better understand the acoustic correlates of emphasis. A number of independent variables were tested, see Table 1 above. Among the different variables that were examined, two seem to influence the degree of emphasis and/or emphasis spread: gender of the speaker and vowel quality. As an effect of emphasis, F1 values increase more in males than in females whereas F2 drops significantly more in females compared to males; see Figures 3, 4, 6, 12, and 17 above.

With regard to vowel quality, it is rather obvious that the vowels that are transparent to emphasis, i.e., do not seem to block emphasis spread are /a/ and /i/, where results show that sometimes emphasis as an effect of F1 increase is significantly more evident in /a/ compared to /i/. However, the high back vowel /u/ seems to block emphasis spread. This result holds for both the target vowels and the vowels in adjacent positions. Since emphasis involves a clear secondary back articulation, it is not surprising that it affects front and low vowels more than back vowels. This is what the data on bisyllables confirm.

The acoustic findings on the bisyllables substantiate earlier findings on the monosyllables and give a better idea of emphasis spread and its extent/domain. It is fair to claim that most effects of emphasis can be observed in the vowels within the target or adjacent syllables – despite a general feeling among native speakers of UJA, and MSA as well, that the target consonant triggers the emphatic perception of the consonant. These acoustic findings will be tested in the next chapter to verify, from the point of view of the listener, whether the vowels or the consonants carry the effects of emphasis.

Chapter Four

The perception study

The main findings of the acoustic study for the monosyllables showed that emphatic stops in word-final positions were consistently longer than their plain counterparts. While this was the only significant difference in terms of duration, the frequency measurements on the vowels provided deeper and more vivid insights into the nature of emphasis. Vowel F1 and F3 rose or tended to rise while F2 was consistently lower in emphatic positions compared to their plain counterparts. However, different interactions showed that some independent variables affected the degrees of increase or decrease of formant frequency such as vowel quality, position of the target consonant and vowel length. In the present chapter, I investigate whether some of the findings of the acoustic study map on to perception. Namely, whether the difference in formant frequencies between plain and emphatic obstruents and its variability due to vowel quality affect perception. Of course, investigating every aspect of the difference between plain and emphatic consonants and vowels in their neighborhood requires extensive efforts and experimental designs to account for every interaction between the consonant-type (plain and emphatic) and all other independent variables. This is beyond the scope of this chapter. For the purposes of this study, I included two independent variables: manner of articulation: a stop /t-$t^ʕ$/ and a fricative /s-$s^ʕ$/, and vowel quality: low front /a/, and high back /u/.

While high front vowels /i-i:/ and low front vowels /a-a:/ maintain similar effects on emphasis, cf. Section 2.3.2.2., high back vowels /u-u:/ show different effects. For low front vowels in word-initial position, F2 onset drops by 529 Hz in emphatic positions compared to their plain counterparts, whereas F2 onset for high back vowels drops only by 375 Hz. F2 midpoint drops by 412 Hz for low front vowels and only by 184 Hz for high back vowels, both in word-initial position. And finally, F2 offset drops by 280 Hz for low front vowels and only by 42 Hz for high back vowels in the same position. F3 midpoint rises in emphatic positions for low front vowels but it does not show significant differences for high back vowels. No other interactions were found for /a-a:/ or /u-u:/ with consonant-type that affected F1 or F3 measurements. All measurements on duration and spectral moments for /b/ in plain and emphatic positions yielded no differences.

Given these results, it is crucial to test the effects of the target consonants and target vowels (that is, those vowels in the same syllable with the target consonant) on the perception of emphasis. To investigate this issue, the present experimental design utilizes splicing the segments that make up the target word and rearranging them such that the one segment that is crucial to emphasis can be singled out. The first requirement for this design is to establish whether subjects detect emphasis in spliced target words. That is, to examine whether subjects can detect the plain or emphatic target consonants in words that have been spliced and reassembled. This provides the grounds for arguing that splicing per se does not affect perception. The following are the questions this experiment attempts to address:

1. Is the perception of emphasis primarily driven by the target consonant or by the target vowel?
2. Is the perception of emphasis affected by the manner of articulation of the emphatic consonant?
3. Is the perception of emphasis affected by vowel quality?

To answer these questions, an experimental design is adopted to find out what segment is crucial to the perception of emphasis and under what conditions, the reaction times to the different conditions, and the rating of the subjects with regard to their confidence level in their answers. Based on the findings of the acoustic study on monosyllables and aided by the literature on emphasis, I make the following hypotheses:

1. The perception of emphasis is not affected by the presence or absence of the emphatic target consonant.
2. The perception of emphasis is governed by the target vowels.
3. Vowel quality affects the perception of emphasis: emphasis is more clearly perceivable in low front vowels than in high back vowels.

4. 1. Method

4.1.1. Subjects

20 participants, 16 males and 4 females, whose native dialect was UJA took part in the experiment. 16 of them were recruited from Kansas (Kansas City, Lawrence and Manhattan) and 4 were recruited from Arkansas (Fayetteville). All of them were college-age students, employees or their spouses. None of them reported having any hearing or speech impairments.

4.1.2. Materials and Procedure

Four pairs of plain and emphatic words produced by the same subject were selected from the sound files used in the acoustic study on the monosyllables: /tab-tˤab/, /tub-tˤub/ /sab-sˤab/, and /sub-sˤub/. Table 1 shows the duration and formant frequency measurements for each of these sounds.

Table 1: The duration and formant frequency measurements for the perception stimuli

Word	TC duration	Vowel duration	/b/ duration	V_F1 onset	V_F1 midpoint	V_F1 offset	V_F2 onset	V_F2 midpoint	V_F2 offset	V_F3 onset	V_F3 midpoint	V_F3 offset
sab	161	117	105	368	473	390	1457	1432	1252	2464	2385	2246
sˤab	145	134	90	443	505	301	1117	1157	1102	2405	2538	2352
sub	126	120	106	354	404	309	1387	1230	1029	2551	2378	2291
sˤub	127	107	126	374	434	328	1308	1527	1140	2920	3262	2390
tab	114	109	126	372	480	345	1568	1455	1316	2714	2377	3113
tˤab	149	126	108	477	525	385	1248	1146	1026	2649	2579	2281
tub	151	136	126	379	416	214	1425	1232	936	2745	2447	2466
tˤub	139	100	109	434	411	345	1833	1037	1363	3105	2486	3277

Each of these words was cut into its three segments, and then spliced back together such that every word that the subjects heard had been spliced. This condition ensures that none of the words used in the experiment is presented intact. Each segment was defined in accordance with the procedure used in the acoustic study on the monosyllables. Specifically, the same criteria adopted for the duration measurements of the stops, the fricatives and the vowels in Chapter 2 were also adopted for these stimuli, *cf.* Section 2.1.3. Two other conditions were applied to each sound file. For each pair, the plain and the emphatic target consonants were cut and swapped. This created two stimuli: the plain word with the emphatic target consonant, and the emphatic word with the plain target consonant. Then, the same process is repeated for the vowels: for each pair, the vowels in the plain and the emphatic environments were cut and swapped, yielding two other stimuli: the plain word with the vowel from the emphatic word and the emphatic word with the vowel from the plain word. The same procedure was used for the four pairs of target words. Every condition is applied to a copy of the original 'intact' target word. Each condition was repeated 10 times for a total of 240 sound files. Table 2 below shows the conditions used to create the stimuli. Letters in upper case represent the segments that are emphatic; letters in lower case represent the segments that are plain.

Table 2: The conditions used in the perception study

No.	Condition	Plain	Emphatic
1	original words spliced	tab	$T^{ʕ}AB$
2	change target Stop	$T^{ʕ}ab$	tAB
3	change target Vowel	tAb	$T^{ʕ}aB$
4	original words spliced	tub	$T^{ʕ}UB$
5	change target Stop	$T^{ʕ}ub$	tUB
6	change target Vowel	tUb	$T^{ʕ}uB$
7	original words spliced	sab	$S^{ʕ}AB$
8	change target Fricative	$S^{ʕ}ab$	sAB
9	change target Vowel	sAb	$S^{ʕ}aB$
10	original words spliced	sub	$S^{ʕ}UB$
11	change target Fricative	$S^{ʕ}ub$	sUB
12	change target Vowel	sUb	$S^{ʕ}uB$

The experiment was conducted using the Superlab software (Version 2). A picture file containing the text "How confident are you of your answer" written in Modern Standard Arabic orthography was created in Microsoft Paint. The sound files were used to determine what target consonant the subjects heard and also to collect reaction time data; the picture files were used to measure confidence ratings for each sound file. Subjects heard the sound files on a Sony MDR-7502 Dynamic Stereo Headphone and used a laptop with defined keyboard buttons to record their responses.

Each subject took a practice session of 24 trials, followed by the experimental set of 240 trials. No feedback was given during the practice session. Each trial consisted of a sound file and a picture file. Trials were randomized by Superlab, and a 1000 ms ISI separated each event. Subjects were tested individually and were instructed that they would hear a list of monosyllabic words starting with one of the target consonants: /t, $t^ʕ$, s, $s^ʕ$/. They were asked to push a response button that represented the initial consonant of the word that they heard. Reaction time was measured from the onset of the sound file until the subject pushed the response button. Once they responded to the sound file, a picture file would appear asking them how confident they were of their answers. They were asked to push a response button indicating their confidence level at a scale from 1 (least confident), to 5 (most confident). Therefore, every time the subjects heard a sound file, they responded to it, and then the picture file with the question "How confident are you of your answer" followed. Average time for completing the experiment was around 16 minutes per subject.

4.2. Analysis

For each subject, responses to the sound file, reaction time and confidence ratings were collected. These were the dependent variables. For the sound file responses and the confidence ratings, a simple frequency count was used. Different ANOVA's were used to compare reaction times among the different conditions. The results will be presented for stops first, then for fricatives. Though it was expected that subjects would respond with a plain or an emphatic segment of the same manner, some subjects responded with a different manner. In other words, where a certain condition was applied to /t/ or /t^{ʕ} /, responses were expected to be confined to these two stops. However, in some of these conditions, a few subjects responded with an /s/ or /s^{ʕ} /.

4.3. Results

In this section, I report the responses to the three conditions applied to the sound files, the reaction times, and the confidence ratings.

4.3.1. Original words

Under this condition, the original sound files were cut into their segments and spliced back together. Subjects detected the correct target consonants at rates ranging from 99% correct responses for /T^{ʕ}UB/ and /S^{ʕ}UB/ to 100% correct responses for /tab/, /sab/, /S^{ʕ}AB/ and /sub/. /T^{ʕ}AB/ and /tub/ fell in the middle with 99.5% correct responses. Despite the fact that the results go in the expected direction for this condition, the reaction time data in each case tell a slightly different story. A one-way ANOVA on reaction times shows that subjects responded significantly faster to /t/ in /tab/ (992 ms) compared to /t^{ʕ}/ in /T^{ʕ}AB/ (1151 ms), [$F (1, 398) = 13.639$, $p < 0.001$]. This difference is not detected for stops in words with high back vowels. Subjects detected /t/ in /tub/ with a mean RT of 1058 ms, and /t^{ʕ}/ in /T^{ʕ}UB/ with a mean RT of 1123 ms. This is not a significant difference, [$F (1, 398) = 2.835$, $p = 0.092$]. While subjects responded faster to /t/ than /t^{ʕ}/ in the low front vowel context, mean RT for /s/ in /sab/ is 1059 ms and

986 ms for /$s^{ʕ}$/ in /$S^{ʕ}AB$/. This difference is significant, [F (1, 398) = 5.188, p = 0.023]. No significant difference is obtained in RT for /s/ in /sub/ (1098 ms) and /$s^{ʕ}$/ in /$S^{ʕ}UB$/ (1124 ms), [F (1, 398) = 0.389, p = 0.532].

The confidence rating data show that subjects were highly confident in most of their answers. Table 3 shows the mean confidence for each condition.

Table 3: Mean confidence in responses for spliced words

Condition	Confidence rating
tab	4.9
$T^{ʕ}AB$	4.7
tub	4.8
$T^{ʕ}UB$	4.7
sab	4.9
$S^{ʕ}AB$	4.9
sub	4.9
$S^{ʕ}UB$	4.7
total	4.8

4.3.1.1. Summary

The results for the first condition show that subjects detected the target consonants with a high degree of accuracy ranging from 99 – 100%. Reaction time data show that subjects detected plain stops faster than emphatic stops in the environment of low front vowels and they detected emphatic fricatives faster than plain fricatives in the same vocalic environment. In the environment of high back vowels, no significant differences were found. And finally, subjects expressed a high confidence rating of their answers ranging from 4.7 to 4.9.

4.3.2. Changing target consonant

To investigate whether the target consonant is crucial in the perception of words with plain and emphatic consonants, the target consonants were swapped in this condition. Subjects were presented with one of two types of words: a plain word with the emphatic target consonant, or an emphatic word with the plain target consonant. If the target consonant is the key, then perception of emphatic words is expected to follow the emphatic consonant regardless of the vocalic environment. This condition was used for fricatives and stops in the context of the low front vowel /a/ and the high back vowel /u/. In condition 2 in Table 2 /$T^{ʕ}$ab/ and /tAB/ the emphatic target consonant was placed in the plain word and the plain target consonant was spliced in the emphatic word. In /$T^{ʕ}$ab/, 94.5% reported hearing /t/ and only 5.5% reported hearing /$t^{ʕ}$/. In /tAB/, 66% reported a /$t^{ʕ}$/ and 34% reported a /t/. The same condition was applied to words with the high back vowel, /u/. In /$T^{ʕ}$ub/ 52.5% responded with a /t/ and 42.5% responded with a /$t^{ʕ}$/. 5% responded that they heard /$s^{ʕ}$/. In /tUB/, 65.5% reported that they heard /t/ and 29.5% reported that they heard /$t^{ʕ}$/. Similar to the case in /$T^{ʕ}$ub/, 5% reported hearing /s/. Figure 1 shows these results. Letters in upper case represent the emphatic segments.

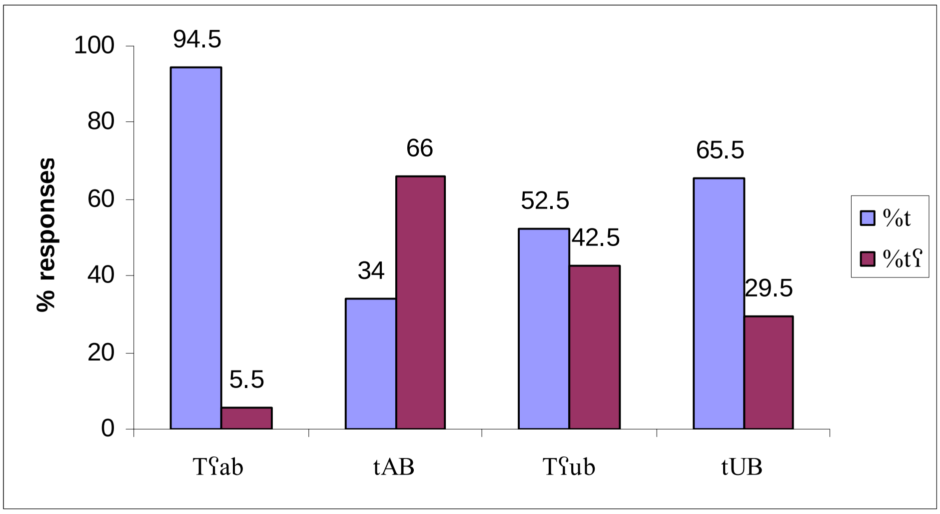

Figure 1: percent /t/ and /tʕ/ responses for words where target consonants were swapped

The same conditions in fricatives yielded similar results. For /Sʕab/, 93.5% reported hearing an /s/ and only 1.5% said they heard an /sʕ/. For /sAB/, 95% reported hearing an /sʕ/ and no one reported hearing an /s/. 2% reported hearing /t/ and 3% reported hearing /tʕ/. In the vowel /u/ environment, detection of plain and emphatic target consonants is affected. In /Sʕub/, only 24% reported hearing /s/ and 76% reported hearing /sʕ/. In /sUB/, 53.5% reported hearing /s/ and 46.5% reported hearing /sʕ/. Figure 2 shows these results.

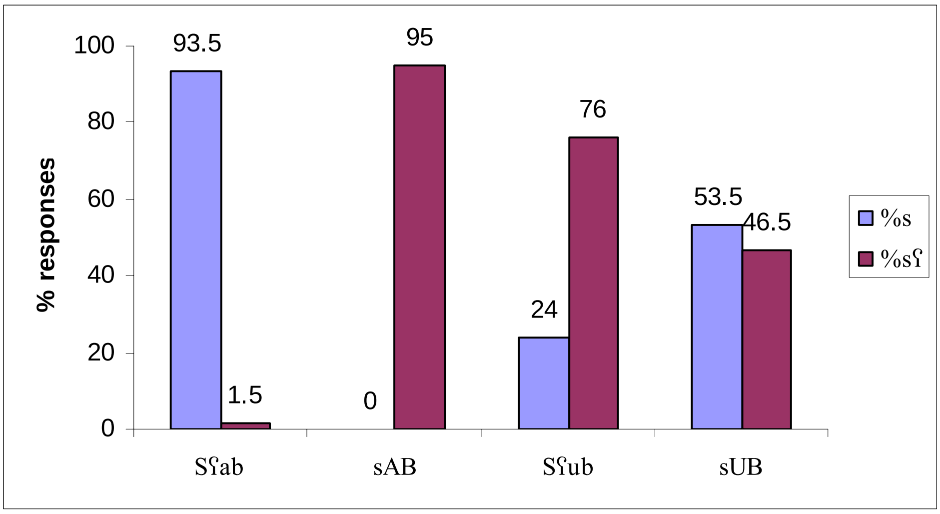

Figure 2: percent /s/ and /$s^ʕ$/ responses for words where target consonants were swapped

In terms of reaction time, subjects responded significantly faster to detecting the plain stops (1094 ms) than their emphatic counterparts (1379 ms) in the context of low front vowels ([F (1, 398) = 15.796, p < 0.001]). With high back vowels, subjects detected plain stops faster than their emphatic counterparts, (1255 ms) and (1299 ms), respectively, but this difference was not significant, [F (1, 398) = 0.383, p = 0.536]. See Figure 3.

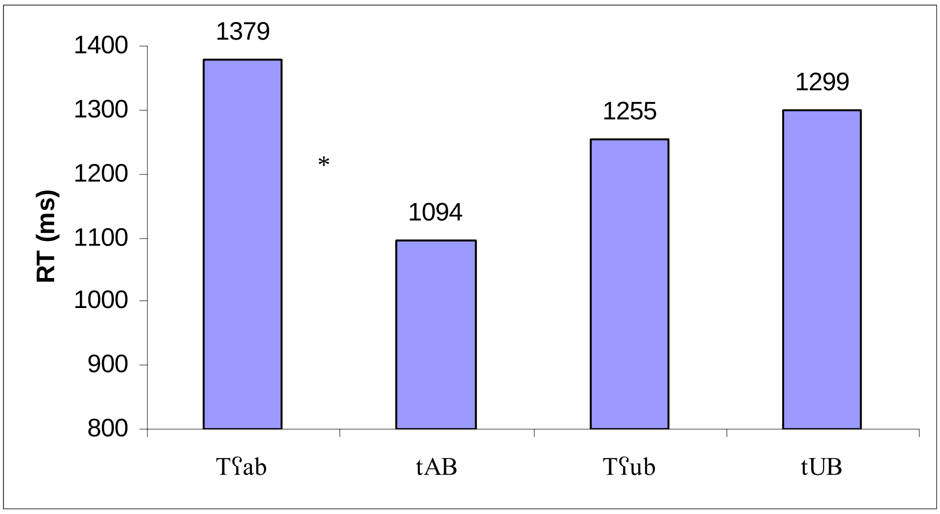

Figure 3: Mean reaction time for /t/ and /tˤ/ when target consonants are swapped

For fricatives, similar results are obtained in the context of low front vowels but opposite results are obtained in the context of high back vowels. Subjects detected /sˤ/ with a mean RT of 986 ms and /s/ with a mean RT of 1059. This difference is significant, [F (1, 398) = 15.796, p < 0.001]. This is not detected in the context of the high back vowel. Subjects' mean RT for detection of /s/ was 1098 ms and 1125 ms for /sˤ/. This difference is not significant, [F (1, 398) = 0.390, p = 0.533]. Figure 4 shows these results.

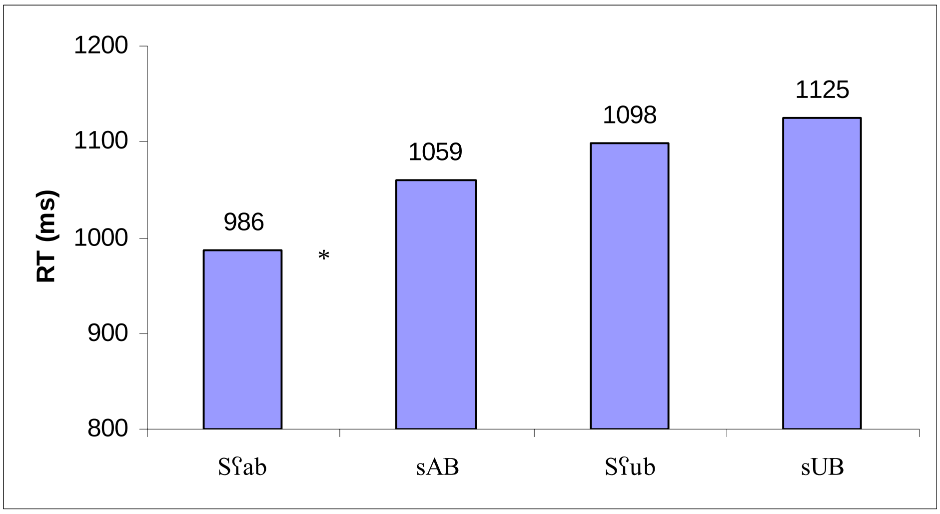

Figure 4: Mean reaction time for /s/ and /s ʕ/ when target consonants are swapped

The confidence rating data show that subjects were largely confident of their responses. Confidence ratings ranged from 4.5 for swapping the target stop to 4.9 for swapping the low front vowel and the emphatic fricative. Table 4 shows these ratings for the different conditions of changing the target consonant.

Table 4: Mean confidence for responses to changing the target consonant

Condition	Confidence rating
tAB	4.6
Tʕab	4.6
tUB	4.5
Tʕub	4.5
sAB	4.9
Sʕab	4.9
sUB	4.7
Sʕub	4.6
total	4.7

4.3.2.1. Summary

For /tab/ and /t^{ʕ}ab/, when the emphatic target consonant was spliced in /tab/, 94.5% subjects reported a plain /t/, and only 5.5% reported an emphatic /t^{ʕ}/. However, in the mirror image condition: the plain target consonant in /t^{ʕ}ab/, only 66% subjects reported an emphatic /t^{ʕ}/ and 34% reported a plain /t/. When this manipulation is applied to /t/ and /t^{ʕ}/ in /tub/ and /t^{ʕ}ub/, that is, when the emphatic target consonant from /t^{ʕ}ub/ was spliced in /tub/, only 52.5% reported a plain /t/ and 42.5% reported /t^{ʕ}/. In the mirror image condition: /t/ in /t^{ʕ}ub/, 65.5% reported a plain /t/ and 29.5% reported an emphatic /t^{ʕ}/. In fricatives, for /sab/ and /s^{ʕ}ab/, when the emphatic target consonant was spliced in /sab/, 93.5% subjects reported a plain /s/, and only 1.5% reported an emphatic /s^{ʕ}/. In the mirror image condition: the plain target consonant in /s^{ʕ}ab/, 95% subjects reported an emphatic /s^{ʕ}/ and no one reported a plain /s/. When this manipulation is applied to /s/ and /s^{ʕ}/ in /sub/ and /s^{ʕ}ub/, that is, when the emphatic target consonant from /s^{ʕ}ub/ was spliced in the /sub/, only 24% reported a plain /s/ and 76% reported /s^{ʕ}/. In the mirror image condition: /s/ in /s^{ʕ}ub/, 53.5% reported a plain /s/ and 46.5% reported an emphatic /s^{ʕ}/.

With regard to reaction time, subjects detected the plain stops faster than the emphatic ones in the context of low front vowels. No significant differences were obtained in the context of high back vowels. For fricatives, subjects detected the emphatic fricatives faster than their plain counterparts in the context of low front vowels. No significant differences were obtained in the context of high back vowels.

Finally, confidence ratings are still high under all of the manipulations in this condition. A total of 4.7 confidence rating is scored for the condition of changing the target consonant.

4.3.3. Changing target vowel

In this condition, the vowel in the same syllable with the target consonant, also referred to as the target vowel, was cut and swapped. Therefore, the conditions resulting from this manipulation are the plain word with the vowel from its emphatic counterpart and the emphatic word with the vowel from the plain one. The perception of emphasis is expected to follow the target vowel in these conditions – in line with the findings from the acoustic study. While this finding is not expected to be affected by the manner of the target consonant, the quality of the target vowel is expected to have an effect on the perception of emphasis. It is expected that emphasis is perceived more clearly in the presence of low front vowels than in the presence of high back vowels.

For / tAb /, only 6.5% responses were /t/ and an overwhelming 93.5% responses were /$t^ʕ$/. For / $T^ʕ$aB /, subjects reported hearing 97.5% /t/ and only 2.5% /$t^ʕ$/. For /tUb/, 69% responses reported hearing a /t/ and only 26% reported hearing /$t^ʕ$/. When the plain /u/ is spliced in the emphatic word, /$T^ʕ$uB/, 53% reported hearing a /t/ and 41.5 reported hearing a /$t^ʕ$/. See Figure 5.

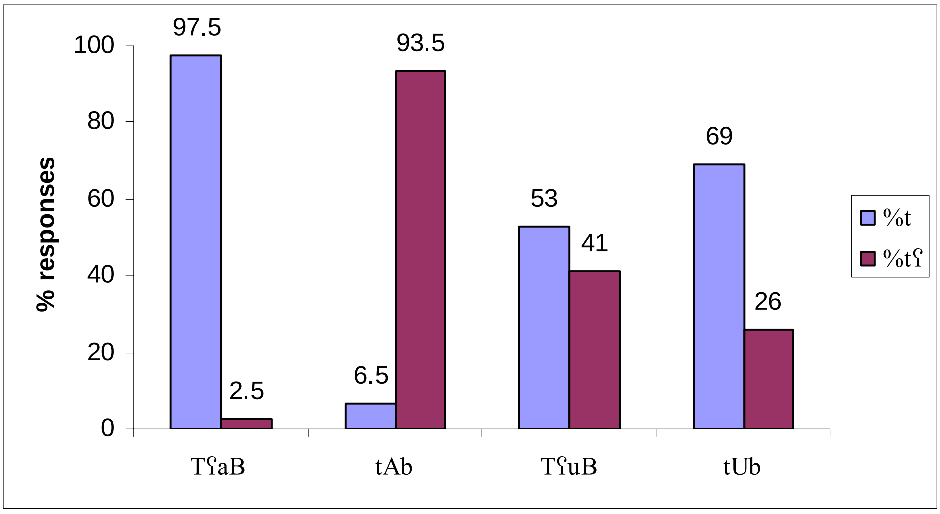

Figure 5: percent /t/ and /$t^ʕ$/ responses for words where target vowels were swapped

The results obtained for fricatives are similar. In /sAb/, 91.5% responses were /$s^ʕ$/ and only 3% were /s/. In /$S^ʕ$aB/, only 3% responses were /$s^ʕ$/ and 92% were /s/. In the environment of high back vowels, responses are split for /sUb/: 50% /s/ and 50 % /$s^ʕ$/ but in /$S^ʕ$uB/, 95.5% responses were /s/ and only 4.5% responses were /$s^ʕ$/. Figure 6 shows these findings.

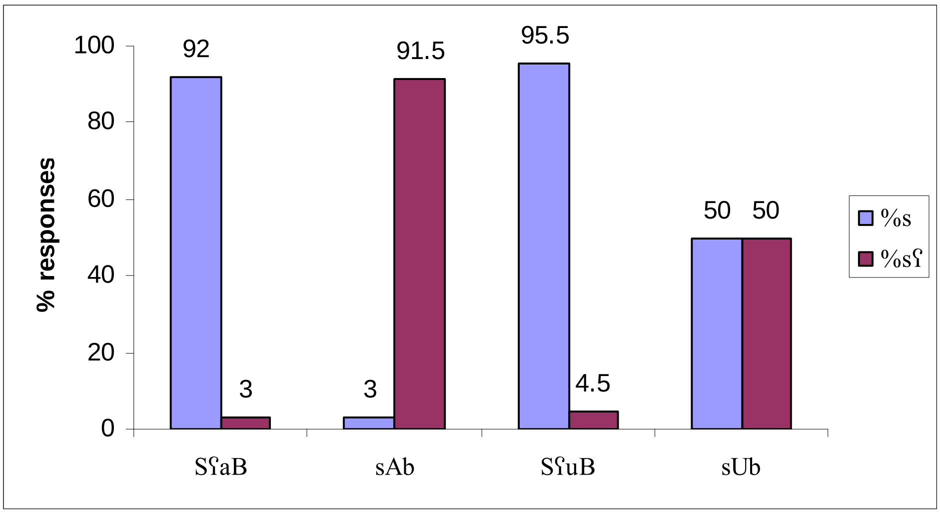

Figure 6: percent /s/ and /sˤ/ responses for words where target vowels were swapped

The reaction times between these conditions did not show any significant differences. Subjects detected /tˤ/ in /TˤaB/ with a mean RT of 1083 ms and 1097 ms for /t/ in /tAb/. Also, similar reaction times are obtained in the context of high back vowels: 1255 ms for /tˤ/ in /TˤuB/ and 1289 ms for /t/ in /tUb/. Figure 7 shows these results.

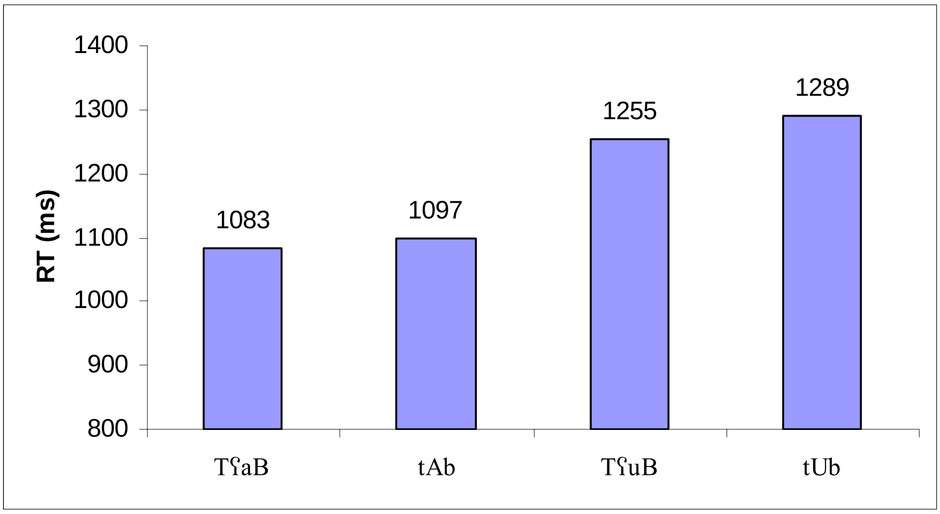

Figure 7: Mean reaction time for /t/ and /t ˤ/ when target vowels are swapped

For stops, the reaction time data do not show significant differences. In the context of low front vowels, mean reaction time for /s^ʕ/ in /S^{ʕ}aB/ was 1079 ms and 1058 ms for /s/ in /sAb/. In the context of high back vowels, subjects detected /s/ in /sUb/ faster than they detected /s^ʕ/ in /S^{ʕ}uB/: 1259 and 1311 ms, respectively. See Figure 8.

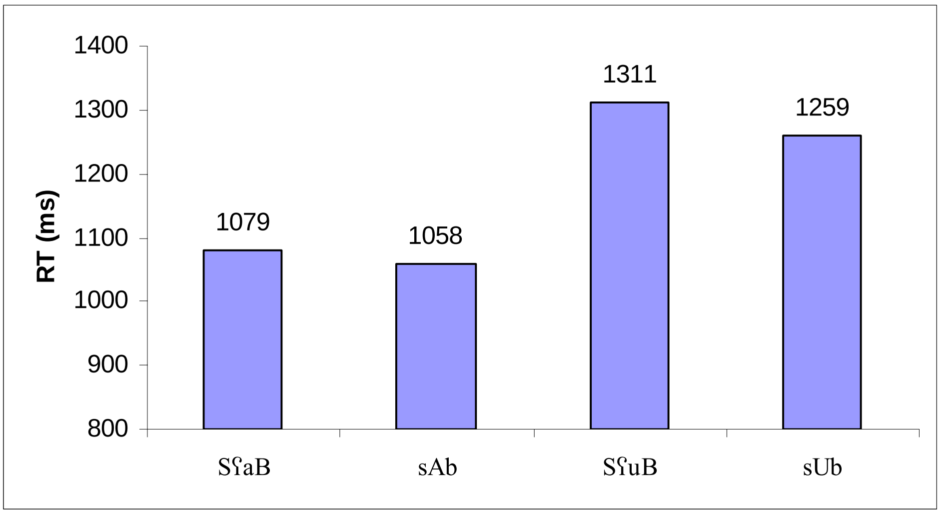

Figure 8: Mean reaction time for /s/ and /s ^{ʕ}/ when target vowels are swapped

The confidence ratings for the sound files in this condition were also very high. Similar to the previous condition where the target consonant was spliced, subjects responded with a high confidence level to sound files under this condition. Table 5 shows these results.

Table 5: Mean confidence for responses to changing the target vowel

Condition	Confidence rating
tAb	4.9
$T^{ʕ}aB$	4.7
tUb	4.5
$T^{ʕ}uB$	4.6
sAb	4.8
$S^{ʕ}aB$	4.9
sUb	4.6
$S^{ʕ}uB$	4.7
total	4.7

4.3.3.1. Summary

In stops, when the plain vowel /a/ is spliced in the emphatic word /$t^{ʕ}$ab/, 97.5% subjects reported hearing a plain /t/, and only 2.5% reported the hearing the emphatic /$t^{ʕ}$/. When the emphatic vowel /a/ is spliced in the plain word /tab/, 93.5% reported an emphatic /$t^{ʕ}$/ and only 6.5% reported hearing /t/. The same conditions for /$t^{ʕ}$ub/ and /tub/ yielded different results. When the plain vowel /u/ is spliced in the emphatic word /$t^{ʕ}$ub/, 53% reported a plain /t/ and 41% reported an emphatic /$t^{ʕ}$/. When the emphatic vowel /u/ is spliced in the plain word /tub/, 69% reported a plain /t/ and only 26% reported an emphatic /$t^{ʕ}$/. In fricatives, when the plain vowel /a/ is spliced in the emphatic word /$s^{ʕ}$ab/, 92% subjects reported hearing a plain /s/, and only 3% reported the hearing the emphatic /$s^{ʕ}$/. When the emphatic vowel /a/ is spliced in the plain word /sab/, 91.5% reported an emphatic /$s^{ʕ}$/ and only 4.5% reported hearing /s/. The same conditions for /$s^{ʕ}$ub/ and /sub/ yielded similar results in one manipulation and different results in another. When the plain vowel /u/ is spliced in the emphatic word /$s^{ʕ}$ub/, 95.5% reported a plain /s/ and 4.5% reported an emphatic /$s^{ʕ}$/. However, when the emphatic vowel /u/ is spliced in the plain word /sub/, subjects were equally split between /s/ and /sˤ/ reporting 50% each.

Reaction time data for this condition did not yield any significant differences. Subjects reacted faster to emphatic stops than to their plain counterparts but slower to emphatic fricatives than to their plain counterparts. None of these differences was significant.

The same pattern in terms of confidence rating is obtained here. The lowest confidence ratings were obtained for swapping the target high back vowel in the word with the stop consonant, 4.5. The highest ratings were obtained for swapping the target low front vowel and the target emphatic fricative, 4.9.

4.4. Discussion

The results for the original target words show that they were detected at high accuracy rates ranging from 99% to 100% expected responses. This finding suggests that splicing the word into its segments and reassembling these segments does not affect the detection rates considerably, which enables us to eventually conclude that different responses to the other two conditions would not be due to splicing as opposed to swapping the target consonants and vowels. Detection percentages for spliced words did not seem to have been influenced by vowel quality. Subjects responded with similar detection rates to words that had low front vowels and high back vowels. The significant differences in reaction times, however, seem to be harder to explain.

Subjects detected plain stops faster than emphatic stops and plain fricatives slower than emphatic fricatives – both in the context of low front vowels. This difference might not be related to emphasis per se. It could be related to a possibility that /tab/ and /s^{ʕ}ab/ are more commonly frequent in the language than /t^{ʕ}ab/ and /sab/, which seems to hold water, from an impressionistic perspective, given the lack of word frequency charts for UJA.

The difference in reaction times reported for words with low front vowels is absent in high back contexts. This discrepancy in reaction times is compensated by the results on the confidence ratings for these words. The confidence ratings obtained for this condition ranged from a low of 4.7 to a high of 4.9, which indicates that subjects were highly confident on their answers.

With regard to changing the target consonant, a few interesting findings can be reported. When the emphatic stop is spliced into the plain word, a vast majority of the responses, 94.5%, recognized a plain stop. The mirror image, though at a lesser magnitude, is obtained when the plain stop is spliced in the emphatic word: 66% reported hearing an emphatic stop. This suggests that the target consonant does not carry the effects of emphasis in the environment of low front vowels. That is, perception of emphasis does not depend on the properties of the emphatic stop. The same results are fostered by the findings on the fricatives. In conditions identical to the ones mentioned here, subjects reported hearing a plain fricative when an emphatic fricative was spliced in a plain word, and reported hearing an emphatic fricative when a plain one was spliced in an emphatic word. Therefore, we can state that regardless of the manner of articulation for the target consonant, the perception of emphasis is not driven by the consonant in the environment of low front vowels.

Contrary to the findings on manner of articulation with regard to emphasis perception, vowel quality seems to be critical in influencing the perception of emphasis. As mentioned in the acoustic study, see Chapter 2, the mean difference in the second formant frequency between low front vowels in plain and emphatic environments is larger than that in high back vowels. This difference maps on to perception. Based on the frequency of target consonant detections, subjects found it harder to decide whether they heard a plain or an emphatic /t/ when these two stops were swapped in / $T^{ʕ}$ub/ and /Tub/. However, when the plain stop was spliced into the emphatic word, 65.5% responses reported a plain /t/ compared 29.5% /t ^{ʕ}/ responses. On the other hand, subjects showed preference for /$s^{ʕ}$/ (76%) when the emphatic fricative was spliced in the plain word in the environment of high back vowels. These results show that the high back vowels tend to impede the clear effects of emphasis because the magnitude of F2 lowering in emphatic environments is smaller compared to that in low front vowels. The findings on the reaction time data support the overriding influences of low front vowels compared to the lesser effects of high back vowels. In stops and fricatives, differences in reaction times to plain and emphatic segments were significant only in the environment of low front vowels. They were, however, contradictory. While subjects detected plain stops faster than emphatic stops, they detected emphatic fricatives faster than plain fricatives. No significant differences were found in the context of high back vowels. Despite these findings on reaction time, subjects thought they were confident of their answers. The lowest end on the confidence ratings scale was at 4.5 and the highest was at 4.9. Both of these ratings are substantially indicative of high confidence.

In the third condition, swapping the target vowels, the perception results support the overriding effects of the vowels in emphasis. When the vowel from the plain word is spliced into the emphatic word, subjects detected the plain stop /t/ with a very high percentage. When the vowel from the emphatic word was spliced into the plain word, subjects detected the emphatic stop /tˤ/. These results were also true for the fricatives. In both cases for stops and fricatives, these results are obtained clearly in the context of low front vowels. In the context of high back vowels, subjects' responses were close to chance level. However, the results for the vowels show some differences from those obtained for the stops. When the plain vowel was spliced into the emphatic word, 95.5% responses reported a plain /s/, meaning that the high back vowel /u/ did influence subjects' perception. The mirror image of this manipulation, splicing the emphatic vowel in the plain word, yielded perfect chance level responses split between the plain and emphatic fricative detections. In terms of reaction time data, no significant differences have been found under the different manipulations in this condition. One finding is that reaction times were generally shorter for words that had the low front vowel compared to those that had the high back vowel. As for the confidence ratings, the results follow the pattern in the first two conditions. Subjects respond with high confidence ratings averaging 4.7.

While the results are neat and tidy in the environment of the low front vowel /a/, the change in vowel quality to /u/ does not yield consistent results. In the environment of the vowel /a/, wherever the vowel is spliced, subjects' perception is driven by it. So, if the vowel comes from an emphatic word, the perception of the target consonant is largely /tˤ/ or /sˤ/, and vice versa. In the context of the high back vowel /u/, these results do not form a pattern. Sometimes subjects report hearing a plain consonant by high percentages and sometimes their perception is close to or at a chance level. The intrinsic characteristics of the high back vowel, namely that the difference between F1 and F2 is too small compared to that in /a/, leaves less room for F2 to decline and F1 to rise in the emphatic environments. This leads to inconsistent results in the perception of emphasis under the conditions presented in this chapter. Another consistent result that supports this finding is that reaction times to words with low front vowel were consistently shorter compared to these with high back vowels.

The results of this study show that perception of emphasis is not driven by the target consonant. Although emphasis is triggered by the existence of an emphatic segment, which is always an obstruent, its effects are observed on the vowel. The low front vowel is more susceptible to emphasis than the high back vowel. While emphasis is clearly realized on the low front vowel, it is not as salient in the context of high back vowels. This is due to the fact that there is more room for F1 rising and F2 lowering in the context of low front vowels than in the context of high back vowels.

Chapter Five

Summary, discussion and conclusion

The present study examined the acoustic and perceptual correlates of emphasis in Urban Jordanian Arabic. The study consisted of three main experiments: two acoustic experiments: one on monosyllabic words, and another on bisyllabic words, and a perception experiment. In the acoustic experiment on monosyllables, four pairs of plain and emphatic consonants were used along with the six vowels of UJA to create a list of 48 minimal pairs of monosyllabic words of the CVC structure. The target consonants were either word-initial or word-final. The duration of the plain and emphatic consonants was measured, and their spectral moments and locus equations were calculated. The three formant frequencies of the vowel, F1, F2, and F3 were measured at onset, temporal midpoint and offset of the vowel. As for the acoustic experiment on bisyllables, the wordlist consisted of 80 target CV.CVC pairs where the target consonant was word-initial, word-medial or word-final. The perception of emphasis was also investigated by means of splicing and swapping the target consonants and vowels. Four pairs of words were selected from the stimuli used in the acoustic experiment. The perception experiment was used to test whether the results in the acoustic study are perceptually valid.

5.1. Summary of results

5.1.1. Acoustic study: the monosyllables

The results for the acoustic study show that emphatic consonants are longer than their plain counterparts. This difference is, however, limited to fricatives in word-final positions. Word-initial and word-final stops do not show significant differences in plain and emphatic positions. Additionally, fricatives in word-initial positions are not significantly different. Target vowel duration was not significantly different in plain and emphatic environments. Only one of the four spectral moments measured showed significant differences; the center of gravity is significantly higher for emphatic stops and lower for emphatic fricatives in word-final positions. Locus equations showed that emphatic consonants had a lower mean slope compared to their plain counterparts while *y*-intercept values showed no significant differences.

As expected, vowel F1 was significantly higher in emphatic environments. However, this effect was strongest closest to the target consonant. There was often a tendency for this effect to fade as the measurement was taken further away from the target consonant. F2 was consistently lower in emphatic environments. The results for F3 were similar to those attested for F1: F3 increased in emphatic environments but this increase faded away as the measurement was taken further away from the target consonant. Several interactions were observed for the formant frequency measurements. The formant frequency values were often affected by vowel quality. High front and low front vowels were less resistant to emphasis effects compared to high back vowels. In other words, where the formant frequency was expected to increase or decrease, it did so by a greater extent in the environment of high and low front vowels and by a lesser extent in the environment of high back vowels. Sporadic interactions were found for position of the target consonant, manner of articulation, vowel length and word type. No interactions were observed for voicing and gender.

5.1.2. Acoustic study: the bisyllables

Measurements on consonant and vowel durations and spectral moments for consonants did not reveal consistent differences. Measurements on the bisyllables focused on spectral measurements for vowels. For most of the data, vowel F1 and F3 significantly increase but vowel F2 significantly decreases in emphatic environments. Formant values usually show these results when the measurements are taken for the target vowels: that is, vowels in the same syllable with the target consonants. As the measurements are taken outside of the target vowel, effects of emphasis tend to fade away. This is clearer when the measurements are taken on the left rather than right of the target vowel, thus showing more prominence for anticipatory emphasis spread. Furthermore, the effects of emphasis are clearer in the environments of high and low front vowels compared to high back vowels. This was also attested for monosyllables. Finally, measurements on vowel formant frequency show greater plain – emphatic differences for males than females, thus suggesting that emphasis is more salient in male speech.

5.1.3. The perception study

As for the perception study, the two types of consonants, stop and fricative, were included along with two types of vowel quality: low front and high back. Three conditions were used in this study: the original words spliced, the target consonant swapped, and the target vowel swapped. Results for the first condition show that subjects responded with a high degree of accuracy. That is, they identified each target consonant as expected with an accuracy rate ranging from 99 – 100%. In the second condition, results showed that subjects identified the consonant based on the vocalic environment and not on the target consonant itself. If the target consonant was plain but spliced in an emphatic vocalic environment, subjects reported an emphatic consonant, and vice versa. The mirror image was detected for the third condition – splicing the target vowel. If the vowel came from the emphatic word and was spliced into the plain environment, subjects detected an emphatic target consonant, and vice versa. These results, however, were influenced by vowel quality. If the vowel was low front, it carried the effects of emphasis. If the vowel was high back, in most cases, responses were close to a chance level.

5.2. Discussion

The results of the present study are in line with previous research on emphasis in the areas where similar measurements and procedures have been adopted. Previous findings for the duration of the target consonant showed that emphatic consonants were significantly longer than plain ones, see Obrecht (1968). In the present study, the target vowel durations were not significantly different. There have been two accounts in the literature with contradicting findings for target vowel durations. The acoustic study of the bisyllables shows that durational differences are not consistently influenced by the presence of emphatic consonants. It seems that consonant and vowel duration are not a stable cue for emphasis, especially in the case of short vowels. The allophonic changes in the Arabic vowels seem to be easier to capture in quality rather than quantity. The investigations regarding the spectral moments did not yield significant differences. Apart from the findings on the center of gravity, which showed significant differences in monosyllables, none of the other moments turned out to show significant differences. While Norlin (1987) found significant lowering in the center of gravity for word-initial emphatic sibilants, the present study reports such findings in the same direction only for word-final fricatives and in the opposite direction for word-final stops. None of the moments was significantly different in word-initial position. It should be noted here that the measurements for spectral moments were characterized by a wide degree of variability depending on the point at which the moments were calculated. This variability was inevitable due to the differences in burst duration for stops. Based on findings for the monosyllables, and due to the unclear effect of consonantal spectral moments, moments were not reported in the study on the bisyllables.

As reported by almost all studies that investigated the acoustics of emphasis, vowel F2 turns out to be a very salient cue for emphasis. Vowel F2 drops in emphatic positions compared to their plain counterparts. This is true for vowels in monosyllables and in bisyllables as well. In monosyllables, Vowel F2 in words with initial target consonants drops by 516 Hz, 253 Hz, and 165 Hz at onset, temporal midpoint and offset positions, respectively. For words with final target consonants, F2 drops by 228 Hz, 248 Hz and 462 Hz at onset, temporal midpoint and offset positions, respectively. It should be noted here that we are looking at the mirror image in word-initial and word-final positions. While F2 onset is closest to the target consonant in words with initial emphatics, F2 offset is closest to the target consonant in words with final emphatics. This points to the gradient nature of emphasis spread within the same word, (*cf.* Zawaydeh 1999; Al-Masri and Jongman 2004). F1 and F3 are higher in emphatic positions compared to their plain counterparts. While the gradient effect is evident in the degree of drop in F2 in emphatic positions, it is similarly evident in the results for F1 and F3 in that the increase in emphatic positions diminishes as the measurement is taken further away from the target consonant. Additionally, the extent of emphasis was not similar for all vowels. It is worth noting that emphasis is realized more in the environment of high front and low front vowels compared to high back vowels where the relatively compact spectrum for /u/ limits the degree of formant increase or decrease. This leads us to predict that high back vowels are more likely to block emphasis spread compared to high front and low front vowels.

In terms of locus equations, the set of emphatic consonants in UJA patterned like it did in other dialects of Arabic (Yeou, 1997) with flatter slopes compared to their plain counterparts.

In bisyllables, the results pattern similarly. In addition, measurements on the bisyllables give us a clearer idea about emphasis spread. It shows that emphasis clearly crosses the left syllable boundary but is confined in the right direction to the target syllable. Further, measurements on the bisyllables show a clear influence of vowel quality, whereby the high back vowel /u/ seems to be a stronger blocker compared to the high front and high back vowels. Finally, the magnitude of the plain-emphatic difference suggests a greater tendency among males for pronouncing emphasis compared to females.

The third experiment illustrates the perceptual consequences of the findings in the acoustic study. The most salient findings on the acoustics of emphasis carried over to perception, indicating that the target vowel drives the perception of emphasis. In addition to this result, the more intricate findings on vowel quality materialized in perception. Perception of emphasis was carried by low front vowels but not by high back vowels. Despite the differences in the experimental design, these findings replicate reports in the literature (Obrecht, 1968).

5.3. Conclusion

The findings reported in this study are significant in several ways. Experimental research on Arabic has been limited compared to other languages. It is only recently that more similar studies are reported. The previous literature on Arabic, especially the literature written in Arabic, has been mostly descriptive. The present study lends itself to the experimental domain. The findings reported in the present study should be incorporated in the pedagogical fields, especially now that textbooks on Arabic are in demand. In the absence of the emphasis distinction in most world languages, it is crucial that the methods adopted in presenting emphasis as a phonemic distinctive feature in Arabic be relevant to the tools available for the second language learner. Rather than focusing on the differences between the consonants, which is how most native speakers of Arabic *think* they perceive emphasis, the differences in the vowels should be highlighted.

5.4. Follow-up

This study is basically one step on a long way. Several aspects of emphasis are still wanting. While the acoustic correlates of monosyllables and bisyllables have been systematically presented, analysis of emphasis spread beyond the neighboring syllable is still lacking. Studying the acoustics of trisyllables should complete the picture. It should allow us to understand the extent and directionality of emphasis spread, possible consonantal and vocalic segments that block emphasis spread or limit it to its minimum domain. Moreover, the investigation of the possible role of amplitude and spectral moments and locus equations for consonants in adjacent syllables is warranted. Studying the effects of these factors on the perception of emphasis is yet another possible area of investigation. In addition to the investigation of emphasis in trisyllables, geminate and adjacent emphatics have not been discussed in the literature so far. A follow-up study using these data would possibly complete the picture.

This is the first step in a series of more acoustic and perceptual experiments to cover all the unexplored characteristics of the emphatic signal. Conducting these experiments should allow for much needed contributions to the field of Arabic linguistics.

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Appendices

Appendix I: The acoustic study: the monosyllables:

Monosyllables: target word-initial

No	Plain	Gloss	Emphatic	Gloss	Structure
1	sab	He cursed	$s^ʕ$ab	He poured	CVC
2	sib	He cursed	$s^ʕ$ib	Nonword	
3	sub	You curse	$s^ʕ$ub	You pour	
4	sa:b	He left	$s^ʕ$a:b	He scored	
5	si:b	You leave	$s^ʕ$i:b	You score	
6	su:b	Nonword	$s^ʕ$u:b	Nonword	
7	tab	He perished	$t^ʕ$ab	It touched	
8	tib	Nonword	$t^ʕ$ib	You recover	
9	tub	You repent	$t^ʕ$ub	Nonword	
10	ta:b	He repented	$t^ʕ$a:b	He recovered	
11	ti:b	Nonword	$t^ʕ$i:b	You recover	
12	tu:b	You repent	$t^ʕ$u:b	Brick	
13	dab	He fell	$d^ʕ$ab	Nonword	
14	dib	Nonword	$d^ʕ$ib	Nonword	
15	dub	Bear	$d^ʕ$ub	You keep	
16	da:b	It melted	$d^ʕ$a:b	Nonword	
17	di:b	Bear	$d^ʕ$i:b	Nonword	
18	du:b	You melt	$d^ʕ$u:b	Nonword	
19	ðab	Nonword	$ð^ʕ$ab	Nonword	
20	ðub	You protect	$ð^ʕ$ub	Nonword	
21	ðib	Nonword	$ð^ʕ$ib	Nonword	
22	ða:b	It melted	$ð^ʕ$a:b	Nonword	
23	ðu:b	You melt	$ð^ʕ$u:b	Nonword	
24	ði:b	Wolf	$ð^ʕ$i:b	Nonword	

Monosyllables: target word-final

No	Plain	Gloss	Emphatic	Gloss	Structure
1	bas	Enough!	basˤ	He saw	CVC
2	bis	Cat	bisˤ	Nonword	
3	bus	Nonword	busˤ	You see	
4	ba:s	He kissed	ba:sˤ	Bus	
5	bi:s	Nonword	bi:sˤ	Nonword	
6	bu:s	You kiss	bu:sˤ	Nonword	
7	bat	He decided	batˤ	Nonword	
8	bit	You decide	bitˤ	Nonword	
9	but	You decide	butˤ	Nonword	
10	ba:t	He slept	ba:tˤ	Armpit	
11	bi:t	You sleep	bi:tˤ	shoes	
12	bu:t	Shoes	bu:tˤ	Nonword	
13	bad	Big stone	badˤ	Nonword	
14	bid	Nonword	bidˤ	Nonword	
15	bud	Nonword	budˤ	Nonword	
16	ba:d	It ended	ba:dˤ	It laid eggs	
17	bi:d	You kill; end	bi:dˤ	White (pl)	
18	bu:d	Nonword	bu:dˤ	Nonword	
19	bað	Nonword	baðˤ	Nonword	
20	bið	Nonword	biðˤ	Nonword	
21	buð	Nonword	buðˤ	Nonword	
22	ba:ð	Nonword	ba:ðˤ	Nonword	
23	bi:ð	Nonword	bi:ðˤ	Nonword	
24	bu:ð	Nonword	bu:ðˤ	Nonword	

Appendix II: The acoustic study: the bisyllables:

Rightward spread

Bisyllables: (target C word-initial)

No	Plain	Gloss	Emphatic	Gloss	Structure
1	sabat	he selpt	sabat	nonword	CV.CVC
2	sibat	nonword	sibat	nonword	
3	subat	nonword	subat	nonword	
4	saabat	she left you	saabat	she touched you	
5	siibat	nonword	siibat	nonword	
6	suubat	nonword	suubat	nonword	
7	thabat	nonword	thabat	nonword	
8	thibat	nonword	thibat	nonword	
9	thubat	nonword	thubat	nonword	
10	thaabat	it melted	thaabat	nonword	
11	thiibat	nonword	thiibat	nonword	
12	thuubat	nonword	thuubat	nonword	
13	tabat	nonword	tabat	nonword	
14	tibat	nonword	tibat	nonword	
15	tubat	nonword	tubat	nonword	
16	taabat	she repented	taabat	she recovered	
17	tiibat	nonword	tiibat	kindness	
18	tuubat	nonword	tuubat	his brick	
19	dabat	nonword	dabat	nonword	
20	dibat	nonword	dibat	nonword	
21	dubat	nonword	dubat	nonword	
22	daabat	it melted	daabat	nonword	
23	diibat	nonword	diibat	nonword	
24	duubat	nonword	duubat	nonword	

Leftward spread

Bisyllables: (target C word-final)

No	Plain	Gloss	Emphatic	Gloss	Structure
1	tabas	nonword	tabas	nonword	CV.CVC
2	tabis	nonword	tabis	nonword	
3	tabus	nonword	tabus	nonword	
4	tabaas	nonword	tabaas	nonword	
5	tabiis	nonword	tabiis	nonword	
6	tabuus	she kisses	tabuus	nonword	
7	tabath	nonword	tabath	nonword	
8	tabith	nonword	tabith	nonword	
9	tabuth	nonword	tabuth	nonword	
10	tabaath	nonword	tabaath	nonword	
11	tabiith	nonword	tabiith	nonword	
12	tabuuth	nonword	tabuuth	nonword	
13	tabat	nonword	tabat	nonword	
14	tabit	nonword	tabit	nonword	
15	tabut	nonword	tabut	nonword	
16	tabaat	she sleeps	tabaat	nonword	
17	tabiit	she sleeps	tabiit	nonword	
18	tabuut	nonword	tabuut	nonword	
19	tabad	nonword	tabad	nonword	
20	tabid	nonword	tabid	nonword	
21	tabud	nonword	tabud	nonword	
22	tabaad	nonword	tabaad	nonword	
23	tabiid	nonword	tabiid	it lays eggs	
24	tabuud	nonword	tabuud	nonword	

Bidirectional spread

Bisyllables: (target C word-medial)

No	Plain	Gloss	Emphatic	Gloss	Structure
1	kasak	nonword	kasak	nonword	CV.CVC
2	kasik	nonword	kasik	nonword	
3	kasaak	nonword	kasaak	nonword	
4	kasiik	nonword	kasiik	nonword	
5	kisak	nonword	kisak	nonword	
6	kisik	nonword	kisik	nonword	
7	kisaak	nonword	kisaak	nonword	
8	kisiik	nonword	kisiik	nonword	
9	kathak	nonword	kathak	nonword	
10	kathik	nonword	kathik	nonword	
11	kathaak	nonword	kathaak	nonword	
12	kathiik	nonword	kathiik	nonword	
13	kithak	nonword	kithak	nonword	
14	kithik	nonword	kithik	nonword	
15	kithaak	nonword	kithaak	nonword	
16	kithiik	nonword	kithiik	nonword	
17	katak	nonword	katak	nonword	
18	katik	nonword	katik	nonword	
19	kataak	nonword	kataak	nonword	
20	katiik	nonword	katiik	nonword	
21	kitak	nonword	kitak	nonword	
22	kitik	nonword	kitik	nonword	
23	kitaak	nonword	kitaak	nonword	
24	kitiik	nonword	kitiik	nonword	
25	kadak	nonword	kadak	nonword	
26	kadik	nonword	kadik	nonword	
27	kadaak	nonword	kadaak	nonword	
28	kadiik	nonword	kadiik	nonword	
29	kidak	nonword	kidak	nonword	
30	kidik	nonword	kidik	nonword	
31	kidaak	nonword	kidaak	nonword	
32	kidiik	nonword	kidiik	nonword	