Speech Characteristics of Arabic Speakers: Dialect Variations

A thesis submitted for the degree of

Doctor of Philosophy

By

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Abstract

Arabic is spoken by more than 280 million people around the world and has been subject to attention in a number of acoustic phonetic studies. However, there are a limited number of studies on Gulf Arabic dialects and the majority of these studies have focused mainly on male speakers. Therefore, this study aimed to explore two Gulf Arabic dialects, the central Najdi dialect from Saudi Arabia and the Bahraini Bahraini dialect from Bahrain. It aimed to establish normative data for the Diadochokinetic Rate (DDK), Voice Onset Time (VOT), Fundamental Frequency (F0) and Formant Frequencies (F1-F3) for male (n = 40) and female (n = 40) speakers from both dialects. Furthermore, it aimed to investigate whether there are differences between the two dialects. Another direction of the research was to examine whether differences between male and female speech will be evident in both dialects.

The study was accomplished using different stimuli where the monosyllables /ba, da, ga/ and a multisyllabic sequence /badaga/ were selected to analyse the DDK rates. VOT duration was examined in monosyllablic minimal pair words containing the initial voiced stops /b, d/ and the three long vowels /a:, i:, u:/, and in words containing the initial voiceless stops /t, k/, initial voiced/voiceless stops /d, t/ and plain/emphatic alveolar stops /t, $t^ʕ$/ and the two long vowels /i:, u:/. F0 was examined in the sustained phonation of the /a, i, u/, vowels in the words presented earlier and in sentences from the Arabic version of “The North Wind and the Sun” (Thelwall & Sa’Adeddin, 1990) and two verses from the first chapter of the Quran. F1, F2 and F3 values were examined in the sustained phonation of individual vowels and in vowels in the words described earlier. Acoustic analysis was carried out by using Praat (Boersma & Weenink, 2013). A series of mixed model ANOVAs were performed to investigate dialect and sex differences for each of the parameters. Dialect and sex were the main independent variables; however, additional variables were assessed (syllable type, voicing, vowel context, place of articulation and emphasis).

The first aim has been met, with normative data being established for males and females from both dialects. The results showed that for each of the parameters (DDK, VOT, F0 and formant frequencies), the dialect differences as well as the degree of differences were dependent on the stimuli type. Furthermore, sex differences were apparent for F0, F1, F2 and F3 where males had lower frequencies than females in all tasks. In addition, the results showed that females had longer VOT durations than males for voiceless stops; and in the initial emphatic /tˤ/ context; males had longer VOT duration than females. However, there were no differences between male and female speakers with regard to the DDK rates, and in the VOT analysis, initial voiced stops did not show an effect for dialect and sex. Furthermore, the impact of other variables other than dialect and sex are discussed. In conclusion, dialect, and to a lesser extent, sex differences in the Arabic dialects under study, are dependent on the stimulus type. The study also showed that emphatic /tˤ/ might help in differentiating between different Arabic dialects.

Dedication

This thesis is dedicated to the soul of my grandfather

and to my Mother and Father

Acknowledgments

بسم الله الرحمن الرحيم

"In the Name of Allah the most merciful, the most compassionate"

Thank you Allah for your blessing and for giving me the strength to overcome those difficult times

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It is not possible to remember everyone that had helped me during these years; however, you are not forgotten and thank you.

Author's Declaration

I hereby acknowledge that the work contained in this thesis is my own original work and has not previously in its entirety or in part been submitted to any academic institution for degree purposes.

Majid Ibrahim Alshahwan

2015

Table of contents

List of Tables

List of Figures

Chapter 1. Introduction

1.1 Introduction

This chapter presents an overview of the Arabic language. It also indicates the aims of this study, followed by a discussion of the motivation for embarking on this research which explored the Saudi Najdi and Bahraini Bahraini Arabic Gulf dialects. In addition, the chapter presents the structure of the thesis.

1.2 Overview of the Arabic language

> "…the language of 22 Member States of UNESCO, a language with more than 422 million speakers in the Arab world and used by more than 1.5 billion Muslims."
>
> (United Nations Educational, Scientific and Cultural Organization (UNESCO), 2015)

Arabic is a Semitic language and is the spoken language of more than 280 million people across different parts of the world. While it may be the first language spoken in many countries, it is also the second language in many other countries. It is spoken in countries of the Middle East and North Africa, namely, Algeria, Egypt, Morocco, Libya and Tunisia; it is also spoken in other parts of Africa, including the Sudan, Djibouti and Somalia. In addition, Arabic is spoken by ethnic minorities in Nigeria, Chad, Senegal and Eritrea, amongst others. Arabic is also spoken in the following countries in the Middle East: Saudi Arabia, Jordan, Iraq, Syria, Kuwait, the United Arab Emirates, Bahrain, Oman, Qatar, Yemen and Lebanon. It is the native language of the Palestinians living in the occupied parts of Gaza and the West Bank as well as the native language of residents of Alahwaz in the southern region of Iran. Additionally, it is a spoken language amongst immigrants in parts of Europe, the United Kingdom and North America.

A large number of these countries have been subject to colonisation. North Africa was mostly occupied by the French, except for Libya which was occupied by Italy. Middle Eastern countries were colonised by the United Kingdom, namely, Bahrain, Jordan, Kuwait, the United Arab Emirates (UAE) and Egypt. However, other parts were left unoccupied, such as the central areas of the Arabian Peninsula, where the Najdi dialect is spoken (Ingham, 1994). The colonisation might have influenced the spoken colloquial forms of Arabic (Rosenhouse & Goral, 2005). In addition, other languages might have had an effect on the dialects of Arabic (e.g. Berber and Persian) (Rosenhouse & Goral, 2005).

The spoken form of Arabic includes different dialects. In addition, there is a higher form of Arabic; the presence of these two forms of Arabic has been termed 'diglossia' (Ferguson, 1959a, 1959b). The focus of this study is on dialects of Arabic, particularly two Gulf Arabic dialects; the Najdi central dialect and the Bahraini Bahraini dialect.

1.3 Aims of the study

This study aims to explore two Gulf Arabic dialects, the Najdi central dialect spoken in Saudi Arabia and the Bahraini Bahraini dialect spoken in the Kingdom of Bahrain. It aims to establish normative speech characteristics based on data collected from 80 male and female dialect speakers for the use of speech and language pathologists in clinics.

The means for exploring these dialects are two durational measures, the Diadochokinetic Rate (DDK) and Voice Onset Time (VOT), as well as two types of spectral measures, Fundamental Frequency (F0) and Formant Frequencies, derived from a number of tasks. In addition, the study aims to answer two main research questions using the chosen parameters (see Figure 1.1):

1. Are there differences between the two Gulf Arabic dialects (Saudi Najdi and Bahraini Bahraini) in the speech of males and females?

2. Are there differences in the speech of males and females in the Saudi Najdi and the Bahraini Bahraini dialects?

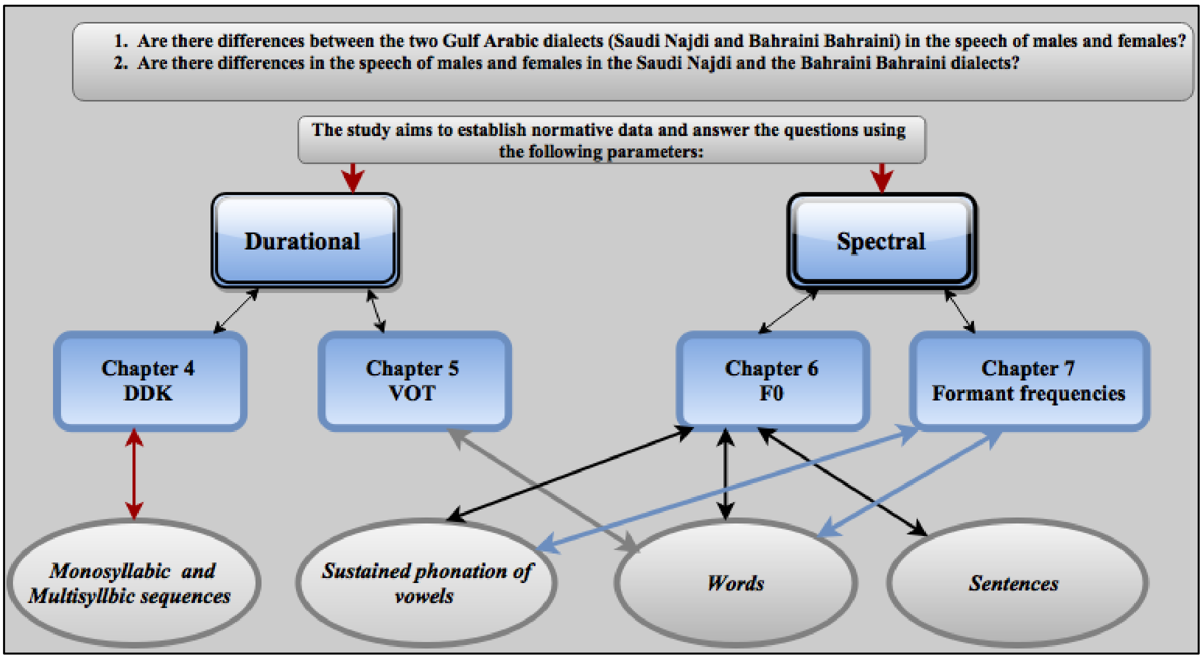

Figure 1.1 Main research questions that this thesis will address as well as the parameters used to answer them using different tasks.

1.4 Motivation for the study

This research is motivated by a number of factors, the first of which is that there is a need to establish normative data for a number of speech parameters (DDK, VOT, F0 and formant frequencies) that are used frequently in clinics. In the opinion of the researcher, having a better understating of normative speech characteristics of voice and dialects is the foundation of becoming a more improved and efficient clinician as it would enhance speech and language pathologists' understanding of speech and voice disorders in Arabic speakers. Therefore, the Saudi Najdi dialect was selected for analysis.

Two incidents recalled by the researcher were motivating factors for the choice of the Bahraini Arabic dialect. The first involved a Bahraini client in a clinic in Riyadh, Saudi Arabia, where a colleague had assessed a client's family member as having a speech disorder.

In fact what the clinician was observing was a dialectal difference. The second incident was when an expatriate working in Saudi visited the Kingdom of Bahrain and had commented that the Bahrani Bahraini dialect (differences between Bahrani and Bahraini dialects in Bahrain will be described in chapter 2) was perceptually different to the Najdi Saudi dialect he is familiar to hearing. This led the researcher to focus on the dialects of Bahrain.

1.5 Contributations of the thesis

This study provides normative data including means and range (maximum and minimum) for a number of speech parameters (DDK, VOT, F0 and F1- F3) for two Arabic speech dialects (Saudi Najdi dialect in central Saudi Arabia and the Bahraini Bahraini dialect from the kingdom of Bahraini) from both sexes. In addition, it explores dialect differences between the two Arabic dialects understudy for a number of stimuli in each of the parameters which will be explained briefly below and extensively in subsequent chapters.

Another contribution made by this study is to the knowledge of this researcher, the Bahraini Bahraini (Bahraini Arabs) Arabic dialect has not been explored before acoustically, therefore it expands on the knowledge on this Arabic dialect for both sexes. Studies on sex differences in Arabic are scarce, particularly the dialects chosen in this study, thereby this study contributes to the knowledge on Saudi Najdi and Bahraini Bahraini female speakers.

Another advantage is it provides normative data (means, minimum and maximum) for DDK (chapter 4) in two different Arabic dialects which have not been established before to the knowledge of this researcher. It showed differences between the two dialects understudy for the monosyllable sequences while no sex differences were observed between sexes for the Arabic dialects.

Another contribution is established from chapter 5 on VOT, where it shows the typology of the two Arabic dialects understudy amongst Arabic dialects. In addition, it shows that both

Arabic dialects in this study follow a three voicing category distinction (Lead, short lag and long lag) for words with initial voiced/voiceless, voiceless/ emphatic stops. It also shows differences between the two Arabic dialects for voiceless stops. In addition, it showed interesting differences between male and females for the emphatic voiceless stop /tˤ/. It shows potential on the use of the emphatic stops in the differentiation between Arabic dialects.

Another advantage in this study as observed in chapter 6 on F0 is the use of different stimuli (sustained phonation, vowels in words and sentences) for the two Arabic dialects in this study as well as sex differences. It also utilises a Quranic verse as one of the sentences used for analysis which might be considered a classical form of Arabic for clinical settings which might be expanded upon in future studies as it used widely amongst Muslims. It adds to knowledge on dialects differences that were shown to be significant to stimuli type. The results showed dialects differences depending on the stimuli, while sex differences were apparent where males showed lower F0 for males than females in agreement with cross-linguistic studies. It also showed differences between types of sentences.

In chapter 7 on formant frequencies, it yielded new observations about the two dialects understudy for the sustained vowels as well as vowels in words. In addition, it showed agreement with cross-linguistic differences between sexes. In agreement with chapter 5, the emphatic stops might be useful tool in differentiating between Arabic dialects.

It also provides some clinical applications from the normative data provided for this study for the Najdi Saudi and the Bahraini Bahraini population. It shows that speech and language pathologist should be cautious when treating patients from different Arabic dialects. In addition, use of different stimuli is suggested to clinician as this study has shown. Further clinical implications are provided in the subsequent chapters.

1.6 Organisation of the thesis

The current research is based on exploring a series of speech parameters to establish normative data for the Najdi central Saudi dialect and the Bahraini Bahraini dialect. Speakers of both sexes were investigated to understand dialect and sex differences. Chapter 2 provides background information on the spoken form of Arabic and expands on the issue of "diglossia". It also provides a brief history of the Najdi Saudi and the Bahraini Bahraini Arabic Gulf dialects as well as providing information on the phonology of these dialects. Chapter 3 describes the recruitment of participants from both dialects. It describes the stimuli used in the study, in addition to the data preparation for the analysis which is presented in the hfollowing chapters (4-7).

Chapters 4 and 5 present the durational measures used in the study, where Chapter 4 provides a literature review on DDK rates and their use as well as the methodology used to obtain DDK rates. It also presents the DDK results, together with a discussion and summary. Chapter 5 provides a literature review on VOT in Arabic and describes the procedure of VOT analysis as well as presenting the results, a discussion and summary. Chapters 6 and 7 presents the spectral measures under investigation, where Chapter 6 defines F0 and presents a literature review on Arabic studies, followed by the methodology used to obtain F0 data and a discussion of the results. Chapter 7 defines formant frequencies, examining the literature on Arabic followed by information on the method of analysis and a discussion of the results. Chapter 8 concludes with a summary of the aims of the study and answers the two main research questions. It also comments on the implications of the study and presents its limitations. Suggestions for future research are proposed in the closing sections of the chapter.

Chapter 2. Arabic: the Dialects of Najdi Saudi and Bahraini Bahraini

2.1 Introduction

As described earlier (§1.1), Arabic is a Semitic language spoken in a number of countries throughout the world; however, the Arabian Gulf dialects have received little attention in the sociolinguistics literature. The few studies that have focused on the Najdi dialect in Saudi Arabia (Ingham, 1994, 2006) have shed some light on its morphology and syntax, as well as phonology, to some extent. Similarly, the Bahraini dialect has received prominent attention from Holes (1983, 1984, 1990) and Al-Tajir (1982), who were interested in understanding the dialect from a historical point of view, in addition to examining its phonology, morphology and syntax. This chapter aims to explain the complexity of the Arabic language, in order to understand the phonology of the Arabic dialects (Riyadh Najdi Saudi and Bahraini Arabs) under investigation in this thesis.

This chapter is structured as follows. First, it briefly presents the written forms of Arabic. Second, it presents the spoken form of Arabic with a brief discussion on the classification of Arabic. Third, it presents a history of the Najd region together with the phonology of the Najdi dialect. Fourth, Bahrain's history and the phonology of the Bahraini dialect under investigation will be detailed. Finally, a summary of the chapter will be presented.

2.2 Written Arabic

The written form of Arabic is unified in script, running right-to-left. It is written in a cursive style, in which the letters are joined together to form a word. The Arabic alphabet consists of 28 letters, which are mostly consonants. The term referring to the "Abjad" system of writing was coined by Bauer (1996). The term "Abjad" (أبجد) is not new and was used to describe the Arabic alphabet that was more similar to the Phoenician alphabet (used before the present Arabic alphabet form) (أب ت ث).

Arabic script is used in the Arabic-speaking world, but other languages also use this script, including Persian, Kurdish, Urdu and Pashto, among others. A distinctive feature of Arabic script is the diacritical dots and signs; these were historically added to differentiate between letters and to represent some of the vowels as well as consonants (Bauer, 1996). Although diacritical dots are now used in written Arabic, the signs representing consonant gemination and short vowels are optional. The Qur'an extensively uses diacritics, but they are used in other texts less frequently (Bauer, 1996). The use of diacritics has an added decorative purpose in books and texts and for calligraphers (Bauer, 1996). However, the presence of diacritics in Arabic have been shown in a recent study by Hermena et al. (2015) that it might come on the expense of slightly longer processing times. Arabic script is read throughout the Arabic-speaking world so that people from other Muslim countries can read and recite the Qur'an in their prayers. For example, an Arabic reader from Morocco can read an Arabic text written in Oman without difficulty. However, a reader of Quran from Indonesia might not understand a text written in Oman.

2.3 Spoken Arabic

In contrast to written Arabic, spoken Arabic is far more complex in its structure and code. The term "diglossia" was associated with Arabic-speaking countries as well as Greece, Haiti and German-speaking Switzerland. Krumbacher, in 1902, first used the term to describe the spoken language in Greece; William Marçais later used it in 1930 to also describe the language situation in Greece. Only later was it associated with the Arabic language, as discussed by Ferguson (1959a, 1959b), and more recently by Kaye (1990).

Ferguson (1959a, 1959b) defined the term “diglossia” as two forms of one language coexisting, one being considered of high “H” prestige and the other of low “L” prestige. Abu-Al-Makarem (2005) recently defined this phenomenon as a sociolinguistic term referring to a linguistic situation whereby two forms of the same language (formal and colloquial) are used side-by-side to perform different functions in a given society.

Formal Arabic is termed Modern Standard Arabic (MSA). Although, colloquial and formal (MSA) forms are often associated with “diglossia” in Arabic, there is an additional form that is often overlooked: the “classical” form. It is worth mentioning that some researchers such as Parkinson (1991)[1] indicated that another simpler form of MSA is present and labelled it as modern *Fusˤħa*[2]. However, it remains under the umbrella of MSA. Referring back to the example which is the Holy Qur’an, which is written in the Arabic script of this “classical form” (Crystal, 1997). Furthermore, Abu-Al-Makarem and Petrosino (2007) suggested that MSA may be based on Classical Arabic (henceforth, CA) or Quranic Arabic. Although this claim has been challenged by many (e.g. Owens (2006)). However, the discussion on origins of Arabic and its descent to current Arabic is beyond the scope of this thesis. Therefore, the approach to origins of MSA from CA had been adopted. From this view, CA is therefore, another spoken Arabic form that should not be neglected. Saiegh-Haddad (2003) and Amayreh et al. (1999) proposed that “diglossia” may not be the most appropriate term to describe the Arabic language situation and that it should be substituted with “triglossia”.

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[1] Outcomes from Parkinson's study (1991) are limited by the Egyptian Arabic dialect. Further studies are recommended as to whether this view is applicable across different Arabic dialects.

[2] Parkinson's study (1991) suggested an additional form which he labeled as the “plain grammatically correct” form which might be considered under both the colloquial form and modern Fusˤħa form. Furthermore, the classifications in his study are more reflective of written Egyptian form in contrast to Egyptian spoken form.

However, before the introduction of Islam by Prophet Mohammed (570–632 A.D.), Arabic was used by nomadic Arab tribes who travelled in the Arabian Peninsula regions. The people of that time were prolific writers of poetry. Collections such as Al-Mu'allqat "*the pendants*" were a product of that period and were written in the "classical Arabic" form (Holes, 2004). The coining of the term "The Pendants" derived from the fact that the poetry was written on sheaths that were hung on the "Kaaba"[3] in Makkah for everyone to see. This period boasted Jahili poetry, signifying that it was written before the introduction of Islam. This form of poetry is still read to this day; however, it is different to that of the Qur'an, thereby suggesting another form of CA. Therefore, the term CA may be too general, as it includes "Quranic and Islamic scriptures", with poetry from the pre-Islamic and Islamic eras (Ingham, 1994; Amayreh et al., 1999; Saiegh-Haddad, 2003; Holes, 2004).

Arabic is the language of the Holy Qur'an, which was collated after the Prophet had passed away. According to Muslims, the Qur'an includes revelations to Mohammed by "Gabriel" from Allah (God). Maurice Bucaille (2003) noted that the Qur'an's authenticity is somewhat unquestionable. The Qur'an's situation is different from that of other religious textbooks. As Bucaille (2003) explained, the Qur'an was gathered during Mohammed's life by "reciters", who memorized and recited the teachings daily. During the Wars of "Apostasy" after the death of Mohammed, the third Kaliph 'Othman ibn Affaan' was able to collate the Qur'an to establish its current form (Holes, 2004). Bucaille & Pannell (1978) and Bucaille (2003) commented that the Qur'an was able to be carefully preserved because of the reciters.

[3] The "kaaba", which is the cube in the centre of Makkah (Mecca) toward which all Muslims pray, was re-built, according to the Qur'an, by the Prophet Ibrahim and his son Ismael (Ishmael) (The Qur'an, The Cow, Ayah 125–128).

In addition, Muslims, who form the majority of Arabic speakers, come from many different ethnicities and different geographical regions yet are able to understand most of the Qur’an by reading it. Although some words are now not used, it is often taught to Muslim children as young as 5 years old. Although it has been translated into other languages, the Qur’an is read in its original Arabic script daily in Muslim prayers, or “sˁalat”, at least five times a day, as well as being recited by Muslim followers on their own. In this thesis, the MSA form as well as a chapter from of the Quran will be employed in analysis. In addition, the Hadith is defined by the Oxford English Dictionary as a “body of traditions relating to Muhammad, which now form a supplement to the Qur’an, called the Sunna” (Oxford English Dictionary, 2010).

These Islamic scriptures (Qur’an and Hadith) were traditionally preserved among Muslims. The majority of Arabic speakers throughout the world, even non-Muslim Arabs, are often able to recite some verses from the Qur’an. Additionally, Muslims from different parts of the globe use the Qur’an and Hadith, but the Qur’an is used more often, as previously noted, in prayers and recitation. As these Islamic scriptures are highly regarded throughout the Muslim and Arab worlds, AlAwaji & Alshahwan (2012) suggested the presence of a dichotomy between Islamic scripture and poetry. This categorization renders Arabic as a quadriglossic language, whereby the Qur’an and Islamic scripture are categorized as one form and poetry and literature from the Jahili period as another distinctive form (see Figure 2.1).

In addition to the categorization of spoken Arabic, the effects of languages spoken in a given area (e.g. Berber and Persian), as well as those brought into the region (e.g. English and French), may influence the spoken colloquial forms of Arabic (Rosenhouse & Goral, 2005). The next sections will report on differences observed in the dialects of Arabia.

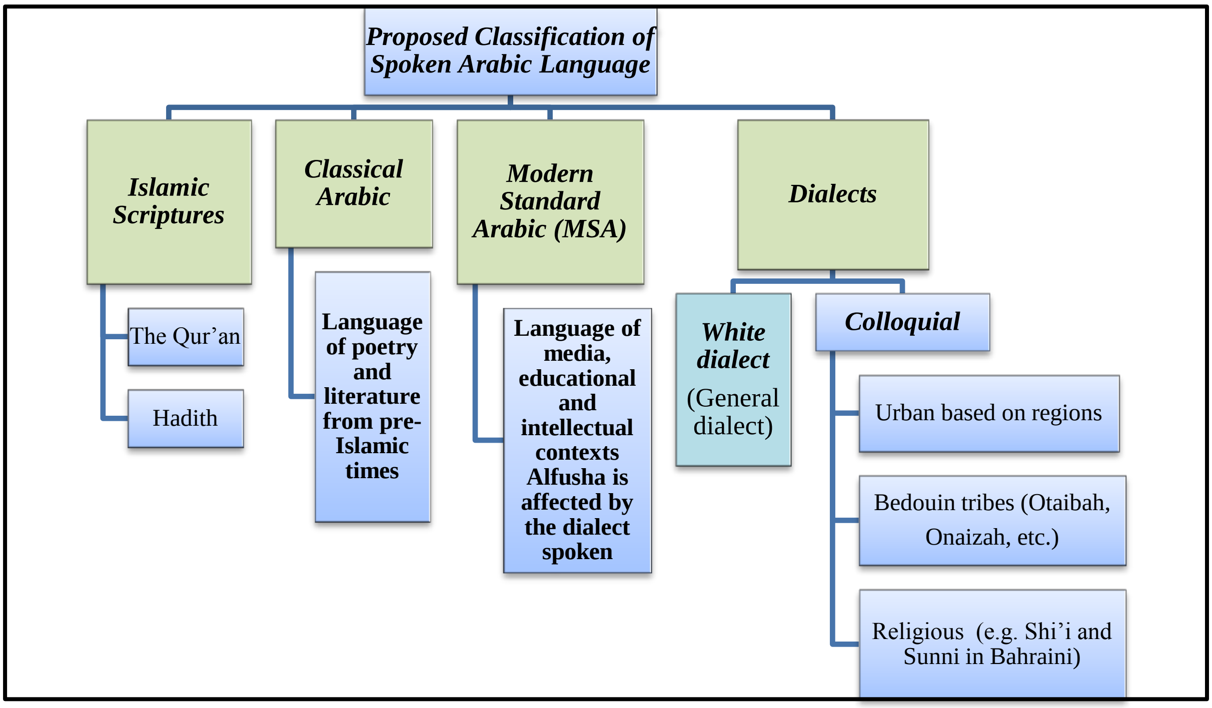

Figure 2.1 Proposed classification of spoken Arabic language by AlAwaji & Alshahwan (2012), White dialect will be defined in page 14.

2.3.1 Dialects of the Arabic language

Differences can be found between dialects in colloquial Arabic. Many opinions have emerged relating to the classification of Arabic dialects, but four classifications appear to be key:

1. **Social division**: Ibn Khaldūn (1969) described dialects surfacing as early as the fourteenth century, relating to sedentary and nomadic "Bedouin" people. He later revised his work to include rural and urban dialects. Although these communities often live side-by-side, they have distinctive dialects through which they are able to distinguish themselves.
2. **Religious division:** Blanc (1964) suggested that dialects are based on religious communities, dividing groups of people into Muslims,

Christians, Jews, or others. He formulated his assumption based on people in the Mesopotamian areas, which is in present-day Iraq.

3. **Geographical division – General:** A number of studies (Fischer & Jastrow, 1980; Kaye & Rosenhouse, 1997; Barkat, 2000; Abu-Al-Makarem, 2005) proposed that dialects could be divided into Eastern and Western groups. The Eastern groups are those lying to the east of the Nile, while the Western groups are those to the west of the Nile.

4. **Geographical division – Specific:**

Versteegh (2001) classified Arabic dialects into five main categories seen below; however, within the five main categories divisions were made. However, expansion on the first category will be made as it is the scope of the study, see Versteegh, (2001, p. 153) for remaining categories :

a) Dialects of the Arabian Peninsula : according to Ingham (1982) and Palva (1991) as cited Versteegh (2001) classifies into four sub-categories:

   a. North-east Arabian dialects: in this category Najd dialects and the Bahraini Bahraini (Sunni) (see §2.3.2.1 ~ §2.3.2.2) are under one category amongst others.

   b. South (-west) Arabian dialects including dialects of Yemen as well as dialect of Bahraini Bahrani (Shi'ite), (see §2.3.2.2).

   c. Hijazi in the western part of the Arabian Peninsula.

   d. North-west Arabian dialects: the dialects of Negev and the Sinai as well as those of southern Jordan amongst others.

b) Mesopotamian dialects;

c) Syro-Lebanese dialects;

d) Egyptian dialects; and

e) Maghreb dialects.

It is the opinion of the author of this thesis that the final classification might be adequate, as it enables dialects to be categorized in terms of specific geographical regions. Versteegh's (2001) classification can be used to explain the general differences observed among Arabic dialects. However, it is felt that the Arabic language may be better described by using a combination of the above and not relying on regional differences alone. For example, the dialects of the Arabian Peninsula can be divided into sedentary and Bedouin dialects, with the same rationale applying to Syro-Lebanese dialects. Another example is that the Mesopotamian dialect can be divided according to religion, as suggested by Blanc (1964).

MSA is often used in spoken and written media and is understood by most people from the Gulf region to Morocco (Abdelali, 2004). However, it may be the case that a person from one of the variation within Saudi Arabia with an example from the Southern Saudi Arabian Ghamdi dialect (spoken by the tribe of Alghamid) may have some difficulties understanding a person speaking in one of the Moroccan dialects. Where , the Moroccan dialect, has its own variations; as Jeffrey Heath (1997) explained, it was influenced by the language of the Berbers and also the Muslims and Jews that fled Spain in 1429.

A number of studies (Abdulaziz, 1986; Abu-Absi, 1986; Abdelali, 2004; Cote, 2009) argued that one dialect could be used throughout the Arabic-speaking world, which would make people understand each other more easily. In earlier studies on the concept of diglossia or polyglossia as put by Kaye (1994)[4], authors such as Blanc (1960) and Badawi (1973) had suggested in their classifications' of spoken Arabic of the presence of a Higher Colloquial form[5]. AlAwaji & Alshahwan (2012) later had affirmed this and suggested in that in current time that a widely-used dialect is present and is often used on television programmes and in conversations between people from different dialects, and have termed it the "white dialect"[6] regardless of the origin of the Arabic speaker. The white dialect is defined as:

> "*a semi-conscious higher form of dialectal Arabic that is characterized by detaching itself as much as possible from the distinctive features of the person's dialect, specifically, suffixes and prefixes, and other features depending on the dialect are absent*" (AlAwaji & Alshahwan, 2012).

The authors later noted differences in its morphological and syntactical features as well as phonemic features. Furthermore, they added that the level of presence of the white dialect might be related to other factors (e.g. age, level of education, exposure to media). They provide an example where an elder Saudi Najdi male speaker would address a female with /saʔil͡ts/ "I am asking you a question?" which is a characteristic of Najdi Arabic. While a younger Najdi speakers (i.e. the second author), would apply the MSA's final /k/ as in /saʔiltk/ to a female speaker of another Arabic dialect.

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[4] See Kaye's 1990 paper for review on the complexity of spoken Arabic.

[5] Namley the elevated colloquial form in Blanc's study (1960) and a combination of educated coliqual and enlightened colliqual in Badawi's study (1973).

[6] The white dialect is named white as it is ambiguous and has similarities to a white canvas where each Arabic speaker has a unique pattern that might be or might not be similar to others speaking that dialect.

In the next section, MSA will be compared to the Najdi and the Bahraini Arabic dialects, which are the focus of the current literature review and research study.

2.3.2 MSA, Arabic dialects and the Najdi and Bahraini Arabic dialects

The MSA phonetic inventory is presented in Table 2.1, with 28 consonants (Embarki, 2013); however, Arabic dialects vary in their realizations of some of the consonants depending on the dialects spoken (For a review, see Watson, 2002). Example will be provided for the Najdi Saudi Najdi dialect and the Bahraini dialects in §2.3.2.1 ~ §2.3.2.2.

Embarki (2013) suggested that MSA has three short vowels: /a, i, u/; in addition to three long vowels /a:, i:, u:/. Furthermore, Omar (1991) suggested the addition of two diphthongs, /aj/ and /aw/, as well as two approximants, /w/ and /j/.

	Bilabial	**Labiodentals**	**Dental**	**Alveolar**	**Post-alveolar**	**Palatal**	**Velar**	**Uvular**	**Pharyngeal**	**Glottal**
Plosive	b			t d			k	q		ʔ
				tˤ dˤ						
Nasal	m			n						
Trill		f		r						
Fricative			θ ð	s z		ʃ		χ ʁ	ħ ʕ	h
				sˤ ðˤ						
Affricate					d͡ʒ					
Approximant	w					j				
Lateral approximant				l						

Table 2.1 Phonetic inventory for consonants in MSA according to Embarki (2013).

In the next section, a brief history on the dialects under investigation in this thesis will be reviewed, as well as the phonetic inventories of each dialect.

2.3.2.1 Najdi Saudi dialect

2.3.2.1.1 History and dialects of Najd

2.3.2.1.1.1 History

Hijaz, Yemen, Oman, Eastern Arabia and Najd were populated areas in the Arabian Peninsula (Ingham, 1994). Najd, in particular, was located in the middle of the Arabian Peninsula between Hijaz and under the Eastern part of Saudi Arabia (see Figure 2.2), the site of present-day Alhasa, Kuwait and Bahrain.

Najd lacked water and thus relied on the exportation of goods and livestock, such as sheep and camels that resided on green patches of land, from neighbouring parts of the Peninsula (as opposed to Alhasa and Shatt Al-Arab which depended on wells and springs) (Ingham, 1994). However, sedentary occupants were present in cities and villages in the Najd area. Hamed AlJassir (2001), a well-known historian in Saudi Arabia, describes them as often working in fields as farmers in the few areas that had water or as what were called “Sunna’a”, or craftsmen (AlJassir, 2001).

During this period, members of a few tribes fled to other nearby Gulf regions; one assumed underlying reason for their migration was to seek better living conditions (Ingham, 1994). For example, the rulers of Kuwait, Bahrain and Saudi Arabia, (Alsabaah, Alkhalifah and Alsaud, respectively) were all from the Anizah tribe who resided in Najd.

Figure 2.2 Saudi Najdi dialect in Saudi Arabia (adapted from www.joshuaproject.net)

What is distinctive about Najd? Throughout history, it has never been occupied and, therefore, has had little contact with other languages in the past. For example, the Western region of the Peninsula was occupied by the Ottoman Empire until 1925, although it was ruled by the Alsharif family (Ingham, 1994). In addition, the Western region had a wealth of cultures and ethnicities from different parts of the world. Hajj pilgrimages are made once a year to Makkah during the first days of the Hajj month of the Arabic calendar, and some of these pilgrims would ultimately settle in the area (Ingham, 1971). Likewise, Umrah is a pilgrimage which is not performed at a specific time and takes place throughout the year. It is another reason for the increase of the flow of people of different ethnicities to the Western region of Arabia (Hejaz).

Present-day Najd has been changing since the beginning of the twentieth century due to the ruling family of Al-Saud, who urged the nomadic people of Saudi Arabia to become settlers in areas called /heʤrat/, which are small villages that eventually transformed into today's small cities (AlJassir, 2001; AL-Juhany, 2002).

Riyadh has been the capital city since 1932, when Al-Saud ruled, and most of its occupants were from the Najd area. Riyadh offered more job opportunities and educational institutes, which drew people from different areas of Saudi Arabia (AL-Juhany, 2002). In addition, English is spoken by expats in Riyadh and is increasingly spoken by the Najdi people.

2.3.2.1.1.2 Dialects of Najd

Ingham (1994) divided the dialects of Najd into three general groups according to definable features that differentiate them from surrounding dialects on the Peninsula:

1. Central Najd: a dialect that belongs to the districts of AlA'arid, Al-Washm and Sudair. The Northern districts of Qasim and Jabal Shammar and the Southern districts of Najran and Bisha are included in this group.
2. Bedouin speech: the speech of the Anizah, Utaiba, Subai'e, Suhul, Bugum, Dawasir, Harb, Mutaair, Awazim and Rashayiad tribes. It also includes the populace of Northern Najd: the Shammar, Dhafir, Al-Murra and Ajman tribes from the south and east.
3. The speech of those exiled Bedouin tribes, Shammar and Anizah, who are in the Syrian Desert and Iraq.

Ingham (1994) further divided the above three groups based on their linguistic similarities into four groups:

1. Central Najd speech: the speech of the Bedouin tribes and that of the Anizah tribe that resided in Syria.
2. Northern Najd speech: the speech of the Shammer tribe, including those residing on Jabal Shammar as well as members living in Northern Najd and Iraq.

3. The speech of the Qassim areas and that of the Dhafir tribes, which is found in Northern and Central Najd.
4. Southern speech: Southern Najd, which includes Najran and the South Eastern tribes of Ghatan, Al-Murra and Al-Ajman.

The first three groups differ across the whole linguistic spectrum, specifically at the level of phonetics and morphology. However, the southern group is marked by certain syntactic and lexical features, which relates it to dialects of the southern Peninsula, specifically the Yemen dialect.

As noticed by the author of this thesis, the description of the Najdi dialects in both of the above sections is to some extent reflective of Bedouin tribal dialects of Najdi Arabic. Only in the first group of the first classification of Najdi Arabic has Najdi Arabic been divided to Bedouin and sedentary, whereby Ingham (1994) refers to them as AlA'arid, Al-Washm and Sudair Najdi speakers. These might be considered of sedentary Najdi dialects. However, in this study, the selected Najdi dialect is very specific and more reflective of a linguistically homogeneous group, whom are sedentary speakers of Riyadh Najdi dialect.

There are major distinctions between Najdi Arabic dialects (see Inventory Table 2.2), MSA and other dialects in the Gulf region; the following distinctions are the most common:

- Gutturals affect syllable structure, and CVC (second consonant guttural) would become CCV. An example is MSA /qah.wa/ 'coffee' becoming /ghawa/ (Johnstone, 1964).
- There is an overlap between the use of /i/ and /u/ in pharyngealized and bilabial consonant environments, as in /mutaˤr/ 'rain' and /mitˤar/ (Ingham, 1994).
- The realization of /k/ and /q/, which occur as /t͡s/ and /d͡z/, respectively. An example is /kalb/ 'dog' realized as /t͡salb/ and /qalb/ 'heart' realized as /d͡zalb/ (Johnstone, 1964).

However, some sedentary speakers of the dialect only realise the final /k/ as /t͡s/ (e.g. /saʔiltk/ → /saʔilt͡s/ "I am asking you a question?" when addressing a female.

- The glottal stop /ʔ/ is often absent in the Najdi dialect where, for example, realizations such as /ras/ are found instead of /raʔ.s/, which means 'head' in Arabic (Versteegh, 2001). However, Ingham (1994) as well as the author of thesis indicate it is present in Najdi when using MSA words such as /ʔakil/ "food" and /qurʔa:n/ "Qura'an".
- The uvular stop /q/ is realised often in Najdi dialects as /g/ (e.g. /haqi:qa/ 'truth' → /hagi:ga/. Similar to the above, some MSA words retain the /q/ (e.g. /qurʔa:n/ and /waqiʕ/ "realistic").
- One of the main features of mostly all Najdi dialect is the absence of the alveolar emphatic stop /dˤ/ which is realised as the emphatic fricative /ðˤ/ (e.g. /dˤab/. "lizard" → /ðˤab/.

As observed by the author, the first three realizations are characteristic of certain tribes (e.g. Al-dawasir) and those not living in Riyadh, and particularly those who live in the Northern areas of Najid (Qassim). For the Riyadh Najdi sedentary dialect under investigation in this study, the remaining realisations are reflective of those participating in this study, in addition to the final /k/ to /t͡s/ realization when addressing a female. The affrication of /k/[7] was observed by the researcher in a few male Najdi Riyadh participants. While, female Najdi Riyadh participants were not shown to retain this attribute except for one female participant which was 35 years old which shows that females might prefer the

[7] The stimuli in the study was not designed to asses this feature.

/k/ to the /t͡s/. Another observation is that younger male and female generation of Riyadh Najdi speakers were showing a shift towards the use of /k/. Moroveor, the researcher of this thesis noticed that Riyadh Najdi speaker's whome are younger than those collected and some that were exclueded from the outset were often spkeaking a lighter form of Riyadh Najdi diaelcts. Although, this is speculative, Riaydh Najdi might be undergoing some change.

2.3.2.1.1.3 Phonetic inventory

According to Ingham (1994), the Najdi Saudi dialects has 31 consonants, as presented in Table 2.2. However, for the Najdi Riyadh dialect understudy, only 30 consonants are presents where the /d͡z/ is absent (see Table 2.2.). Emphatics are distinctive in Arabic; however, only three emphatic consonants are present: one plosive, the alveolar voiceless emphatic /tˤ/, and the voiced dental fricative /ðˤ/ and voiceless alveolar fricative /sˤ/, while the voiced alveolar empahtic /dˤ/ is absent in all Najdi dialects.

	Bilabial	**Labiodental**	**Dental**	**Alveolar**	**Post-alveolar**	**Palatal**	**Velar**	**Uvular**	**Pharyng-eal**	**Glottal**
Plosive	b			t d			k g	q		ʔ
				tˤ						
Nasal	m			n						
Trill				r						
Fricative		f	θ ð	s z		ʃ ʒ		χ ʁ	ħ ʕ	h
			ðˤ	sˤ						
Affricate				t͡s d͡z*	d͡ʒ					
Approximant	w					j				
Lateral approximant				l						

Table 2.2 Phonetic inventory of consonants for the Najdi Saudi dialects according to Ingham (1994) and the author of this thesis, the asterisk is indicative that the consonant is absent in the Riyadh Najdi diaelct understudy in this thesis.

In addition, Najdi Saudi Arabic has the short vowels /a, i, u/ and the long vowels /a:, i:, u:/, in addition to two diphthongs, /aj/ and /aw/ (Ingham, 1994).

2.3.2.2 Bahraini dialect

2.3.2.2.1 History and dialects of Bahrain

2.3.2.2.1.1 History of Bahraini

Despite being a small country (see Figure 2.3) compared to those within the Gulf region, the ethnic and cultural makeup of this area is far more complex than that of Najd.

Figure 2.3 Bahrain map in relation to Saudi Arabia and Qatar (adapted from www.joshuaproject.net)

The ethnic structure of current Bahrain can be divided into the following groups, based on their backgrounds and the geographical areas from which they have emigrated if applicable:

Bahraini Arabs, who live in Bahrain, mostly descend from Saudi Arabians who came to

Bahrain; well-known families include Al-Khalifa, Al-Zayani and Al-Gosabi (Al-Tajir, 1982). Most of them live in the main city of Manama and other nearby cities, such as Almuharaq (Al-Tajir, 1982).

Another part of the community is the *Huwlah* who are members of the same religious sect as the Arabs, namely, Sunni Islam. They profess to be the Arab descendants of people who lived on the Iranian coast and, thus, have always considered themselves as Arabs and not Persian (Al-Tajir, 1982). Nonetheless, influences from Persian culture affected them and gave distinctness to their bloodlines (Al-Tajir, 1982). The Huwlah speak Arabic, as they consider themselves Arabs. However, among themselves, they speak a variety of Persian called Bastik, which is spoken in the southern region of Iran (Al-Tajir, 1982). Most of the Huwlah live among the Arabs in Manama and are often thought of as forming one community with the Arabs. Not neglecting their identity, they are proud of being the descendants of Arabs who lived in southern Persia. Both the Bahraini Arabs and the Huwalah speak the same dialect.

The *Baharnah* are the people who lived in Bahrain prior to the arrival of the Arabs, according to Al-Tajir (1982), who also described their conflicting origins. However, according to Al-Tajir (1982), they coined the term Baharnah to distinguish themselves from Arabs. In addition, they are distinguished by sect: they are mostly of the Shiia sect in Islam. The Shiia sect is currently influenced by Iran, and most of them are Persian speakers (Al-Tajir, 1982). The Baharnah often lived in villages surrounding Manama and around the islands of Bahrain and are often referred to as *Qarawi*, or Villagers. In comparison, the city dwellers are called *Madani*, which is used when referring to Sunni Bahrainis, either of Arab or Huwalah origin.

The Baharnah often lived in areas that excluded people who were not Baharnah, although a few lived in Manama side-by-side with Arabs and Huwalah (Holes, 1982). In recent times, the government of Bahrain has tried to socially mould or engineer both sects into a new modern group, called the *Madinat Issa*, and to encourage the two groups to live with each other (Holes, 1987).

Another Bahraini group is the "ʕajm" who are of a Shiia sect. Although they share common beliefs with the Baharnah, they are mostly recent arrivals from Iran (Holes, 1987). Holes (1978) described them as speaking fluent Persian and few words of Arabic.

Other Bahraini minorities exist in Bahrain, such as Jewish Bahrainis. Although they are small in number, their political presence can be seen in Parliament (*Shura*), where they speak a Bahraini dialect. Christian Bahrainis are also present in Bahrain and are greater in number compared to Jewish Bahrainis; the majority of both Jewish and Christian Bahrainis are of Levantine and Iraqi origins (Central Intelligence Agency, 2015).

According to a recent Bahraini Census (2010), half of the population currently residing in Bahrain are foreigners who work or teach in Bahrain. The majority of these foreigners are from Asian countries and the rest are from different parts of the world (Bahrain Census, 2010).

2.3.2.2.1.2 Dialects of Bahraini

In the previous section, a description of the social and ethnic makeup of Bahrain was provided. Despite its small size, many linguistic studies, such as Johnstone (1961, 1964, 1965), have focused on the dialects of the eastern province of the Arabian Peninsula. Prochazka (1981) and Al-Tajir (1982) focused on the Baharnah dialect in Bahrain. Meanwhile, Holes (1983, 1984, 1986, 1987, 1995, 2005, 2007a, 2007b) is an avid researcher on Arabic in the Arabian Peninsula; he has mostly reflected on the dialects of Bahrain and observed the effects of modernization in Bahrain.

The Arabic language is still the most dominant language in Bahrain, as it is the official language and is used in all media forms. Linguistic divisions appear to correspond with the ethnic boundaries of the Bahrainis' backgrounds. Al-Tajir (1982), Prochazka (1981) and Holes (1987, 1995, 2005) divided the dialects in Bahrain into the Bahraini Arab dialect (Arabs and Huwlah) and Bahraini Baharnai. This division is based upon the linguistic differences between the Shiia (Baharnah) and Sunni sects (Arab and Huwlah). Although the majority of Bahrainis are Baharnah, the Bahraini Arab dialect is the most dominant and is widely used in the media (Holes, 1987).

Holes (1987) studied the Bahraini dialects; one of his observations was that Bahraini Arabs (henceforth, BA) often do not lose their dialect even if they live among Bahraini Baharnahs (henceforth, BB). However, BB adopt the BA dialect if they live among the BA community, as in the cities of Bahrain. The BA dialect has many similarities to the Najdi dialect, which is not surprising considering the origin of the Arab Bahrainis which are Saudi tribes and families who immigrated to Bahrain (Holes, 1987).

Some of the differences in phonology between the BA and BB dialects are the following:

- The realization of /k/: the BA dialect uses /k/, while the BB dialect uses an alveolar affricate /ʧ/ (Holes, 1987). An example is in MSA /kabar/ 'grew old', which is realized as /kubar/ in the BA dialect and /ʧubar/ in the BB dialect.
- The MSA voiced palatal-alveolar affricate /ʤ/ is realized as the glide /j/ in the BA dialect, while the BB dialect retains the original (Holes, 1987). The form /dʒumʔ'a/ 'Friday' is realized as /jimʔ'a/ in BA, and as /dʒumʔ'a/ in the BB dialect.
- Holes (1987) explained how the BA dialect commonly uses the voiceless/voiced uvular plosive /q/, instead of a voiced uvular fricative /ʁ/ and vice versa. One example is the MSA form /ʁe:r/ 'different', which is /qe:r/ in the BA dialect, and MSA /taqaddum/,

which is /taʁaddum/ in the BA dialect and /ʁe:r/ for BB (Holes, 1987). Another realisation is used interchangeably with the previous realisation, for use of the MSA /q/: BA dialect is realised as /g/, while the BB dialect uses a voiceless retracted velar fricative /ɣ/. For example, /qal/ 'said' is realized as /gal/ in the BA dialect and /ɣal/ in the BB dialect (Holes, 1987).

- The voiced/voiceless interdental stops /t/, /d/ and pharyngealized voiced interdental fricative /ðˤ/ are preserved in the BA dialect, while the BB dialect realisations is the empathic /tˤ/ where in BA is /θalθatʕaʃ/ " number thirteen", while for BB /θaltˤtˤʕaʃ/ while /d/ and /ðˤ/ are realised as /dˤ/ where /sˤadir/ "chest" and /ðˤi:l/ "tail" are realised in BB as /sadˤir/ and /dˤi:l/ (Al-Tajir, 1982). Furthermore, the /dˤ/ in BA is realised as /ðˤ/ similar to Najd dialects (Holes, 1987).

2.3.2.2.1.3 Phonetic inventory

According to Holes (1987), there are 30 consonants in the BA dialect, as shown in Table 2.3. There are three emphatic consonants: one plosive, the alveolar voiceless /tˤ/ emphatic, and the voiced dental fricative /ðˤ/ and voiceless alveolar fricative /sˤ/. In addition, the BA dialect has an additional voiced uvular plosive /ɢ/, while it lacks /ʦ/ and /ʣ/, which are present in the Saudi Najdi dialect.

	Bilabial	Labiodental	Dental	Alveolar	Post-alveolar	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	b			t d			k g	q ɢ		ʔ
				tˤ						
Nasal	m			n						
Trill				r						
Fricative		f	θ ð	s z		ʃ ʒ		χ ʁ	ħ ʕ	h
			ðˤ	sˤ						
Affricate					d͡ʒ					
Approximant	w					j				
Lateral approximant				l						

Table 2.3 Phonetic inventory of consonants in the BA dialect (Holes, 1987)

In addition, BA Arabic has the short vowels /a, i, u/ and the long vowels /a:, i:, u:/, in addition to two long vowels, /e:/ and /o:/ (Holes, 1987).

2.4 Will there be a difference between the two Arabic dialects (Saudi Najdi and Bahraini Bahraini)?

Despite minor differences in the phonetic inventories of the Saudi Najdi and BA dialects for consonants and vowels as well as realizations of a number of phonemes (presented in §2.3.2.1–2.3.2.2), a number of studies (Amayreh & Dyson, 1998; Amayreh, 2003; Abu-Al-Makarem, 2005; Abu-Al-Makarem & Petrosino, 2007) consider the Arabic dialects in the Arabian Gulf to be similar and have coined the term ‘the Gulf Arabian dialect’ to group them into one dialect. Similarly, Versteegh (2001) grouped the dialects of the Arabian Peninsula under one umbrella as well as according to Ingham (1982) and Palva (1991) as cited in Versteegh (2001) grouped both dialect under the category of North East Arabian dialects. Moreover, Holes (1987) commented that the two Arabic dialects (Najdi and BA) share more similarities in their realizations and spoken Arabic characteristics. In addition, Bellem (2008) commented that the dialects in this region can be considered to be of Bedouin origin amongst others. Therefore, with regards to the differences between the dialects, the general hypothesis is that there will be no differences between the Najdi Saudi dialect and the BA dialect. On sex differences, a general hypothesis has not been offered due to the different properties for the speech parameters. Therefore, the detailed hypothesis for dialect and sex will be discussed for each parameter in their subsequent chapters as followed: for DDK in §4.3.3.2, for VOT in §5.6.3.2, for F0 in §6.5.2 and finally for formant frequencies in §7.4.2.

In order to assess the speech characteristics of Najdi and Bahraini speakers to establish normative data for the two dialects for speech and language pathologists, and to answer the two main questions, stimuli compiled from syllables, words and sentence were employed for the different measures (DDK, VOT, F0 and formant frequencies) is presented in the next chapter §3.3.3.

2.5 Summary

In this chapter, a review of the spoken form of Arabic was presented as the MSA inventory. Furthermore, a review of the two Arabic dialects (Riyadh Najdi Saudi and Bahraini Arabs) understudy in this thesis was explored, finally presenting a general hypothesis of differences between the Arabic dialects where it is anticipated that no differences will be observed between the Najdi Saudi and Bahraini Bahraini Arabic dialects.

Chapter 3. General Methodology

3.1 Introduction

This chapter will describe the participants as well as the procedures for data recording, data labelling and data transfer employed in the study. A detailed account of the acoustic data analysis will be given in the relevant chapters regarding the parameters selected for investigation in this study (DDK ~ chapter 4, VOT ~ chapter 5, F0 ~ chapter 6 and formant frequencies ~ chapter 7) as well as the stimuli used for the respective parameters. The data will be used in order to explore the differences between speech characteristics in two Arabic dialects: Riaydh Najdi Saudi (spoken in the central region of Saudi Arabia) and Bahraini (primarily spoken by Bahraini Arabs in the islands of the Kingdom of Bahrain). In addition, it will also be used to explore differences between male and female speakers in the Arabic dialects investigated in this study.

3.2 Ethics and recruitment of participants

This study was approved by the University Research Ethics Committee at the University of Sheffield (see Appendix 3.1). The participants in this study were volunteers who responded to a bulletin letter (see Appendix 3.2) that was circulated via e-mail to contacts in hospitals and universities in Riyadh, Saudi Arabia, and Manama, Bahrain. The volunteers contacted the researcher by either phone or e-mail and meetings were arranged to take place in clinics or university rooms.

3.2.1 Participants

In order for the participants to be selected, they had to fulfil specific health and dialect criteria. The initial group of volunteers was composed of 87 participants, but 6 were excluded, as audio files were lost during data transfer and 1 is relevant to health status which will be described later in §3.2.3.1. The final group of 80 participants consisted of 40 males and 40 females: 20 males and 20 females representing the Najdi dialect and 20 males and 20 females representing the Bahraini dialect. The participants ranged in age from 22 to 35 years old; the mean age and standard deviation of each group of participants is shown in Table 3.1.

Sex	Dialect	Number of participants	Mean age	Standard deviation
Male	Saudi	20	27.45	3.98
	Bahraini	20	25.96	3.75
	Total	40	26.70	3.89
Female	Saudi	20	26.39	3.66
	Bahraini	20	27.71	3.51
	Total	40	27.05	3.60
Total	Saudi	40	26.92	3.81
	Bahraini	40	26.83	3.69
	Total	80	26.88	3.73

Table 3.1 Mean age (years) and standard deviation for 20 male and 20 female participants from the Bahraini and Najdi Arabic dialects.

3.2.2 Age analysis

In order to ascertain whether there were age differences between the four groups of participants in this study (Saudi males and females, Bahraini males and females), each group was assigned a group number and a one-way ANOVA was conducted to compare the ages of participants in the four groups. The results showed no significant differences between the four groups ($F(3,76) = 1.008$, $p = 0.394$).

3.2.3 Inclusion criteria

3.2.3.1 Health status

All participants self-identified as having no current or previous symptoms of voice, speech or fluency difficulties; this was confirmed by the researcher through informal observation and initial discussion prior to the start of data collection. Participants had not undertaken any professional speech or voice training. All participants in the study identified themselves as non-smokers. Participants did not self-report hearing loss or a history of ear infections, which may have an impact on auditory acuity or self-monitoring. To confirm auditory acuity, all participants were subjected to the whisper test, which Pirozzo et al. (2003) have identified as a credible screen for auditory competence in adults. All subjects were in good health and showed no signs or symptoms of voice-related problems such as allergic rhinitis, upper respiratory problems or a cold, which could have influenced the recording of the data except for one participant which later said that she had the flu a couple of days earlier.

3.2.3.2 Dialect

Participants in this study were from two different dialects; all participants identified themselves as speakers of their respective dialect, either the Riaydh Najdi dialect (spoken in central Saudi Arabia) or the Bahraini Arabs dialect (spoken in Bahrain). The author is proficient in Arabic dialects and is aware of spoken variation within the dialects of Arabia; he therefore monitored the speech of all Najdi participants to confirm their dialects. Furthermore, the author of this thesis diaelct is the Riaydh Najdi dialect. For the Bahraini dialect, participants from Bahrain self-identified themselves as Bahraini dialect speakers. However, to confirm the validity of the participants' self-identifications, two colleagues from Bahrain that spoke the Bahraini Arabs dialect and the Bahraini Bahrani (Shi'a) dialect were requested to judge the participants' dialects. Based on both colleagues confirmation, these participants were included in the study. In addition, one of these colleagues' was present at the time of recoding to ensure that participants spoke in their dialect.

3.2.3.3 Socioeconomic status and sociolinguistic homogeneity of participants

All participants in the study responded to a questionnaire (see Appendix 3.4). Two criteria were assessed from the questionnaire, level of education and occupation, in order to ascertain the socioeconomic status of the participants.

As observed in Table 3.2, the educational level of the majority of participants was more representative of a graduate level with the exception of one participant who will be described below in relation to his occupation. Participants' occupations for both sexes and dialects were examined and this revealed that the majority were either from the health sector (including administrative and medical health staff) or were from the governmental sector, ranging from teachers to administrative staff. The only participant that deviated from this was working in a company which is owned by his family. This single participant was a Saudi male participant who had described his level of education as a high school graduate (see Table 3.2). However, this participant's description of his role in the company was that of a top executive and one of his roles is that of an authorised representative of the company for legal matters in court. The language skills required to perform in court suggests that he has a high level of language competence that is equal to that of the other participants.

Dialect	Sex	N	High School	Diploma	Graduate	Post-Graduate
Saudi	Male	20	1	0	15	4
	Female	20	0	1	14	5
	Total	40	1	1	29	9
Bahraini	Male	20	0	4	13	3
	Female	20	0	0	16	4
	Total	40	0	4	29	7
	Total	80	1	5	58	16

Table 3.2 Level of education for male and female Riyadh Najdi Saudi and Bahraini Arab (Sunni) speakers.

The description above for the participants in this study might be described as being reflective of educated fully employed, middle- to upper-class male and female Riyadh Najdi Saudi and Bahraini Arab (Sunni) speakers. This further suggests a high level of consistency and homogeneity amongst the participants.

3.3 Procedure

Upon meeting the study volunteers, the researcher provided them with an information sheet about the study (see Appendix 3.3), and they were given time to ask questions. In addition, the researcher also described the procedure verbally in order to help them feel at ease, since the object of the study was to record their dialect.

Following their initial acceptance, the volunteers who felt they were generally healthy were asked to participate in the study. Further verification of their health status was evaluated by a questionnaire they were asked to complete (see Appendix 3.4), and volunteers were excluded if they had been ill recently. If they fulfilled the criteria for the study (7 were excluded), participants were asked to sign a consent form to confirm their agreement to join the study (see Appendix 3.5). All forms were translated to Arabic.

As described in §3.3, participants identified themselves as speakers of their Arabic dialects (Riaydh Najdi and Bahraini Arab), in addition to the researcher's confirmation for the Najdi dialect and his colleagues confirmation for the Bahraini dialect.

3.3.1 Audio recording

Speech samples were recorded in a room with a low ambient noise level on a high quality digital audio recorder (Olympus DS-40) connected to a microphone (ME53S). The microphone was situated at a relatively constant 20 cm from each participant's mouth. The sampling rate of the recordings was 44 KHz with a 32-bit resolution, and the recordings were stored internally on the digital audio recorder in WMA format. It is acknowledged that the researcher was unaware of the ability of the digital audio recorder to store the recordings to WAV format as this has been shown to affect the quality of recording (Schilling, 2013, p. 235).

Participants were recorded sitting comfortably in a chair either in a quiet clinic room or in the home of the researcher if participants were unable to be recorded during their working hours while in Saudi Arabia. However, in Bahrain, participants were recorded in meeting rooms, offices, clinics, and at the researcher's residence. Furthermore, as described earlier, one of two colleuages was present during the time of reacrding for the Bahraini Arab speakers in the study.

3.3.2 Instructions

Before recording commenced, the researcher spoke informally with the participants for a couple of minutes, as mentioned earlier, in order to help them feel at ease. They were asked to describe their profession or their interests or even current events. Data were collected from speakers in their respective Arabic dialects.

The meeting duration for each participant ranged from 35 to 60 minutes, depending on their progress with stimuli. However, the recording duration for most participants was between 25 and 30 minutes. Participants were told to request breaks if they felt tired and were offered water throughout the session.

3.3.3 Stimuli and speech parameters (DDK, VOT, F0 and formant frequencies)

The stimuli used in the analysis for this thesis were selected from a larger stimuli list (available in Appendix 3.6); only the selected stimuli used for analysis of DDK, VOT, F0 and formant frequencies in this study will be discussed. All participants in this study produced the stimuli as presented in the stimuli list. In this thesis, the stimuli will be presented in accordance with the structure of the thesis rather than in the order presented in the stimuli list. Table 3.3 presents information on the stimuli employed in this study and shared between the selected parameters, together with chapter numbers for the analysis of each parameter. All stimuli were written in Arabic.

3.3.3.1 Syllables

The monosyllables (/ba/, /da, /ga/) and the multisyllabic sequence /badaga/ were selected for the analysis of the DDK. Relevant information on stimuli design and analysis will be discussed in Chapter 4, as seen in Table 3.3.

3.3.3.2 Sustained phonation

The researcher demonstrated the production of sustained vowel by taking a slight deep breath then producing the vowel in a sustained manner for longer than 20 seconds in the most comfortable manner. Each participant in the study were then asked to replicate their production of the vowels /a, i, u/ for more than 20 seconds as comfortably as possible similar to the searchers production. As seen in Table 3.3, this will be used in the analysis of F0 in

Chapter 6 and in the analysis of formant frequencies in Chapter 7. Acoustic analysis procedures differ depending on the parameter studied; therefore, relevant information on acoustic analysis is presented in the relevant chapters.

3.3.3.3 Words

Two lists were generated from 80 target words and 20 word fillers. Randomly selected word fillers were assigned to five words at the beginning and end of each list. The target words had different initial consonants (plosives, fricatives and emphatic fricatives, and plosives) with a different word structure as well as different vowels. An additional six words were generated from the target words as realisations of /q/ and /$d^{ʕ}$/ from the words selected. The target words were randomly placed in the two lists. From these two word lists, an additional two lists were generated randomly in order to elicit a second repetition of the target words. The first and second word lists are available in Appendix 3.7 (lists (a) and (b)).

Stimuli type	Syllables		Sustained phonation	Words				Sentences	
	monosyllables	**multisyllabic**		**Voiced**	**Voiceless**	**Emphatic/plain**	**Voiced/voiceless**		
Stimuli / **Target analysis**	/ba,da,ga/	/badaga/	**/a, i, u/**	/b,d/	/t,k/	/tˤ,t/	/d ,t/	Reading	Quran
				/a ,i, u/	/i,u/	/i, u/	/i, u/		
DDK **Chapter (4)**	Yes	Yes	No	No	No	No	No	No	No
VOT **Chapter (5)**	No	No	No	Yes	Yes	Yes	Yes	No	No
F0 **Chapter (6)**	No	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes
F1-F3 **Chapter (7)**	No	No	Yes	Yes	Yes	Yes	No	No	No

Table 3.3 Highlighted stimuli (syllables, sustained phonation, words and sentences) corresponding to the parameters (DDK, VOT, F0, formant frequencies) employed in the analysis. (Note: Word stimuli show the target consonant and target vowels for analysis).

Only 12 words were selected for analysis in this thesis from the 86 words. As observed in Table 3.4, the initial consonant was interchangeable between voiced bilabial /b/ and alveolar /d/, voiceless alveolar /t/ and velar /k/ and the emphatic /tˤ/ plosives, while the medial vowel was interchangeable between three long vowels (/a:/, /i:/, /u:/) for the voiced plosives and only two long vowels (/i:/, /u:/) for the remaining plosives. Eight words were in list (a) and the remaining four were in list (b); participants repeated their production of the words by reading two additional lists generated from list (a) and (b). Participants were instructed to produce each word and then stop briefly before proceeding to the next word. They were further instructed to repeat the word if they pronounced it incorrectly, and, if they were unaware of the mispronunciation, the researcher would point to the word for repetition. After each word list, participants were allowed to rest before proceeding to the next list.

The words in Table 3.4 were used to elicit data for the analysis of VOT (see Chapter 5), F0 (Chapter 6), and formant frequencies (Chapter 7). Acoustic analysis procedures differ depending on the parameter studied; therefore, relevant information to acoustic analysis is presented in the following chapters.

It is acknowledged that there are limitations on the data set analysed in this study which can be observed in Table 3.3 and Table 3.4. Firstly, only two tokens of /a:/ are present for the voiced stops /b, d/ , while it is absent for the voiceless stops /t , k/ and empathic stops /tˤ/. In addition, /g/ was not present in the data set.

Target initial consonant	Target word	Gloss	Target word	Gloss	Target word	Gloss
Bilabial Vd	/ba:r/	To perish	/bi:r/	Well	/bu:r/	Wild
Alveolar Vd	/da:r/	House	/di:r/	Covenant	/du:r/	Role
Alveolar Vl	NA		/ti:r/	Wooden corner in carpentry	/tu:r/	Cup for drinking water
Velar Vl	NS		/ki:r/	Bellows	/ku:r/	Core
Emphatic alveolar Vl	NS		/tˤi:r/	To fly	/tˤu:r/	Incubate

Table 3.4 Words selected for analysis in this thesis with gloss. In words with an initial consonant, the initial consonant was interchangeable between voiced bilabial /b/ and alveolar /d/, voiceless alveolar /t/ and velar /k/ and the emphatic /tˤ/ plosives, while the medial vowel was interchangeable between three long vowels (/a:/, /i:/, /u:/) for the voiced plosives and only the long vowels (/i:/, /u:/) for the remaining plosives. (Note: Vd=voiced, Vl=voiceless, NA=Not available and NS= Not Selected.)

3.3.3.4 Passages

Participants were instructed to read two passages. The first was 'The North Wind and the Sun', Arabic version (International Phonetic Association, 2004, pp. 53–54) (the translation and transcript are available in Appendix 3.8). The second was the first Sura (chapter) from the Holy Quran, which is called Al-Fatihah ("opening"; the translation and transcript are available in Appendix 3.9). These were read twice by each participant. As seen in Table 3.3, only Chapter 6 on F0 utilises the two passages in the analysis; further information related to acoustic analysis is available in §6.6.2.2.

3.4 Transferring and editing sound files, and preparation for acoustic analysis

3.4.1 Transferring sound files

All of the data elicited from participants from Bahrain and Saudi Arabia were in the form of sound files that were saved on internal storage in the digital audio recorder (DAR) (Olympus DS-40). The sound files were then transferred via USB cable to a computer (Intel® Core i3, CPU 2.53 GHz and 4GB RAM).

All of the files were then allocated to a corresponding folder labelled with the participant's dialect, sex and their allocated number which labelled their questionnaire. The following format, DS--, was used for annotating participants' respective folders, where D represents dialect and S represents sex. The participants' file numbers on the DAR as well as their voices were employed in identifying each participant by the researcher.

3.4.2 Editing sound files

All sound files were saved in WMA format; however, since the means for analysis of this research was the Praat program (Boersma & Weenink, 2013), Windows version, it was necessary to change the format to WAV format. The reasons for using the Praat program will be elaborated on in section 3.5.

For the first two participants in the study, the pause button on the DAR was not used to separate the stimuli between tasks. Therefore, the Audacity program (Audacity Team, 2012) was used to separate their audio files, which were then placed in the participants' folders.

As there were approximately 19 sound files for each participant, the researcher made use of a WMA MP3 converter (Hoo Technologies, 2007), and all sound files were converted to WAV format with a sampling rate of 44 KHz and were saved in the original folder.

3.4.3 Preparation for acoustic analysis

Each participant had a folder containing the WAV files used for analysis. The Praat program (Boersma & Weenink, 2013) was used in the analysis of all the parameters for all participants. A script (see Appendix 3.10) written by Kevin Ryan (2005) was modified and used to extract sound files in WAV format from the folder. The program then opened a text grid corresponding to the WAV information for the selected parameter analysed and closed after the marking was completed. It then opened the next file within the same folder for marking, and so on. The annotation precodue for each paprameter will be elaborated in subsequent chapters.

3.4.3.1 DDK

All audio files pertaining to each participant were stored in their data folders, including the DDK files. These files were identified by annotations in the form DS--, as previously described in §3.3.3.1. The DDK tasks were then identified by the syllables used, and were labelled as DS – D-, where the following numbers identified the syllables under analysis: 1 = /ba/, 2 = /da/, 3 = /ga/ and 4 = /badaga/ (e.g. SM13D4 for the Saudi male participant 13 production of /badaga/).

3.4.3.2 Sustained phonation

The sustained phonation audio files were used in the analysis of F0 and formant frequencies, as previously described in §3.3.3.2. Each participant's sustained phonation samples were identified by the letter ‘p’, indicating the sustained phonation task, and were labelled as DS – p-, where the following number corresponded to the vowel under analysis (e.g. SF1p1 for Saudi female participant 1 vowel /a/, while 2 and 3 would be /i/ and /u/ respectively).

3.4.3.3 Words

The word list audio files were used in the analysis of VOT, F0 and formant frequency. Each participant’s files were identified by annotations in the form DS--, as previously described in §3.3.3.3. The word lists were then identified by list number and were labelled as DS – W-, where the following number corresponded to which list of the four was used for analysis (e.g. BM7W4 for Bahraini Arab male participant 7 prodcution in word list 4).

3.4.3.4 Passages

The reading passage audio files were used in the analysis of F0. Each participant’s files were identified by annotations in the form DS --, as previously described in §3.3.3.4. The sentences were identified by the letter ‘R’, indicating sentence from the Arabic version of ‘The North Wind and the Sun’ was used in the task. Sentences from the Quran were identified by the letter ‘Q’. Following the letter, a number would correspond to the number of repetition produced by the participants as there were two repetitions for each passage (e.g. BF20Q2 for Bahraini female participant 20 second production of the Quran).

3.5 Choice of Praat (Boersma & Weenink, 2013)

The main reason for using Praat (Boersma & Weenink, 2013) for acoustic analysis in this research was because it is a free public tool, unlike alternative programs that are quite expensive, such as Kay Elemetrics Computerized Speech Lab (CSL), the Multi-Dimensional Voice Program (MDVP) and Visipitch from KayPENTAX.

From the literature, it appears that Praat has experienced a growth in users from the field of phonetics, as well as speech and language pathologists and those interested in studying vocal registers.

Furthermore, the choice of analysis and script writing are undertaken manually by researchers using Praat. They have additional support from the authors, Paul Boersma and David Weenik, as they update it based on users' experiences and queries. In addition to the above, the researcher has previous experience in using Praat to take acoustic measurements, having used the software in research for his unpublished master's dissertation (Alshahwan, 2008).

3.6 Summary

This chapter reviewed the methodological procedures related to participant selection and recruitment for participants from each dialect (Saudi Najdi and Bahraini Bahraini) from both sexes in order to explore dialect and sex. In addition, stimuli employed in the study were discussed in relation to the parameters (DDK, VOT, F0 and formant frequencies) that are the focus of the study. In addition, the data preparation for the acoustic analysis procedures adopted in the following chapters were presented.

Chapter 4. Diadochokinetic Rate (DDK)

4.1 Introduction

This chapter is a part of a series of analyses of parameters that will establish normative data for clinic and to examine whether dialect differences are present for Arabic speakers of two dialects (Najdi and Bahraini), and whether sex differences are present for the first temporal measure: Diadochokinetic rate (DDK).

Diadochokinesia can be defined as a series of rapid alternating and repetitive bodily movements. Fletcher (1972, 1978) gives examples such as movements of the jaw and lips while opening and closing the mouth, in addition to lowering and raising the eyebrows, the tapping of fingers, pronation and supination of the hand, and side-to-side movements of the tongue. However, in the context of this thesis, the DDK rate can be defined as a phonoarticulatory speech task where a monosyllable (e.g. /pa/, /ta/, /ka/) or multisyllabic sequence (e.g. /pataka/) is repeated as quickly as possible in a clear manner by an individual (Kent et al., 1987; McClean, 2000; Ziegler, 2002).

DDK tasks have been employed in motor speech assessment, where they are used to assess the integrity of neurological structures involved in speech (Blomquist, 1950; Lundeen, 1950; St Louis & Ruscello, 1981; Kent et al., 1987; Modolo et al., 2011). In addition, they assess the ability to coordinate respiratory, articulatory, and laryngeal behaviours (Portnoy & Aronson, 1982; Padovani et al., 2009; Skodda et al., 2010). The DDK rate is often used by speech and language pathologists in their assessment of motor speech disorders and voice disorders (Maassen et al., 1991; Williams & Stackhouse, 2000; Rosen et al., 2005; Gadesmann & Miller, 2008) as well as other health professionals.

Icht and Ben-David (2014) acknowledged that in order to be able to measure DDK rates in clinics, a set of validated norms should be established in order to conduct comparisons within a language. Normative data for the DDK in Arabic have not been established until now, to the knowledge of the researcher. Therefore, one of the tasks in this chapter is to establish normative data for Arabic speakers in two dialects (Najdi and Bahraini) and to explore whether dialectal differences exist in DDK tasks. Furthermore, it will assess whether sex-related linguistic differences are evident as well as showing differences between the DDK stimuli.

The chapter is structured as follows. First, it presents a general section on the effects of age on DDK rates followed by a review of studies on DDK rates in English and other languages. The procedural differences concerning the stimuli and method of elicitation in these studies are also reviewed. The research questions are addressed, and the methodology is described. Subsequently, the results and discussion are presented.

4.2 General

DDK rates in the literature can and are interchangeably described by the terms Alternate Motion Rates (AMR) and Sequencing Motor Rates (SMR). AMR is defined as the rapid repetition of single syllables such as /pa/, /ta/, /ka/, while SMR is defined as the rapid repetition of a syllable sequence such as /pataka/, as used by Kent et al. (1987).

DDK rate is used to assess the integrity of neurological structures and the ability to coordinate respiratory, articulatory, and laryngeal behaviours, as previously described. Therefore, it should be expected for children's DDK rates to be lower than those exhibited in adults (Mason et al., 1977; Netsell, 1986; Kent et al., 1987; Cohen et al., 1998; Williams & Stackhouse, 2000). In contrast, as age advances and in late adulthood, deceleration and reduction of articulatory movements will lower DDK rates (Shanks, 1970; Kreul, 1972; Amerman & Parnell, 1982; Cheng et al., 2007; Padovani et al., 2009; Neel & Palmer, 2012). Consequently, young adults are expected to have more accurate and consistent DDK production than children and older adults, and are expected to reflect the normative production of DDK rates.

The DDK rate is often obtained by variations of two methods in general. Furthermore, there are two additional methods for obtaining DDK rate for the mulitysyllabic sequence. The first method could be described as the traditional approach. In this method, the number of syllables are counted over a specific period of time (e.g. Lundeen, 1950; Prins, 1962). A time limit is established (e.g. 7 seconds for Lundeen, 1950 and Ptacek et al., 1966) for each DDK rate assessment, as well as the number of syllables to be counted in the time allotted for the task. In addition, it is assessed by using a stopwatch while counting the number of repetitions. As attention would be divided between monitoring the time and counting syllables, the validity of this approach consequently decreases. Variations of this approach can be found; for example, Kreul (1972) selected repetitions over a period of 2 seconds while Ptacek et al. (1966) selected repetitions over a period of 5 seconds. These differences often make it difficult to draw comparisons between studies.

The second approach is known as the "time-by-count method" (Fletcher, 1972, 1978), where the focus of the researcher is on counting the syllables and starting the stopwatch at the beginning, and stopping it as soon as the chosen number of syllables are obtained. With advances in technology, this method is used more often for obtaining DDK rates, though with some modifications which will be discussed in the following section. When collecting DDK repetitions, the focus is mainly on recording the production, which is saved for later analysis. Nonetheless, differences can be found in the number of repetitions selected for DDK syllables. For example, 16 continuous monosyllable repetitions were selected by St. Louis and Ruscello (1987), while Fletcher (1972, 1978) selected 20 continuous monosyllable repetitions for analysis of DDK rates. The use of these variations to obtain the DDK rate often complicates the generalizability of the results and the ability to compare studies. Therefore, there is a need to use a uniform method to obtain the DDK rate.

Two approaches for the multisyllabic sequence, Louzada et al. (2011) selected /pataka/ as one multisyllabic sequence and acquired DDK rate for the number of the multisyllabic sequence in one second. In contrast, majority of the studies in Table 4.1, measured DDK rate for the multisyllabic sequences as syllable rates produced in 1 second regardless of the different syllables. For example, Icht and Ben-David (2014) performed an analysis on multisyllabic /pataka/ for Hebrew over a period of 10 seconds; the results were then multiplied by 0.3 in case of a sequence not being completed. The DDK rate was calculated manually from the recordings for syllables per 1 second. This further demonstrates the lack of consistency in reporting DDK rates.

On the other hand, there is more agreement regarding the stimuli used to obtain the DDK rate, with the monosyllables /pə/, /tə/, /kə/, or their voiced counterparts, /bə/, /də/, /gə/, being analysed (Lundeen, 1950; Sigurd, 1973; Kent et al., 1987). Furthermore, the most common multisyllabic sequence is /pətəkə/ (Kent et al., 1987).

Cohen et al. (1998) drew attention to stimuli design, specifically when comparing two dialects, giving the example of the /pətəkə/ sequence in American English and British English. They postulated that this sequence will often have different repetition rates since articulatory behaviour in the second transition to the second consonant would cause such an effect (Cohen et al., 1998). A number of studies (Crary, 1993; Williams & Stackhouse, 2000) suggested that the use of appropriate stimuli for monosyllables and multisyllabic sequences, depending on the language and dialect being tested, is essential for the validity of the results.

4.3 Normative DDK rate in English and other languages

In this section, a number of studies on English will be reviewed, followed by a review of studies on different languages. Table 4.1 shows the normative DDK rate for the number of syllables produced per 1 second for monosyllables and multisyllables in the studies under review.

Study	Language	Sex (number)	Consonants vowels¹	/CV/	/CV/	/CV/	/CVCVCV/
Lundeen (1950)	English (American)	M (20) F (20)	/p, t, k/ /ə/	7.0	7.1	6.2	-
			/b, d, g/ /ə/	7.0	7.2	6.3	-
Ptacek et al. (1966)	English (American)	M (28)	/p, t, k/ /ʌ/ /pʌtʌkʌ/	7.0	6.9	6.2	5.8
		F (31)		6.9	6.8	6.2	6.3
Kreul (1972)	English (American)	M (20)	/p, t, k/ /ʌ/	6.0	6.0	5.4	
		F (25)		5.3	5.8	5.2	
Amerman & Parnell (1982)*	English (American)	M (10)	/p, t, k/ /ʌ/	6.6	6.6	6.1	
		F (10)		6.7	6.6	6.3	
Deliyski & DeLassus Gress (1997)*	English (American)	M (50)	/pʌ/	6.0	-	-	
		F (50		5.8	-	-	
Topbaş et al. (2012)*	English (American)	M (12)	/pʌ / /pʌtəkə/	5.6	-	-	6.1
		F (12)		5.3	-	-	6.3
Neel & Palmer (2012)*	English (American)	M (16)	/p, t, k/ /ʌ/ /pʌtəkə/	6.4	6.7	6.0	6.6
		F (12)		6.6	6.6	6.1	7.6
Hongzhi et al. (2010)*	English (American)	M (50)	/pa/	5.9			
		F (50)		5.8			
	Chinese (Mandarin)	M (50)		4.1			
		F (50)		5.3			
Padovani et al. (2009)*	Portuguese (Brazilian)	M (9) F (14)	/p, t, k/ /a/ /pataka/	6.7	6.7	6.0	6.6
Louzada et al. (2011)*	Portuguese (Brazilian)	F (30)	/p, t, k/ /a/ /pataka/	5.9	6.0	5.5	2.3**
Breitbach-Snowdon (2003)	German	-	/p, t, k/ /a/ /pataka/	6.0	5.0	4.5	5.0
Icht & Ben-David (2014)	Hebrew	M (53)	/pataka/	-	-	-	6.4
		F (62)		-	-	-	6.3

Table 4.1 Normative DDK rates (syllables/1 second) for monosyllables and multisyllables in the English language (Lundeen, 1950; Ptacek et al., 1966; Kreul, 1972; Amerman & Parnell, 1982; Deliyski & DeLassus Gress, 1997; Yu Hongzhi et al., 2010; Topbaş et al., 2012; Neel & Palmer, 2012), Mandarin Chinese (Yu Hongzhi et al., 2010), Portuguese (Padovani et al., 2009; Louzada et al., 2011), German (Breitbach-Snowdon, 2003) and Hebrew (Icht & Ben-David, 2014).[1] CV used in monosyllables is a combination of the consonants and vowels displayed in the column, * denotes the DDK rates were rounded to one decimal point to match the remaining studie, ** denotes DDK rate was measeured for the full triad per 1 second.

4.3.1 Normative DDK rates in English

In an early study on DDK rates in English, Lundeen (1950) established normative data for different monosyllables. As can be seen in Table 4.1, he firstly compared voiceless /pə, tə, kə/ and voiced /bə, də, gə/, in addition to other phonemes beyond the scope of this study. Lundeen (1950) recorded an audio sample of 7 seconds, excluding the first and last second from the count; the mean repetitions were calculated from the remaining 5 seconds. As one of the few studies that included voiced monosyllables, the results showed no differences between voiced and voiceless monosyllables. Moreover, velars were consistently shown to have the lowest DDK rate (syllables per second) amongst the monosyllables. Furthermore, alveolars were shown to have slightly higher DDK rates than the remaining places of articulation. Although the results were averaged between males and females in Table 4.1, males showed higher rates than females, in contrary to the belief that females speak faster than males (Lundeen, 1950).

Using a similar methodology, Ptacek et al. (1966) reported the results for the same voiceless consonants /p, t, k/ with a different vowel, /ʌ/, in addition to the monosyllabic /pʌtʌkʌ/, as can be seen in Table 4.1. Ptacek et al. (1966) reported similar results to the averaged results from Lundeen (1950); however, sex differences were not apparent for the monosyllables. In contrast, although not statistically tested in the study, the multisyllabic sequences showed that females displayed higher DDK rates than males.

In a different method of analysis, utilizing the same stimuli as Ptacek et al. (1966) for monosyllables only, Kreul (1972) calculated the DDK rate to the nearest half produced in a 2 second sample. The results displayed in Table 4.1 confirm that /kʌ/ had the lowest DDK rate amongst monosyllables. Furthermore, females displayed lower DDK rates than males for /pʌ/ while there were similar DDK rates between sexes for the remaining monosyllables. As indicated by the authors (p.77), that the difference between males and females were small, not indicating whether it was preformed statistically.

Amerman and Parnell (1982) used the methodology adopted by Fletcher (1972, 1978) where measurements were acquired from a wide-band spectrogram and relative speech amplitude trace for 20 repetitions of the monosyllables /pʌ, tʌ, kʌ/. Similar to the above studies, the results displayed in Table 4.1 showed that /kʌ/ had the lowest DDK rate amongst monosyllables, although no statistical assessments were offered. Furthermore, sex differences were not apparent in the monosyllablic data.

Employing /pʌ/ in their analysis, Deliyski and DeLassus Gress (1997) used automatic analysis in the Motor Speech Profile (MSP) software, Model 4300B (Kay Elemtrics, Lincoln Park, N.J., USA) where the DDK rate was measured by averaging the syllable peaks counted from the 8 second sample. The results displayed in Table 4.1 showed that females had slightly lower DDK rates than males which were not statistically significant. The restriction of their analysis to /pʌ/ limits the generalizability of the results. However, it is a move forward to employ computerized analysis in a clinical setting. A similar study using the same method of analysis was conducted by Hongzhi et al. (2010) on American English /pa/ where the results showed similar rates for males to Deliyski & DeLassus Gress's (1997) study, as seen in Table 4.1. However, there were no differences in monosyllable DDK rates between male and female speakers.

In a more recent study, Topbaş et al. (2012) employed /pʌ/ and /pʌtəkə/ as stimuli over a period of more than 10 seconds; the first and the last second of audio were excluded from analysis where the mid 6 consecutive repetitions of the stimuli were identified. The repetition rate was estimated by dividing 6 by the time taken for the repetition of the task. The results displayed in Table 4.1 show that /pʌ/ had a slightly lower rate than the multisyllabic sequences, although not statistically different.

Furthermore, females had lower rates than males for the monosyllables while the multisyllabic sequence showed no differences between male and female speakers. However, both were not statistically different.

Neel and Palmer (2012) performed a study on the monosyllables /pʌ, tʌ, kʌ/ and the multisyllabic /pʌtəkə/ on 5 seconds of audio from the middle portion of the syllable. The DDK rate was measured by counting the peaks that were then averaged over the 5 second period. The results displayed in Table 4.1 also confirm that velars have the lowest DDK rate amongst the monosyllables, although not statistically tested. Sex differences were not observed in relation to the monosyllable DDK rates; however, females were shown to have statistically higher DDK rates than males for the multisyllabic sequences. One of the drawbacks from the study was that the authors did not specify the duration of time that had been excluded from the start or the end of the iteration by the participants.

Comparing the results from the studies on English in Table 4.1 shows that there is variation between the studies on DDK rates in monosyllables and multisyllabic sequences, where a few studies showed similarities in the rates obtained (Lundeen, 1950; Ptacek et al., 1966). However, other studies (Kreul, 1972; Amerman & Parnell, 1982; Deliyski & DeLassus Gress, 1997; Neel & Palmer, 2012; Topbaş et al., 2012) showed lower rates than those in observed in Lundeen (1950) and Ptacek et al. (1966). This is agreement with Cohen et al. (1998), who commented that differences observed in studies on DDK rates in English might be attributed to dialectal differences. Moreover, the lack of consistency in the methodologies concerning the stimuli and methods of analysis seems another plausible cause for the lack of consensus between results. Furthermore, there is more of an agreement regarding the minimal sex-related DDK differences found in the majority of studies (Ptacek et al., 1966; Kreul, 1972; Amerman & Parnell, 1982; Hongzhi et al., 2010; Neel & Palmer, 2012; Topbaş et al., 2012) that are dependent on stimuli.

4.3.2 Normative DDK rates in different languages

A few studies have focused on DDK rates in different languages such as Chinese Mandarin (Yu Hongzhi et al., 2010), Portuguese (Padovani et al., 2009; Louzada et al., 2011), German (Breitbach-Snowdon, 2003) and Hebrew (Icht & Ben-David, 2014) (see Table 4.1).

Chinese Mandarin was investigated by Hongzhi et al. (2010). The results seen in Table 4.1 show cross-linguistic differences between Chinese Mandarin and American English (AE) in their study, where DDK rates were statistically lower for /pa/ in Chinese Mandarin than AE. The authors indicated that DDK rate standard deviation is indicative of lower co-articulation ability and lack of flexibility which might be the reason Chinese (28.06 ms) showed less DDK rates than AE (9.30 ms). Furthermore, male Chinese Mandarin speakers had lower rates than females by more than 1.2 syllables per second; however, this was not statistically tested.

In Brazilian Portuguese, Padovani et al. (2009) conducted a study on the monosyllables /pa, ta, ka/ and the multisyllabic /pataka/; the results shown in Table 4.1 showed agreement with the velar context displaying the lowest DDK rates. The authors commented that /pa/ had higher rates due to the involvement of only the orbicular muscle in the production of /pa/ while tongue tip and laryngeal movement is involved in the production of the other phonemes. Furthermore, sex differences were not examined in the study as the results were pooled from both sexes.

In another study on Brazilian Portuguese, Louzada et al. (2011) performed an analysis on only female data for /pa, ta, ka/ and multisyllabic /pataka/. The results shown in Table 4.1 showed a similar finding in terms of the relationship between the DDK rate and the place of articulation of the phonemes for the monosyllables. However, the results for /pataka/ showed nearly half the production rate seen in monosyllables. This is expceted as described in §4.2, the analysis method for the multisyllabic sequence for these two studies were different, therefore it is clear comparison should not be made. Differences were observed between the two studies, where the DDK rates obtained in Louzada et al.'s (2011) monosyllable results and more so for /pataka/ were lower than those of Padovani et al. (2009). Although a comparison has been made between the two Brazilian Portuguese studies, the methodologies were different: Padovani et al.'s (2009) study employed 8 seconds of analysis whereas Louzada et al. (2011) excluded the first and last seconds of analysis as well performing the analysis on the multisyllabic sequences manually. Furthermore, the data from Padovani et al.'s study (2009) merged results from both sexes , therefore, no comparisons can be made between the two studies.

On German data, Breitbach-Snowdon (2003) analysed /pa, ta, ka/ and /pataka/ using a stopwatch where the DDK rate was calculated by dividing the number of syllables uttered by the time taken. The results displayed in Table 4.1 confirm that amongst the monosyllables, velars continued to a tendency to have lower rates, although no statistical tested were provided. The drawback from this study was the merging between male and female DDK rates, similar to Padovani et al.'s (2009) study on Brazilian Portuguese.

For Hebrew, Icht and Ben-David (2014) performed an analysis on multisyllabic /pataka/ data over a period of 10 seconds; the results were then multiplied by 0.3 in case of a sequence not being completed. The DDK rate was calculated manually from the recordings. The results displayed in Table 4.1 showed no statistical differences between sexes. The authors found no differences between Hebrew and English norms for the multisyllabic sequences.

To summarize, there seem to be differences in the DDK rates amongst American English studies (§ 4.3.1); however, due to the lack of uniformity in the stimuli and analysis methods used, it is difficult to draw conclusions. For example, Cohen et al. (1998) implied that dialect variations play a role. Furthermore, this can be seen in Brazilian Portuguese (see §4.3.2), although method of analysis for the multisyllabic sequences was different. Other languages have established DDK normative rates as seen in §4.3.2. Furthermore, there is more agreement on the minimal DDK rate differences between male and female speakers in the majority of the studies on English (Ptacek et al., 1966; Kreul, 1972; Amerman & Parnell, 1982; Yu Hongzhi et al., 2010; Topbaş et al., 2012; Neel & Palmer, 2012) and Hebrew (Icht & Ben-David, 2014). Additionally, monosyllables with velars have been shown more consistently to have lower DDK rates than other monosyllables. Moreover, the DDK rates of the multisyllabic sequences (see Table 4.1) were more consistently shown to be similar to those of the monosyllables, with the exception of Louzada et al. (2011).

However, in the absence of a consistent and systemic methodology, comparing the results between different dialects and languages is challenging. To the knowledge of the researcher, there have been no published normative DDK rates for Arabic monosyllables and multisyllabic sequences. Therefore, one of the main aims of this study is to establish normative DDK rates for the Arabic population, particularly in the Arabian Gulf, and to explore the differences between two dialects of Arabic (Najdi and Bahraini) using a consistent methodology. In addition, to address the second main research question, this work will assess the DDK rate differences between male and female speakers. Differences between monosyllables and multisyllabic sequences will be further assessed. The research questions are laid out in the next section.

4.3.3 Research aim, questions and hypotheses

4.3.3.1 Research aim

To establish normative DDK rates for monosyllables /ba,da,ga/ and multisyllabic sequence /badaga/ for male and female Najdi Saudi and Bahraini Bahraini speakers.

4.3.3.2 Research questions

4.3.3.2.1 Main research questions

1. Are there statistical differences in the mean DDK rates between the dialects of Najdi and Bahraini?
2. Are there statistical differences in the mean DDK rates between male and female speakers in both Arabic dialects?

4.3.3.2.2 DDK rate-specific questions for monosyllables (/ba/, /da/, /ga/) and the multisyllable /badag/

a) Monosyllables: Are there differences in the DDK rates between the monosyllables /ba/, /da/, /ga/?

b) Multisyllabic sequence: Are there differences in the DDK rates between the monosyllables /ba/, /da/, /ga/ and the multisyllabic /badaga/?

4.3.4 Hypotheses

Cohen et al. (1998) postulated the influence of dialectal differences in AE on DDK rates; however, due to the absence of a consistent methodology, it is impractical to draw a firm inference from the studies reported on AE in this study (see § 4.3.1). Likewise, this also applies to Brazilian Portuguese (see §4.3.2). The dialects chosen in this study are from neighbouring countries and can be considered to be of the same origin, as described in §2.5; therefore, the first hypothesis is that no differences in the DDK rates will be found between the Najdi and Bahraini Arabic dialects for monosyllables and multisyllabic sequences.

Furthermore, there is more agreement on the existence of minimal differences between the DDK rates of males and females in the majority of the studies on English (Ptacek et al., 1966; Kreul, 1972; Amerman & Parnell, 1982; Yu Hongzhi et al., 2010; Topbaş et al., 2012; Neel & Palmer, 2012) and Hebrew (Icht & Ben-David, 2014). Therefore, the second hypothesis is that no differences in DDK rates will be found between male and female speakers in the Najdi and Bahraini Arabic dialects for monosyllables and multisyllabic sequences.

Additionally, monosyllables with velar consonants have been shown to consistently have lower DDK rates than other monosyllables, as has been observed in English (Lundeen, 1950; Ptacek et al., 1966; Kreul, 1972; Amerman & Parnell, 1982; Neel & Palmer, 2012; Topbaş et al., 2012), Brazilian Portuguese (Padovani et al., 2009; Louzada et al., 2011) and German (Breitbach-Snowdon, 2003). Therefore, the third hypothesis is that /ga/ would have the lowest DDK rates amongst the monosyllables analysed in this study for the Najdi and Bahraini Arabic dialects.

Finally, the multisyllabic sequences were more consistently shown to have similar DDK rates to the monosyllables, with the exception of Louzada et al. (2011) (see Table 4.1). Therefore, the fourth hypothesis is the multisyllabic /badaga/ will have a similar DDK rate to the monosyllables /ba/, /da/, /ga/ in this study for the Najdi and Bahraini Arabic dialects for the syllbles produces in 1 second. However, they would be lower when using the method adopted by Louzada et al. (2011).

4.4 Methods

4.4.1 Assessment of the DKK rate using acoustic analysis

One of the aims of this study is to measure the DDK rate in data from Arabic speakers as well as to explore differences in speech characteristics between two Arabic dialects: Saudi Najdi and Bahraini. In addition, a further aim is to explore sex differences in the DDK rates of Arabic speakers. The stimuli were monosyllables (/ba/, /da/, /ga/) and the multisyllabic sequence /badaga/, which will be described in the next section.

4.4.1.1 Stimuli

The speech samples selected for the DDK rate assessment were production data for the monosyllables /ba/, /da/, /ga/ as well as the multisyllabic sequence /badaga/. The choice of these stimuli were based on the lack of /p/ in Arabic as well as earlier studies that have employed the voiced consonants in their assessment of DDK (Lundeen, 1950; Sigurd, 1973). In addition, Lundeen (1950) found no differences between voiced and voiceless monosyllables. Moreover, the choice of the vowel /a/ is assumed to be more appropriate for Arabic language speakers. The choice of vowel

/a/ was due to being a lower vowel similar to those used for DDK in English /æ, ʌ/. In addition, the vowel /a/ is shared between Arabic dialects for future comparisons.

4.4.1.2 Procedure and preparation for acoustic analysis

Participants were shown the stimuli list (Appendix 3.6) and were given a demonstration by the researcher. Further instructions were given on how to produce the monosyllables and multisyllabic seqeunce in succession, in the order present on the stimuli list, as quickly as possible. They were additionally instructed to take a deep breath before initiation of each syllable; a break was offered between each syllable production. The researcher instructed participants to produce each syllable for more than 20 seconds and then were cued when to stop. Preparation for acoustic analysis was described earlier in §3.2.1 for all parameters.

4.4.2 Acoustic analysis

The DDK rates in this study were calculated using Fletcher's (1972, 1978) time-by-count method, with the total time taken for the production of 20 repetitions being calculated for the monosyllables /ba/, /da/, /ga/ and for 20 repetitions of the multisyllable /badaga/ in order to compare the results between the two tasks. Furthermore, the time taken to produce 10 repetitions of the multisyllables was added to the study design.

4.4.2.1 Acoustic marking for monosyllables and the multisyllabic sequence

4.4.2.1.1 Monosyllables

Using visual inspection, the time marker was placed after the first syllable for the production of /ba/, /da/, /ga/ and /badaga/. The first set of syllables was excluded from the analysis because Ackermann et al. (1995) suggested that the first production of the first syllable is longer than the remaining syllables. The time marker was placed at the end of the vowel formant and before the start of the release of the voiced stops /b/ of the next iteration, as seen in Figure 4.1.

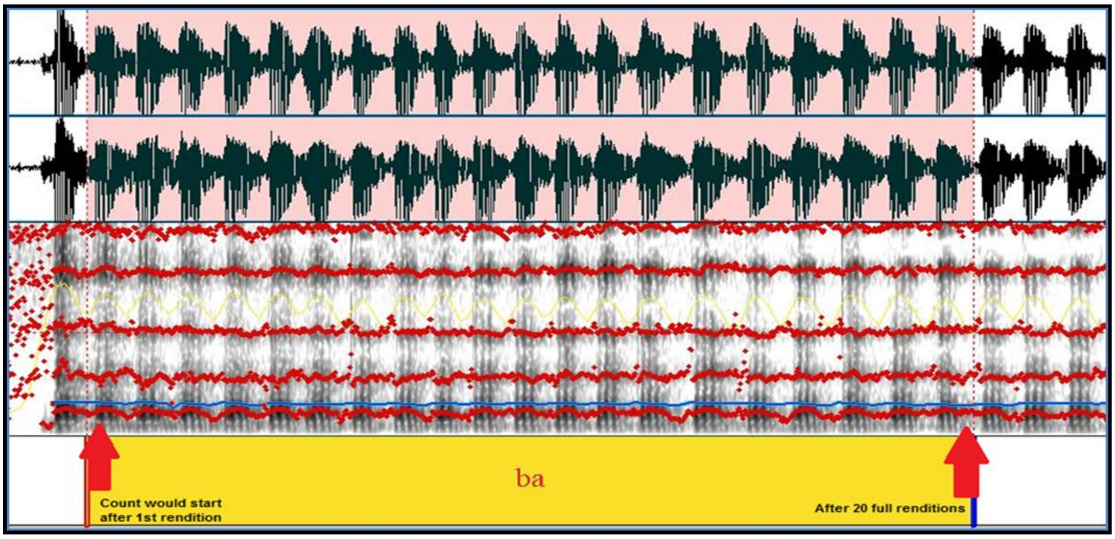


Figure 4.1 DDK rate in seconds for the monosyllables /ba/, /da/, /ga/ according to where the time marker was placed after the first iteration as in Fletcher's (1972, 1978) time-by-count procedure, where the duration for 20 full iterations was measured.

After the count of the 20 full iterations, the time marker was placed at the end of the vowel preceding the voicing of the next iteration that would not be counted. The same procedure was conducted for all monosyllables.

4.4.2.1.2 Multisyllabic sequence

Similar to the monosyllables, with the aid of the sound pressure waveform the time marker was placed after the first full iteration of /badaga/ at the end of the vowel preceding the next repetition, as recommended by Ackermann et al. (1995). The time marker was placed at the end of the number of full repetitions of the selected multisyllable; Figure 4.2 shows 10 iterations that were selected. The procedure was repeated for 20 iterations.

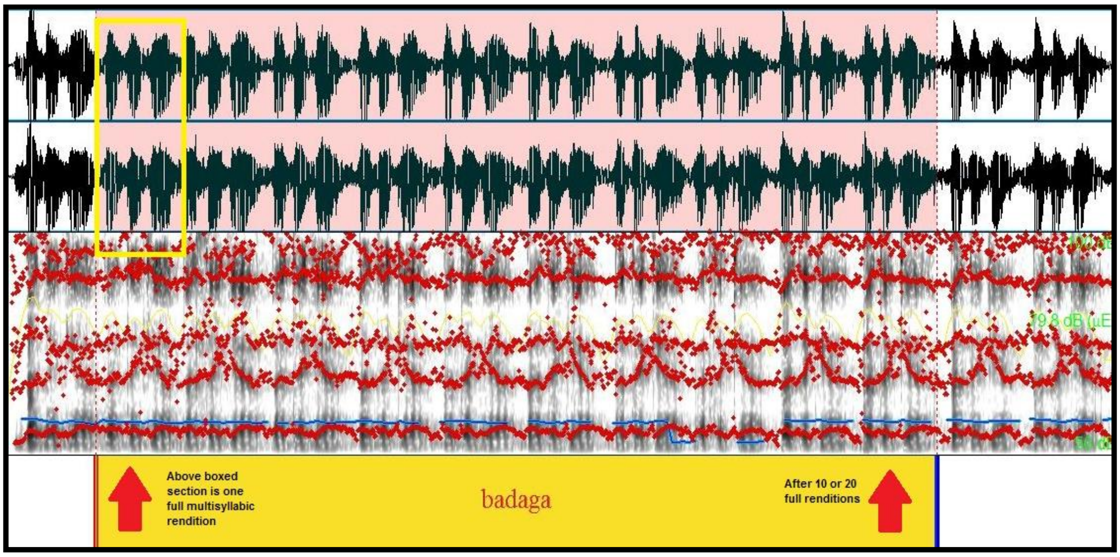


Figure 4.2 DDK rate in seconds for the multisyllable /badaga/ according to where the time marker was placed after the first iteration as in Fletcher's (1972, 1978) time-by-count procedure, where the duration for 10 full iterations was measured (yellow box).

4.4.3 Analysis and transfer

A Praat (Boersma & Weenink, 2012) script (available in Appendix 4.1) that was written by Katherine Crosswhite and modified by Mark Antoniuo (Crosswhite & Antoniuo, 2007) was also modified by the researcher to extract for each participant the syllable duration in seconds from the marked iteration for all syllables from the sound files in WAV format and text grids. The output of the script was then transferred to an Excel (2010) spreadsheet. The results for all participants were then compiled into an Excel spreadsheet that was transferred into the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL), version 19, for statistical analysis.

4.4.4 Reliability

4.4.4.1 Inter-rater reliability:

As the task of annotating the syllables is a manual task that is undertaken by a single researcher, a degree of error can occur. Therefore, in order to ensure optimum reliability, an independent speech and language pathologist familiar with the acoustic process repeated the acoustic analysis. The annotation of text grids for these samples was then acoustically processed by Praat (Boersma & Weenink, 2013).

A total of 8 participants were randomly selected, with 2 representing each group (2 Bahraini and 2 Saudi females, and 2 Bahraini and 2 Saudi males). For each participant, DDK rate measures were obtained for the 3 monosyllables (/ba/, /da/, /ga/). For the multisyllabic /badaga/, there were two measures, one for the 10 iterations and the other for the 20 iterations. A total of 5 measures of DDK syllables for each participant have been made. Therefore, the number of DDK rates analysed for these participants was 40, representing 10% of the total sample (400).

4.4.4.2 Intra-rater reliability:

Marking of the DDK durations was carried out a second time, at least 7 months later, by the researcher in order to further assess intra-rater reliability, comparing the first set of ratings with those obtained in the second period. The selected files were those used in the inter-rater reliability assessment.

The inter-rater and intra-rater reliability was estimated for 10% of the measurements. The Pearson correlation coefficients were calculated as shown in Table 4.2.

4.4.4.3 Results

	Inter-rater reliability	Intra-rater reliability
Monosyllables (20 iterations/)	r = 1.00, n = 24,p<.001	r = 1.00, n = 24,p<.001
Multisyllable (20 iterations/s)	r = 1.00, n = 8,p<.001	r = 1.00, n = 8,p<.001
Multisyllable (10 iterations/s)	r = .998, n = 8,p<.001	r = 1.00, n = 8,p<.001

Table 4.2 Pearson correlation for inter-rater and intra-rater reliability for the DDK rates of 20 iterations/second for the monosyllable and the multisyllabic sequences and 10 iterations/second for the multisyllabic sequence.

The intra-rater reliability levels were used to assess the reliability of the DDK measurements. There was a strong positive correlation between the two measurements taken by the researcher for the monosyllables (r =1.00, n = 24, p <.001) as well as the multisyllabic for 20 repetitions (r = 1.00, n = 8, p<.001) and 10 repetitions (r = .998, n = 8, p<.001). In addition, the second measurement (inter-rater reliability), taken by a colleague, revealed a strong positive correlation for the monosyllables (r =1.00, n = 24, p <.001) as well as the multisyllabic for 20 repetitions (r = 1.00, n = 8, p<.001) and 10 repetitions (r = 1.00, n = 8, p<.001). Overall, there was a strong positive correlation between the measurements revealing a high level of reliability for the acoustic analysis of DDK duration in seconds.

4.4.5 Design and data analysis

The primary aim of this study was to answer two main research questions, in addition to establishing normative data for the two dialects of Arabic. First, it sought to determine whether differences exist between the two dialects of Arabic (Najdi and Bahraini) and, second, whether linguistic differences exist between males and females speaking Arabic. In addition, the study was designed to examine DDK rate differences between the monosyllables /ba, /da/ and /ga/. Also, it aimed to determine whether differences occur between the DDK rate of monosyllables and the multisyllabic sequence /badaga/.

In §4.5.1, normative results are established from the Fletcher method (1972, 1978) for the 20 iterations per second data for the monosyllables /ba, /da/ and /ga/ and the multisyllabic sequence /badaga/ as well as the 10 iterations per second data for the multisyllabic sequence /badaga/. Moreover, as observed in Table 4.1 in §4.3, the results and comparison between sexes, if completed, were analysed by establishing a normative DDK for the number of repetitions produced in one second for the monosyllables and multisyllables. As the results from this study consist of the duration in seconds per 20 repetitions, this would enable a more accurate average per second across the 20 repetitions. Therefore, in order to perform statistical analysis on the monosyllable and multisyllable data, and in a similar fashion to Breitbach-Snowdon (2003), each participants' production of the monosyllables /ba/, /da/, /ga/ and the multisyllabic sequence /badaga/ for the 20 syllables was divided by 20, in order to obtain the number of iterations produced per 1 second. Statistical analysis was then performed using a mixed model ANOVA analysis where dialect and gender were the between subject factors, while the within-subject factors were the DDK rate of the monosyllables /ba/, /da/, /ga/ and the DDK rate of the multisyllabic sequence /badaga/ produced in 1 second similar to Louzada et al. (2011) (see §4.5.2). Furthermore, in order to compare to other studies for the multisyllabic sequence /badaga/, syllables per 1 second were calculated by dividing the rate obtained for whole triad by 3. This was performed in contrast to the method of calculating syllables per second for the multisyllabic sequence in Icht and Ben-David (2014) study.

4.5 Results

4.5.1 Normative data for DDK rates using the Fletcher method (1972, 1978) (20 iterations/second)

The mean, standard deviation,minimum and maximum values for the DDK rate of the 20 iterations per second data for the monosyllables /ba/, /da/ and /ga/ and the multisyllabic sequence /badaga/ after employing the Fletcher method (1972, 1978) are displayed in Table 4.3 as a function of dialect and sex. Furthermore, in the final column in Table 4.3,following the Fletcher method (1972, 1978), the 10 iterations are displayed for the multisyllabic sequence /badaga/.

Sex	Dialect	/ba/ Mean (S.D) Min-Max	/da/ Mean (S.D) Min-Max	/ga/ Mean (S.D) Min-Max	/badaga/ Mean (S.D) Min-Max	/badaga/ (10) Mean (S.D) Min-Max
Male	S (20)	3.53 (0.59) 2.92-5.23	3.57 (0.82) 2.72-6.20	3.73 (0.70) 2.75-5.57	4.45 (0.58) 3.73-6.03	8.89 (1.19) 7.46-12.19
	B (20)	3.92 (0.90) 2.84-6.54	4.18 (1.33) 2.66-7.15	4.68 (1.57) 2.67-8.17	4.73 (0.82) 3.70-6.74	9.20 (1.42) 6.74-12.71
	Mean (40)	3.73 (0.78) 2.84-6.54	3.87 (1.14) 2.66-7.15	4.20 (1.29) 2.67-8.17	4.59 (0.71) 3.70-6.74	9.05 (1.30) 6.74-12.71
Female	S (20)	3.67 (0.68) 2.78-5.27	3.75 (0.77) 2.27-4.97	3.90 (0.86) 2.83-6.26	4.60 (0.63) 3.33-5.81	9.19 (1.42) 6.82-11.92
	B (20)	3.94 (0.83) 2.98-5.95	4.13 (1.02) 2.91-5.79	4.34 (0.91) 3.17-6.39	4.68 (0.55) 4.12-6.39	9.43 (1.08) 8.19-12.43
	Mean (40)	3.81 (0.76) 2.78-5.95	3.94 (0.91) 2.27-5.79	4.12 (0.90) 2.83-6.39	4.64 (0.59) 3.33-6.39	9.31 (1.25) 6.82-12.43
Total	S (40)	3.60 (0.63) 2.78-5.27	3.66 (0.79) 2.27-6.20	3.81 (0.78) 2.75-6.26	4.52 (0.60) 3.33-6.03	9.04 (1.30) 6.82-12.19
	B (40)	3.93 (0.85) 2.84-6.54	4.15 (1.17) 2.66-7.15	4.51 (1.28) 2.67-8.17	4.71 (0.69) 3.70-6.74	9.32 (1.25) 6.74-12.71
	All (80)	3.77 (0.76) 2.78-6.54	3.91 (1.02) 2.27-7.15	4.16 (1.11) 2.67-8.17	4.61 (0.65) 3.33-6.74	9.18 (1.28) 6.74-12.71

Table 4.3 Mean DDK rate for 20 iterations/seconds, standard deviation (SD), minimum and maximum rates for the monosyllables /ba/, /da/, /ga/ and the multisyllabic sequence /badaga/ as well the 10 iterations/seconds data for /badaga/ for male and female Saudi and Bahraini Arabic speakers using the Fletcher method (1972, 1978).

4.5.2 The monosyllables /ba/, /da/, /ga/ and the multisyllabic sequence /badaga/ (iterations/1 second)

The mean and standard deviation values for the DDK rate in iterations per 1 second for the monosyllables /ba/, /da/, /ga/ and the multisyllabic sequence /badaga/ the full triad and Syllbles /1 second are displayed in Table 4.4 as a function of dialect and sex. Statistical analysis was performed for this as it enables comparison with the studies in Table 4.1 and represents a specific number of iterations for 1 second.

Sex	Dialect	/ba/ Mean (S.D) Min-Max	/da/ Mean (S.D) Min-Max	/ga/ Mean (S.D) Min-Max	/badaga/ Mean (S.D) Min-Max	/badaga/ (Syllable/ 1 second) Mean (S.D) Min-Max
Male	S (20)	5.80 (0.80) 3.82- 6.85	5.83 (1.07) 3.23- 7.36	5.53 (0.94) 3.59- 7.28	2.28 (0.27) 1.64- 2.68	6.85 (0.82) 4.92- 8.04
	B (20)	5.32 (1.05) 3.06- 7.04	5.18 (1.34) 2.80- 7.53	4.70 (1.39) 2.45- 7.49	2.22 (0.34) 1.57- 2.97	6.67 (1.02) 4.72- 8.91
	Mean (40)	5.56 (0.95) 3.06- 7.04	5.51 (1.24) 2.80- 7.53	5.11 (1.24) 2.45- 7.49	2.25 (0.31) 1.57- 2.97	6.76 (0.92) 4.72- 8.91
Female	S (20)	5.62 (0.99) 3.80- 7.2	5.58 (1.27) 4.02- 8.81	5.34 (1.05) 3.20- 7.06	2.23 (0.36) 1.68- 2.93	6.69 (1.07) 5.03- 8.8
	B (20)	5.27 (1.01) 3.36- 6.71	5.12 (1.19) 3.45- 6.88	4.80 (0.96) 3.13- 6.32	2.15 (0.22) 1.61- 2.44	6.44 (0.66) 4.83- 7.33
	Mean (40)	5.45 (1.00) 3.36- 7.2	5.35 (1.24) 3.45- 8.81	5.07 (1.03) 3.13- 7.06	2.19 (0.30) 1.61- 2.93	6.56 (0.89) 4.83- 8.8
Total	S (40)	5.71 (0.89) 3.80- 7.2	5.7 (1.16) 3.23- 8.81	5.44 (0.99) 3.20- 7.28	2.26 (0.32) 1.64- 2.93	6.77 (0.95) 4.92- 8.8
	B (40)	5.29 (1.02) 3.06- 7.04	5.15 (1.26) 2.80- 7.53	4.75 (1.18) 2.45- 7.49	2.18 (0.28) 1.57- 2.97	6.55 (0.85) 4.72- 8.91
	All (80)	5.5 (0.97) 3.06- 7.2	5.43 (1.23) 2.80- 8.81	5.09 (1.13) 2.45- 7.49	2.22 (0.30) 1.57- 2.97	6.66 (0.90) 4.72- 8.91

Table 4.4 Mean DDK rate (Syllable/ 1 second), standard deviation, minimum and maximum for the monosyllables /ba/, /da/, /ga/ and the multisyllabic sequence /badaga/ for the full triad and for syllables per 1 second for male and female Saudi and Bahraini Arabic speakers.

A mixed model ANOVA was conducted, with the mean DDK rates (iterations/second) for the monosyllables /ba/, /da/,/ga/ and the multisyllabic sequence /badaga/ for the full triad in 1 second and syllbles /1 second as the repeated measure and sex (males/females) and dialect (Bahraini-Saudi) as the between subject factors. Syllable type was the within-subject factors. The results showed Mauchly's test significance (p < .05); therefore, sphericity was violated. Greenhouse-Geisser estimates were used, since it is considered to be the most conservative measure.

4.5.2.1 Dialect and sex

The results showed a significant effect regarding dialect (F(1,76) = 6.15, p < .05). A post hoc test using Bonferroni correction revealed significance (p < . 05) where Saudis had higher DDK rates per second (5.18 syllable/ 1 second) than Bahrainis (4.75 syllable/ 1 second) (see Figure 4.3).

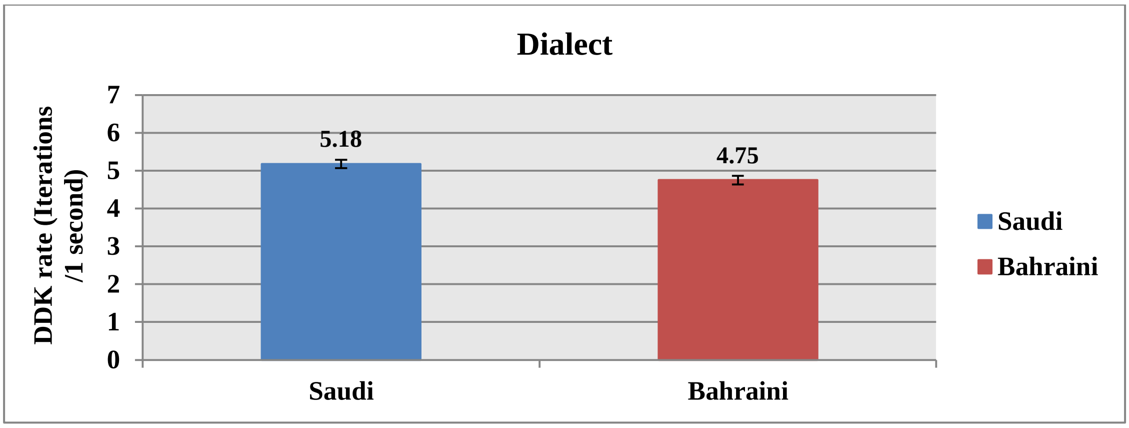


Figure 4.3 Mean ± standard error bars for DDK rates (Iterations/ 1second) for Saudi and Bahraini Arabic speakers.

However, sex was shown to have no significant effect (F(1,76) = .55, p > .05). In addition, there was no significant interaction between dialect and sex (F(1,76) = .113, p > .05).

4.5.2.2 Syllable type

The results showed a significant effect regarding syllable type ($F(1.99, 151.242) = 418.95$, $p < .001$). A post hoc test using Bonferroni correction revealed the full iteration for /badaga/ (2.22 Iterations/ 1 second) to have a significantly lower DDK rate than all the monosyllables ($p < .001$), in contrast to /badaga/ (6.66 syllable/ 1 second) which had the highest rates among syllables (see Figure 4.4). Furthermore, /ga/ (5.09 syllable/ 1 second) had a lower DDK rate than /ba/ (5.50 syllable/1 second) ($p <. 001$) and /da/ (5.43 syllable / 1 second) ($p < .05$) while no differences were observed between /ba/ (5.50 syllable/ 1 second) and /da/ (5.43 syllable / 1 second), ($p > .05$), (see Figure 4.4).

The results showed no significant interaction between syllable type and sex ($F(1.99, 151.242) = .129$, $p > .05$) or between sex, dialect and syllables ($F(1.99, 151.242) = .815$, $p > .05$).

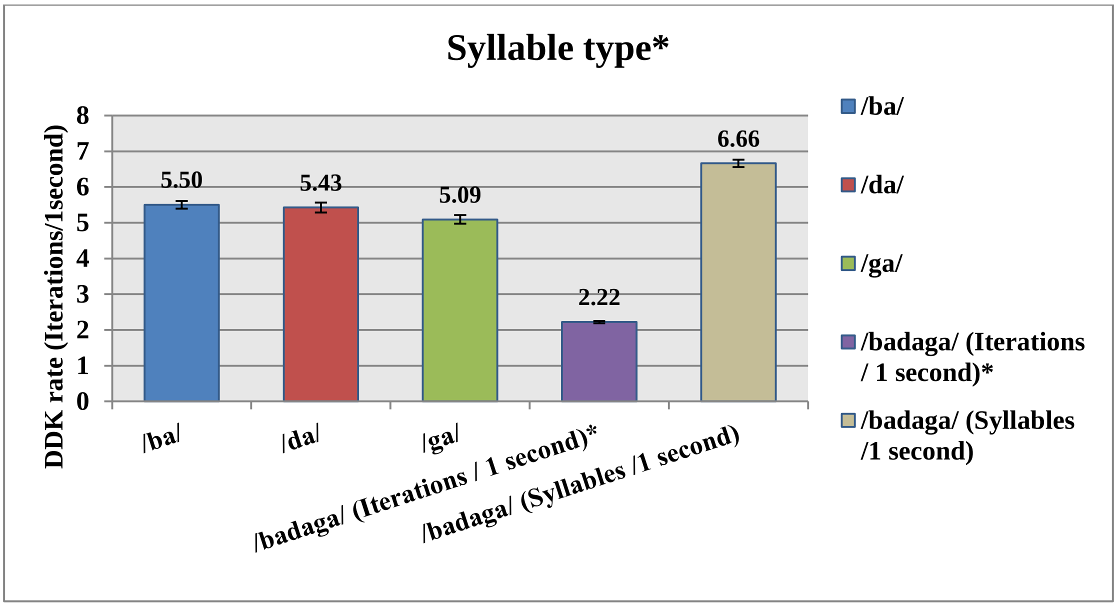


Figure 4.4 Mean ± standard error bars for DDK rates (Iterations /1 second) for the monosyllables /ba/, /da/, /ga/ and the full multisyllabic sequence /badaga/ as well as syllable/ 1 second for the multisyllabic sequence. * Indicates Iteration for the full multisyllabic sequence.

In addition, there was no significant interaction between syllable type and dialect ($F(1.99, 151.242) = 2.362$, $p > .05$). However, in order to understand dialect differences for the iterations, a one-way ANOVA was conducted to compare the effects of dialect on the monosyllables and both multisyllabic sequence. The results showed a significant effect of dialect for /da/ ($F(1,78) = 4.212$, $p < .05$) and /ga/ ($F(1,78) = 8.003$, $p < .05$) where Saudis had higher DDK rates (5.70 syllables/ 1 second for /da/; 5.44 syllables / 1 second for /ga/) than Bahraini speakers (5.15 syllables / 1 second for /da/; 4.75 syllables / 1 second for /ga/), (see Figure 4.5).

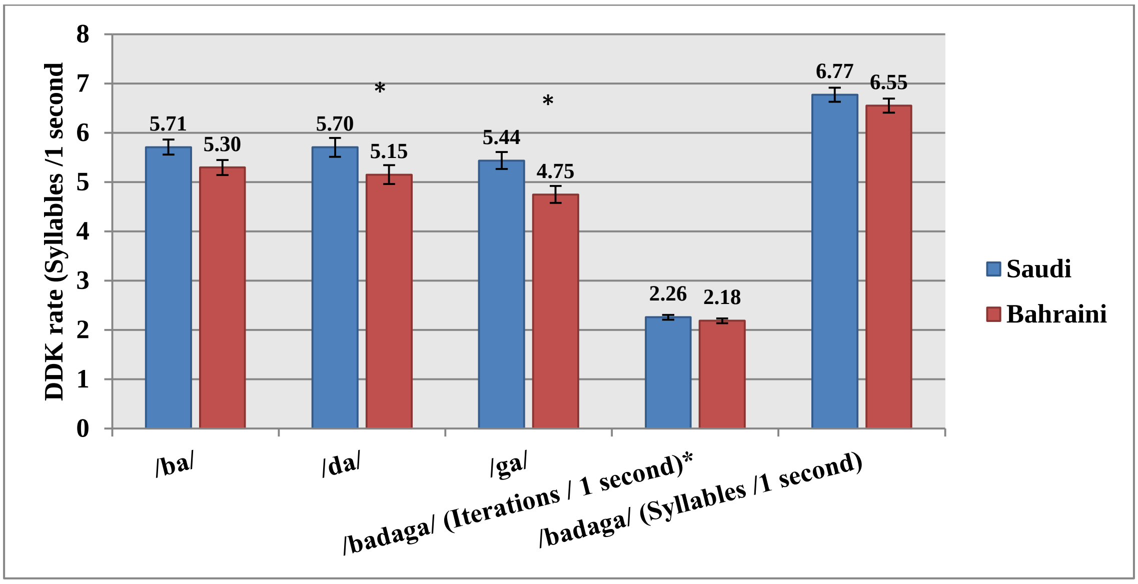


Figure 4.5 Mean ± standard errors bars for DDK rates (iterations/ 1 second) for the monosyllables /ba/, /da/, /ga/ and the multisyllable /badaga/ for full triad* and as syllables /1 second for Saudi and Bahraini Arabic speakers.

Furthermore, dialect was shown to approach significance for /ba/ ($F(1,78) = 3.739$, $p = .057$) where Saudis had higher rates (5.71 syllable /1 second) than Bahraini speakers (5.30 syllables / 1 second) (see Figure 4.5). However, dialect was shown to have no significant effect for full iteration / 1 second for /badaga/ ($F(1,78) = 1.173$, $p = .282$) and syllable / 1 second for /badaga/ ($F(1,78) = 1.173$, $p = .282$).

Study	Language	Sex (number)	Consonants vowels[1]	/CV/	/CV/	/CV/	/CVCVCV/
Lundeen (1950)	English (American)	M (20) F (20)	/p, t, k/ /ə/	7.0	7.1	6.2	-
			/b, d, g/ /ə/	7.0	7.2	6.3	-
Ptacek et al. (1966)	English (American)	M (28)	/p, t, k/ /ʌ/ /pʌtʌkʌ/	7.0	6.9	6.2	5.8
		F (31)		6.9	6.8	6.2	6.3
Kreul (1972)	English (American)	M (20)	/p, t, k/ /ʌ/	6.0	6.0	5.4	
		F (25)		5.3	5.8	5.2	
Amerman & Parnell (1982)*	English (American)	M (10)	/p, t, k/	6.6	6.6	6.1	
		F (10)	/ʌ/	6.7	6.6	6.3	
Deliyski & DeLassus Gress (1997)*	English (American)	M (50)	/pʌ/	6.0	-	-	
		F (50		5.8	-	-	
Topbaş et al. (2012)*	English (American)	M (12)	/pʌ / /pʌtəkə/	5.6	-	-	6.1
		F (12)		5.3	-	-	6.3
Neel & Palmer (2012)*	English (American)	M (16)	/p, t, k/ /ʌ/ /pʌtəkə/	6.4	6.7	6.0	6.6
		F (12)		6.6	6.6	6.1	7.6
Hongzhi et al. (2010)*	English (American)	M (50)	/pa/	5.9			
		F (50)		5.8			
	Chinese (Mandarin)	M (50)		4.1			
		F (50)		5.3			
Padovani et al. (2009)*	Portuguese (Brazilian)	M (9) F (14)	/p, t, k/ /a/ /pataka/	6.7	6.7	6.0	6.6
Louzada et al. (2011)*	Portuguese (Brazilian)	F (30)	/p, t, k/ /a/ /pataka/	5.9	6.0	5.5	2.3**
Breitbach-Snowdon (2003)	German	-	/p, t, k/ /a/ /pataka/	6.0	5.0	4.5	5.0
Icht & Ben-David (2014)	Hebrew	M (53)	/pataka/	-	-	-	6.4
		F (62)		-	-	-	6.3
Current study*	Saudi	M (20)	/b, d, g/ /a/ /badaga/	5.8	5.8	5.5	6.8/2.2**
		F (20)		5.6	5.6	5.3	6.7/2.2**
	Bahraini	M (20)		5.3	5.2	4.7	6.7/2.2**
		F (20)		5.5	5.4	4.8	6.4/2.1**

Table 4.5 DDK rates (Syllables/ second) from current study for male and feamles Saudia and Bahraini speakers for monosyllables and multisyllables as well as those from the English language (Lundeen, 1950; Ptacek et al., 1966; Kreul, 1972; Amerman & Parnell, 1982; Deliyski & DeLassus Gress, 1997; Yu Hongzhi et al., 2010; Topbaş et al., 2012; Neel & Palmer, 2012), Mandarin Chinese (Yu Hongzhi et al., 2010), Portuguese (Padovani et al., 2009; Louzada et al., 2011), German (Breitbach-Snowdon, 2003) and Hebrew (Icht & Ben-David, 2014).[1] CV used in monosyllables is a combination of the consonants and vowels displayed in the column, * denotes the DDK rates were rounded to one decimal point to match the remaining studies. ** denotes DDK rate was measeured for the full triad per 1 second.

		Hypothesis	Monosyllables (/ba/, /da/, /ga/) and the multisyllable /badaga/	Results
Dialect	Main	**Differences will not be found between dialects.**	S>B ($p < .05$)	S>B
	Interaction		Syllables ($p < .05$) S>B (/da/, /ga/),($p < .05$) Approaching significance S>B /ba/,($p = .057$) /badaga/ (S=B), n.s.	/ba/, /da/, /ga/ (S>B)
Sex		**Differences will not be found between sexes.**	n.s	M=F
Monosyllables		**/ga/ would have lower DDK rates than /ba/, /da/.**	/ga/ < /ba/ ($p < .001$) and /da/ ($p < .05$), /ba/ = /da/ n.s	/ga/ < /ba/, /da/
Multisyllable		**Differences will not be found between monosyllables and the multisyllable.**	/badaga/ < /ba/, /da/, /ga/, ($p < .001$)	/badaga/ < /ba/,/ga/,/ga/

Table 4.6 Significant results and interactions as well as the hypothesis predicted and the outcomes of the study for the monosyllables /ba/,/da/,/ga/ and the multisyllable /badaga/ for dialect, sex, monosyllable and multisyllable differences. (S and B denote Saudi and Bahraini while n.s. denotes no statistically significant differences).

4.6 Discussion

The aim of the study was to establish normative DDK rates for male and female Najdi and Bahraini Arabic speakers which was successfully achieved as presented in in §4.5. In addition, to determine the effect of dialect (Saudi and Bahraini) and sex (male and female) on mean DDK rates (syllables/ 1 second) for the monosyllables /ba/, /da/, /ga/ and the multisyllable /badaga/ as well as DDK rate (iterations/1 second) for the full multisyllabic sequence. In addition, it examines the effects of differences within the monosyllables and between the monosyllables and multisyllable. This section begins with a discussion of dialect (includes cross-linguistic differences) and sex results from this study followed by a discussion on the differences within the monosyllables and between the monosyllables and the multisyllable to finally conclude with a summary. Hypotheses were proposed and the results are presented in Table 4.6.

4.6.1 Dialect

The results for dialect showed Saudis to have generally higher DDK rates than Bahraini speakers. Furthermore, the statistical analysis on the monosyllable data confirmed that Saudis have higher DDK rates than Bahrainis. Although /ba/ showed a near-significant result, nevertheless, it showed consistency with the remaining monosyllables (/da/, /ga/). However, the multisyllable /badaga/ showed no significant differences between the dialects for both measures.

The results from this study to some extent support Cohen et al. (1998) as they pointed out that multisyllable results might be different between dialects in languages; however, in Arabic differences were observed in monosyllables between the Saudi and Bahraini dialects. The interpretation of Cohen et al. (1998), however, remains valid as the possible reason behind the differences between the Arabic dialects might be due to differences in the production of /a/. Saudi speakers might have a higher tongue position for this vowel than Bahraini speakers, which might lead to higher rates than Bahraini speakers (see §7.5.2). Another possible reason to account for this finding could be that the production of the consonants is different between dialects; however, without more rigorous analysis of the DDK rate for monosyllables on a number of parameters (e.g. VOT, formant frequencies), this remains a tentative option. Another possible reason might be related to Saudis showing a higher coarticulatory rate and more flexibility of movement of the articulators. Looking at DDK rate standard deviation in Table 4.4 , showed that for the monosyllables, Saudis tended to have slightly higher standard deviations than Bahrainis which indicates that Bahraini speakers might have lower coarticulatory and less rapid movements as suggested by Hongzhi et al. (2010). Another point related to frequency of phenomes where it is described that the more frequent the phoneme the faster and more accurate it is produced (Icht & Ben-David, 2014). There might be differences in frequencies of phonemes between the dialects for the monosyllables where Saudis might have higher frequencies for the phonemes than Bahrainis entailing more syllables per second (further discussion in §4.6.3.1).

The results for iterations per 1 second for the multisyllable /badaga/ go against Cohen et al.'s (1998) point with regards to the role of dialectal differences. A possible explanation is that on the production of the full triad, differences between the Arabic dialects are diminished as a result of coarticulatory behaviour; however, this would require further analysis for confirmation. More support for this claim comes from the other method of analysis of the multisyllabic sequence (syllables /1 second) as no statistical differences were observed between the Arabic diaelcts. Therefore, it can be concluded that no difference were observed for the Arabic dialects investigated in this study for the multisyllabic sequence for both measures.

The results showed a partially significant effect of dialect, most specifically on the monosyllables, thereby partially opposing the first hypothesis, as shown in Table 4.6. Furthermore, the results for the multisyllable /badaga/ support the hypothesis as differences were not found between the Arabic dialects. Therefore, it is imperative to analyse the full range of monosyllables and multisyllables when obtaining the DDK rate using a consistent methodology. This will enable an understanding to be reached on what might be a powerful yet simple tool to understand the differences between dialects and languages. Although, further agreement on method of analysis for syllables is required to support this claim.

4.6.1.1 Cross linguistic differences

In comparing the results from this study with those from Lundeen (1950) (see Table 4.5), who used the phonemes /b,d,g/, it can be stated that the results from Arabic appear to have lower repetition rates than those reported in English, even more so for the Bahraini speakers. Lundeen (1950) used a different method of analysis, his choice of the mid-central vowel /ə/ might be the reason for the higher DDK rates obtained as it requires a higher tongue position (Ozawa et al., 2001; Prathanee et al., 2002) than that for /a/ in Arabic, therefore producing more syllables per second than is the case for Arabic speakers. Moreover, when comparing with the voiceless monosyllables /p,t,k/ from Lundeen (1950), results were similar to those for the voiced monosyllables. In addition, other English studies (Ptacek et al., 1966; Amerman & Parnell, 1982; Neel & Palmer, 2012) and the results from Padovani et al. (2009) for Brazilian Portuguese showed the same pattern.

However, results for the monosyllables from other studies in English (Kreul, 1972; Deliyski & DeLassus Gress, 1997; Yu Hongzhi et al., 2010; Topbaş et al., 2012) showed similarities with the results from this study with Saudi speakers from both sexes, however, the Bahraini speakers still have lower DDK rates. The results from Chinese speakers (Yu Hongzhi et al., 2010) were similar to those from Bahraini speakers in this study but lower than Saudis. Chinese males, however, had lower

DDK rates than both Saudis and Bahraini and might be considered the lowest amongst the studies reported in Table 4.5. The results might be due to cross-linguistic differences and effects from tone as chinsese is a tonal langauge; however, this would need further confirmation with a study employing the same methodology.

The picture for the multisyllabic sequence is different, results from this study for Bahraini and Saudi males and females was only similar to one study, Louzada et al. (2011) for Brazilian Portuguese , where results are considered to be low (i.e. 2.2 iterations per second) compared with the majority of the studies displayed in Table 4.5. However, this is expected due to measurement of the full triad for the multisyllabic sequence in comparison to syllable rate for the multisyllabic sequence.

As presented in Table 4.5, syllables per 1 second for /badaga/ were measured in order to compare between different languages. There seems to be a wide variation, for example, German (Breitbach-Snowdon, 2003) showed to be the lowest DDK rates amongst all languages including Saudi and Bahraini speakers in this study. While, Saudi and Bahraini in this study showed slightly higher rates than Hebrew (Icht & Ben-David, 2014). While, DDK results for /badaga/ showed similarities between the Arabic dialects in this study and Brazilian Portuguese (Padovani et al., 2009). English studies (Ptacek et al., 1966; Topbaş et al., 2012; Neel & Palmer, 2012) showed variations within English as well as with the Arabic dialect’s in this study. These might be suggestive of cross-linguistic differences. However, with the lack of consistency in how DDK rates are measured, comparison between languages and dialects within languages should be made with caution. This is further discussed in §4.6.3.2.

4.6.2 Sex

The results showed no differences between males and females in Najdi and Bahraini Arabic. This supports a number of studies on English (Ptacek et al., 1966; Kreul, 1972; Amerman & Parnell, 1982; Hongzhi et al., 2010; Neel & Palmer, 2012; Topbaş et al., 2012) as well as Hebrew (Icht & Ben-David, 2014). Therefore, the second hypothesis is supported, where no differences in DDK rates were found between male and female speakers in the Najdi and Bahraini Arabic dialects for the monosyllables and the multisyllabic sequence.

4.6.3 Monosyllables and multisyllable

4.6.3.1 Monosyllables

The results from this study showed that /ga/ had a lower DDK rate than /ba/ and /da/ in Najdi and Bahraini Arabic speakers from both sexes. The results are in agreement with the majority of studies on English (Lundeen, 1950; Ptacek et al., 1966; Kreul, 1972; Amerman & Parnell, 1982; Neel & Palmer, 2012; Topbaş et al., 2012), Brazilian Portuguese (Padovani et al., 2009; Louzada et al., 2011) and German (Breitbach-Snowdon, 2003) reporting that monosyllables with velar consonants have lower DDK rates than those with other consonants. This might be due to the involvement of more articulators in producing /g/ as reported by Padovani et al. (2009). Furthermore , as described earlier by Icht & Ben-David (2014) (§4.3.2) that the more frequent the phoneme, the more accurate and rapid the movement of articulators. In MSA, the /b/ phoneme had shown to have higher frequency than /d/ (Wehr, 1979; Newman, 2005). However, in a study of Tunisian Arabic (Krichi & Adnan, 2014) showed that indeed that the frequency of /b/ was higher than /d/ which was higher than /g/. This might have caused the differences between the monosyllables. Further studies are required on frequency of phonemes in Arabic dialects which might help in explaining the results for this study.

The third hypothesis was that /ga/ will have the lowest DDK rates amongst monosyllables, is confirmed for the Najdi and Bahraini Arabic dialects in this study.

4.6.3.2 Multisyllables

As described earlier in §4.6.1.1, the DDK rate for the Arabic multisyllabic sequence full iterations of /badaga/ was lower than that of the monosyllables, which is a similar finding to that reported by Louzada et al. (2011) (see Table 4.5). This is expected due to measurement of the full triad for the multisyllabic sequence in comparison to syllable rate for the multisyllabic sequence.

However, the results for syllables rate per 1 second for the multisyllabic sequence showed higher rates than the monosyllables (see Table 4.5). A probable cause for this might be that the movement between difference places of articulation is easily achieved and has some similarity to speech, resulting in a faster production of DDK rate. In contrast to a repetitive movement that might be unnatural which might slow DDK rates. However, data from other studies (see Table 4.5) show a wide variation for DDK rates in most languages between the monosyllables and the multisyllabic sequence. Again, this might be due to differences in methodologies, in method of analysis or differences between voiced and voiceless stops. No firm conclusion can be made with regard to differences apart from cross-linguistic differences. Further analysis is recommended between voiced and voiceless multisyllabic productions is recommend as well as cross-linguistic studied adopting a similar methodology.

The fourth hypothesis is not supported in the Arabic dialects in this study, as the full iteration of multisyllabic /badaga/ was shown to have lower DDK rates than the monosyllables /ba,da,ga/. In addition, the syllable analysis for the multisyllabic sequences showed to have higher DDK rates than the monosyllables.

4.6.4 Clinical use of normative DDK rates for Saudi and Bahraini Arabic speakers established from this study

In clinical settings, speech and language pathologists frequently employ minimum and maximum, in addition to mean DDK rates to ascertain if abnormal speech difficulties (e.g. from apraxia, dysarthria and aphasia) are present and are not within the range produced by normal speakers. Therefore, this study provides normative DDK rates (means, standard deviation, minimum and maximum rates) for Saudi and Bahraini male and female young adult speakers as seen in Table 4.3 and Table 4.4. The study provided DDK rates following a number of methods: the Fletcher method (1972, 1978) in Table 4.3. While, in Table 4.4, DDK rates for monosyllables and the multisyllabic sequence were provided for syllable prodcued in 1 second similar to other studies (Ptacek et al., 1966; Padovani et al., 2009; Topbaş et al., 2012; Neel & Palmer, 2012). In addition, it provides in Table 4.4, the iterations for the full multisyllabic sequences produced in 1 second similar to Louzada et al.'s (2011). It is recommended for Arabic clinicians when assessing Arabic dialects not included in this study to use the multisyllabic sequence as it showed no dialectal differences. However, this needs further confirmations from exploring DDK rates for other dialects of Arabic. A restriction to analysis between the dialects and sexes to only mean DDK rates is one of the limitations of this study. Further analysis of standard deviation and ranges of DDK rates is recommended.

4.7 Summary

The results from this chapter have revealed that dialect plays a role in determining the DDK rates in Arabic. Further statistical analysis showed Saudi Najdi to have lower DDK rates than Bahraini speakers for the monosyllables /ba/, /da/, ga/. However, no differences in the DDK rate between Arabic dialects occurred for the multisyllable /badaga/ for both methods. Moreover, it was shown that the DDK rate was not affected by sex, as has been exhibited by a number of studies in English (Ptacek et al., 1966; Kreul, 1972; Amerman & Parnell, 1982; Hongzhi et al., 2010; Neel & Palmer, 2012; Topbaş et al., 2012) and Hebrew (Icht & Ben-David, 2014).

In addition, monosyllables with the initial velar /g/ in Arabic were shown to have lower DDK rates than the remaining monosyllables, a similar finding to a number of different studies in different languages. Moreover, monosyllables were shown to have higher DDK rates than the full iterations of the multisyllable /badaga/, similar to Louzada et al.'s (2011) finding. However, syllable analysis for the multisyllabic sequences showed to have higher DDK rates than the monosyllables in this study. Cross-linguistic differences were observed for the monosyllables and multisyllabic sequences for syllables per 1 second. Further agreement on method of analysis of DDK rates is recommended.

Chapter 5. Voice Onset Time (VOT)

5.1 Introduction

Following from the previous chapter on DDK, the second parameter is voice onset time (VOT), which is the focus of this chapter. An effect of dialect has been shown on DDK rates for monosyllables (/ba/, /da/, /ga/), where Bahraini speakers exhibited a longer duration than Saudi speakers. In addition, no significant difference was exhibited between sexes. Therefore, this chapter explores another temporal measure to determine whether dialectical and gender differences are present for Arabic speakers of two dialects (Najdi and Bahraini).

VOT is a temporal parameter that is measured from the release of the closure of a plosive to the initiation of voicing (the laryngeal gesture where the vocal cords vibrate; Cho & Ladefoged, 1999). It has been common to use VOT to describe differences between voiced and voiceless stops for many languages (Lisker & Abramson, 1964; Lisker & Abramson 1967; Cho & Ladefoged, 1999), including Arabic (Khattab, 2002). This chapter also explores the effects of place of articulation for voiced and voiceless stops (Lisker & Abramson, 1964, 1967; Cho & Ladefoged, 1999). It will further look at the emphatic stop /tˤ/ and how differences are exhibited in relation to dialect and gender, as different patterns have been seen in other dialects of Arabic (e.g., Jordanian Arabic (Khattab et al., 2006) and Muslim Baghdadi and Egyptian Arabic (Heselwood, 1996)).

The chapter is structured as follows. First, it presents the definition of VOT and the manner of how voiced and voiceless stops are articulated, followed by a discussion of the voicing categories and how they are used in Arabic. The speaker-related and nonspeaker-related factors that affect VOT are assessed, followed by a review of studies in dialects and accents from other languages. After a review of Arabic studies, the research questions are addressed, and the methodology is described. Subsequently, the results and discussion are presented.

5.2 Voice onset time

When reviewing the production of stops such as /p, t, k/ and /b, d, g/ in initial position in the adult population, it is necessary to mention the research of Lisker and Abramson (1964). In their classic cross-linguistic study, they coined the term voice onset time (VOT) and it can be defined it as the duration between the burst that marks the release of a stop and the onset of voicing.

VOT plays a major role in differentiating perceptually between plosives such as /p/ and /b/ in English, as shown in Lisker & Abramson's (1964) study; moreover, VOT serves as a distinction between stop categories in a number of languages. Although languages differ in their phonetic and phonemic categories, they can be differentiated using VOT.

Lisker and Abramson (1964) documented the voicing contrasts for initial stops in words in 11 languages. They established that VOT was highly effective in differentiating phonemic categories in the languages examined. The most common structure in their study involved languages with two categories of voicing. Before providing examples of voicing categories and elaborating on the differences found amongst distinct languages, it should be stated that VOT is a temporal measure representing a fraction of a second; therefore, it is most often denoted in milliseconds (ms).

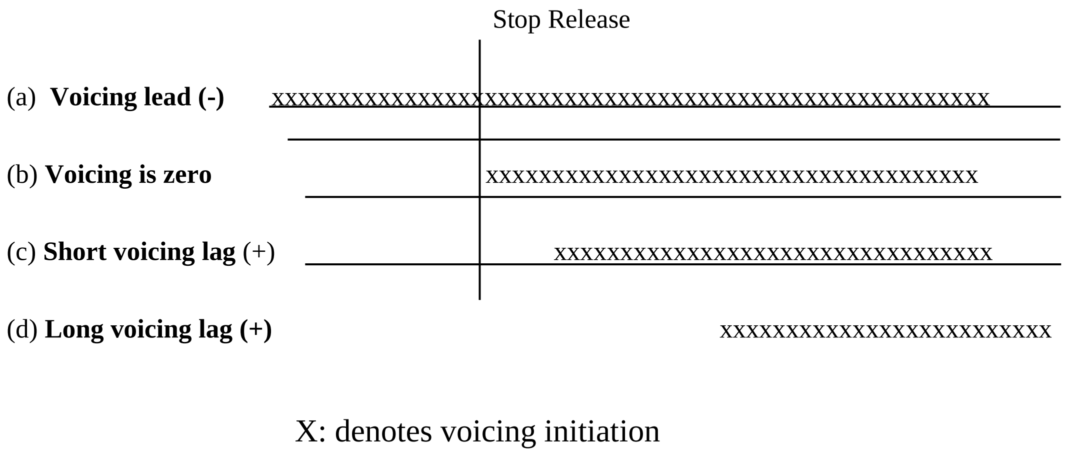


Figure 5.1 Examples of stops in initial position: (a) Prevoiced stops where voicing occurs before the stop release and is negative, (b) voiceless unaspirated stop release that occurs simultaneously with voicing, (c) short voicing lag, representing a voiceless aspirated stop where voicing occurs shortly after release and has a positive sign, (d) long voicing lag, representing a voiceless aspirated stop where voicing occurs shortly after release and has a positive sign.

To illustrate VOT, Figure 5.1 above shows the occurrences of voicing or vocal fold vibration that might happen in a number of languages when stops are in initial position. The figure shows that when phonetically voiced stops occur, the voicing starts before the closure release and, therefore, has a negative value; this is called a voicing lead.

VOT might have a zero value if the vocal cords start vibrating at the time of the occlusion release. However, when the vocal cords delay the vibration after the closure release, VOT has a positive value; this is called voicing lag. Voicing lags can be delayed briefly, as seen in voiceless unaspirated stops, or can be delayed for a longer period of time in voiceless aspirated stops.

To interpret the above in milliseconds, Lisker and Abramson (1964) identified prevoiced initial stops with negative measurements in the -40 to -80 ms range, while short lag stops were close to 0 ms, and aspirated initial stops are marked between 40 and 80 ms.

5.3 Voicing categories

Lisker and Abramson (1964) focused on the main categories found in 11 languages. They found that languages with two voicing categories show distinct manifestations of VOT where they divided these languages into those with a long VOT lag (above 50 ms) for voiceless stops in initial position and those with a short VOT lag(less than 30 ms). These are categorised as group 2a, as represented in Table 5.1, and this group includes languages such as English (Lisker & Abramson, 1964), German (Jessen & Ringen, 2002), Cantonese (Lisker & Abramson, 1964), and Mandarin (Chao & Chen, 2008; Chen et al., 2008).

Languages such as Spanish, French, and Dutch can be categorised in group 2b in Table 5.1 where voiced stops are negative to show a lead, and voiceless stops have a positive value (Lisker & Abramson, 1964).

For the Arabic language, however, reports have been contradictory. Some researchers assert that Arabic belongs to group 2a (Alotaibi & AlDahri, 2011; Mitleb, 2009; Al-Ani, 1970), while others claim that the language belongs to group 2b (Rahim & Kasim, 2009; Alghamdi, 1990, 2006; Khattab, 2002; Hussain, 1985; Mabrouk, 1981; Yeni-Komshian et al., 1977). Further discussion on Arabic is provided in section 5.6.

Category	Language	Prevoiced	Prevoiced aspirated	Short lag	Long lag aspirated
2a (short and long lag)	English	-	-	p	p^h
	German			0 to 30 ms	+40 to 80 ms
2b (lead and lag)	French	b	-	p	-
	Spanish	-80 to -40 ms		0 to 30 ms	
3	Thai	b	-	p	p^h
	Eastern Armenian	-40 to -80 ms		0 to 30 ms	+40 to 80 ms
4	Hindi	b	b^h	p	p^h
	Marathi	-40 to -80 ms	-120 to -40 ms	0 to 30 ms	+40 to 80 ms

Table 5.1 Summary of stop categories used in several languages (Lisker & Abramson, 1964). Phonetic symbols and position on the voicing continuum are given for each category.

Studies on plosive consonants in English in initial position have received a great deal of attention and show some consistency in terms of VOT, where the voiceless plosives /p/, /t/, and /k/ have shown results within the range of 30–100 ms. However, the voiced plosives /b/, /d/, and /g/ have been shown to either have a short lag of 0–25 ms or to be fully voiced, where they are negative between -100 and 0 ms (Lisker & Abramson 1964, 1967; Klatt, 1975; Docherty, 1992; Cho & Ladefoged, 1999).

It was reported in Lisker & Abramson (1964) that there were two sets of voiced plosives (/b, d, g/), where one had a positive short lag and the other had a negative voicing lead; therefore, voiced plosives might have negative values in English. However, the authors emphasized that a single speaker from their study was responsible for 95% of the occurrence of voicing lead. It is possible that the dialect or accent of that participant might have skewed the voiced lead results.

In her analysis of voiced plosives /b, d, g/, Keating (1984) reported that a voicing lead was present, while Docherty (1992) and Klatt (1975) maintained that there were short and long voicing lags for voiced plosives /b, d, g/, and voiceless plosives /p, t, k/, respectively. Whiteside and Irving's results (1998) reported that males had additionally produced voiced stops /b,d/ with voicing leads in comparison with females who had only prevoiced /b/.

In the next section, factors that may have an effect on VOT are discussed, including differences between dialects in particular languages.

5.4 Factors affecting VOT

VOT has been investigated in recent years to determine the relationship between VOT and the range of factors that play a role in shaping VOT. Therefore, for the purpose of this study, these factors are divided into two categories: speaker related and nonspeaker related.

5.4.1 Nonspeaker-related factors

5.4.1.1 Place of articulation of stops

VOT is a temporal-acoustic measure and therefore is expected to be sensitive to the context in which it is placed. One aspect of this context is place of articulation, and 28 languages have been investigated from this perspective (Cho & Ladefoged, 1999; Lisker & Abramson, 1964). There appears to be a general trend involving the place of articulation of the stops used and VOT duration. Specifically, the more posterior the point of occlusion, the longer the VOT duration is expected to be. Many studies have indicated that the common sequence related to length of VOT duration and place of articulation is velar > alveolar > bilabial (Cheng, 2013; Morris et al., 2008; Volaitis & Miller, 1992; Klatt, 1975; Lisker & Abramson, 1964). This pattern can be seen for both voiceless and voiced stops.

However, reports on different languages have often been conflicting; for instance, in British English ,Whiteside & Irving (1997, 1998) reported longer VOT duration for alveolar voiceless stops /t/ in comparison with voiceless velar /k/ stops. In addition, Lisker and Abramson (1964) described VOT duration for alveolar /t/ as shorter than that of bilabial /p/ for unaspirated stops in Tamil and for aspirated stops in Cantonese and eastern Armenian. Therefore, place of articulation plays a major role in VOT duration but it should be noted that this might be affected by cross-dialectal and cross-linguistic differences.

Cho & Ladefoged (1999, pp. 213–214) proposed six physiological and aerodynamic characteristics that might "*to some extent*" account for differences in VOT duration depending on place of articulation: (1) the volume behind the point of constriction, where the lower the volume behind the supralaryngeal cavity in velars, the longer it would take to fall to an adequate transglottal pressure for vocal cord vibration; (2) the volume in front of the point of constriction, as an increase in volume in contained air would cause a stronger obstruction that would lead to longer duration in velars, for example; (3) the articulatory movement, where the faster the movement (articulatory velocity where movement of the lower lip has a faster velocity than movement of the tongue dorsum), the faster the decrease in pressure behind the closure and the shorter the time before an appropriate build-up of transglottal pressure; (4) the size of the articulatory contact area, where an increase in the contact area would increase duration as it would entail a longer time for articulators to come together before achieving the right amount of transglottal pressure; (5) changes in the glottal opening area, where after a release the glottal opening area would decrease in size less rapidly for velars than alveolars or labials as the intraoral pressure would drop gradually; and (6) temporal adjustment between closure duration and VOT as there would be a fixed duration of vocal fold opening. Cho and Ladefoged (1999) stated that characteristics 1-4 are better at describing unaspirated or slightly aspirated stops while 5 and 6 hold better for aspirated stops.

5.4.1.2 Vowel context following stops

Another main factor that plays a role in VOT is the vowel following the stop Lisker and Abramson (1967) had proposed that this had no significant effect on VOT durations. However, later, other researchers observed longer VOT duration after high vowels (Weismer, 1979; Klatt, 1975). In addition, Whiteside and Irving (1997, 1998) showed that VOT durations are longer with high vowels (/i/ and /u/) and shorter with low vowels (/æ/ and /ɑ/). Furthermore, results from Nearey and Rochet (1994) support that stops followed by the high front vowel /i/ had a longer VOT duration than the high back vowel /u/, which had a longer VOT duration than the low vowel /æ/ in English and French.

5.4.1.3 Stimulus type

Another factor is stimulus or utterance type, where in American English, VOT durations for stops in words embedded in a carrier phrase were found to be shorter than for isolated words (Baran et al., 1977; Lisker & Abramson, 1967). Although the studies by Whiteside and Irving (1997, 1998) focused on gender differences, they had indirectly investigated stimulus type where their results showed that in isolated words, VOT duration was longer (Whiteside & Irving, 1998) than in the carrier phrase (Whiteside & Irving, 1997). Furthermore, Morris et al. (2008) examined voiced and voiceless stops in isolated syllables and reported longer VOT durations for isolated words. It is important to note that these results should be compared to those of other studies cautiously, as different methodologies were used. In addition, it is difficult to evaluate the study results comparatively, as different stimuli have been used; that is, some studies employed CV syllables, while others used CVC words (Ryalls et al., 1997; Smith, 1978).

5.4.1.4 Fundamental frequency

Fundamental frequency was shown to play a role in American English speakers for voiceless stops, where longer VOT durations were correlated with higher F0 when compared to voiceless stops which were produced with medium and low F0. However, voiced stops have not been found to show any effect from F0 (McCrea & Morris, 2005).

5.4.2 Speaker-related factors

5.4.2.1 Age

With the progression of age, some developmental changes are expected. In their study of British English, Whiteside and Marshall (2001) reported that children reach an adult-like phonetic categories and VOT duration at 11 years of age. However, Koenig (2000) showed that children presented with more variability in their VOT duration compared to adults. As age progresses, older adults show an inclination to produce larger variability, and syllable duration is shorter than in younger adults (Morris & Brown, 1994; Sweeting & Baken, 1982). However, the focus in this study is on the adult population where it might be considered more stable in contrast with children and older adults.

5.4.2.2 Ethnicity

Few studies have investigated speech communites , but Ryalls et al. (1997) compared young adult African Americans with Caucasian Americans (European descent) and found statistically significant differences between the two groups, where African American speakers showed more longer negative leads for voiced stops /b,d,g/ than Caucasian speakers.

5.4.2.3 Speech rate

Speaking rate has an effect on VOT durations because as speech rate increases, VOT duration for long lag voiceless stops has been shown to become shorter (Magloire & Green, 1999; Kessinger & Blumstein, 1997, 1998). However, speech rate does not seem to play a role in voiced and voiceless short lags stops (Magloire & Green, 1999; Kessinger & Blumstein, 1997, 1998).

5.4.2.4 Speaker sex

Speaker sex is another factor that might have an effect on VOT duration. However, there are inconsistencies in the results of VOT durational studies focusing on the linguistic variation between males and females. Both studies main focus was on different ethnicities, in the earlier study by Ryalls et al. (1997) sex showed to have a significant effect, where females exhibited longer VOT duration for voiceless stops /p,t,k/ and shorter negative leads for voiced stops than males. However, in a follow-up study, with older participants (50–70 years), the two groups showed no significant differences between their VOT durations, and no gender effects were found between these groups (Ryalls et al., 2004). This raises the following question: Did age play a role in the contradictory results of their study? Yao (2009) speculated on the results from Ryalls et al. (2004), suggesting that age might have affected their results and explaining that the older the participant, the less was the volume exerted from the lungs, leading to shorter aspiration durations, limiting the effects of gender differences in VOT duration.

Sweeting and Baken (1982) and Smith (1978) reported no significant differences between males and females in terms of voiceless plosives. Moreover, Smith (1978) described differences in which males exhibited longer VOT duration than females in terms of voiced plosives, which was replicated in the Whiteside and Irving (1998) study. Whiteside and Irving (1998) studied VOT in 10 participants (5 male, 5 female) aged 25–39 years. The outcomes were significant sex differences for voiceless (/t, k/) only, which showed that males had shorter VOT duration than females. In addition, voiced (/g/) had a significant difference. However, the data suggested the remaining voiced (/b, d/) had a longer voicing lag for males than females, while voiceless (/p/) did not show any differences between sexes. This finding is in contrast with an earlier study by Whiteside and Irving (1997) in which sex showed only significant differences for (/p, d/) where males had shorter VOT duration than females. However, remaining results for (/b, t, k, g/) showed a trend of males producing shorter VOT duration than females.

Swartz (1992) conducted a study only for (/t, d/) and found significant differences between males and females with men having shorter VOT duration than females. Robb et al. (2005) conducted a study where they analysed voiced stops (/b, d, g/) and voiceless stops (/p, t, k/) in two different environments (laboratory setting vs. non-laboratory setting). Results showed significant differences between sexes for voiceless stops where females showed longer VOT values than males in both settings. Voiceless stops had longer lags in non-laboratory setting than laboratory setting for males and females. However, differences were not found between sexes for voiced stops in both settings.

In a later study by Morris et al. (2008), however, the researchers controlled speech rate and compared VOT between males and females in isolated syllables for stops (/p/, /t/, /k/, /b/, /d/, and /g/) and vowels (/ɑ/, /i/, and /u/). While maintaining speech rate, no significant differences were found between male and female participants in isolated syllables. Although not significant, females showed a trend for longer VOT durations than males. In addition, place of articulation showed a similar trend as described in 5.4.1.1, where for voiced and voiceless stops, longer VOT durations were produced with a more posterior place of articulation. Furthermore, the following vowel showed similar results to Nearey and Rochet (1994), where high front vowel /i/ had a longer VOT duration than /u/, which had a longer VOT duration than low vowel /ɑ/. Overall, results appear to reveal a trend in which voiceless stops show sex differences (Whiteside & Irving, 1997, 1998; Ryalls et al., 1997; Swartz, 1992).

In the next section, dialectal differences found in VOT in a few languages, including English, are reviewed. Furthermore, the section assesses sex differences that appear in other languages included in the review (Spanish, Greek, and French).

5.5 VOT, English varieties, and dialects

In this section, studies that have been performed on English dialects and accents are reviewed.

5.5.1 English, varieties of English, and accents

In Table 5.2, the results from American English voiced (/b, d, g/) and voiceless (/p, t, k/) stops (Lisker & Abramson, 1964), British English and more specifically Southern British speakers (Docherty, 1992), and Scottish English from Aberdeen (Watt & Yurkova, 2007) are presented.

Plosives		**American English (AE)** (Lisker & Abramson, 1964)	**Southern British English (SBE) Speakers** (Docherty, 1992)	**Scottish English (SE) (Aberdeen)** (Watt & Yurkova, 2007)
Voiceless	/p/	58	42	63
	/t/	70	64	72
	/k/	80	62	77
Voiced	/b/	1	15	-17
	/d/	5	21	-32
	/g/	21	27	25

Table 5.2 Mean VOT duration in milliseconds for voiced (/b, d, g/) and voiceless (/p, t, k/) stops in three dialects of English (Watt & Yurkova, 2007; Docherty, 1992; Lisker & Abramson, 1964).

Although the methodologies adopted in these studies are different, a visual inspection of the data in Table 5.2 shows voiceless stops having longer VOT durations in American English stops than Southern British English (SBE) ones. For labial /p/, the difference was 16 ms, while the difference was 6 ms for alveolar /t/, and the difference between velar /k/ was 18 ms. In addition, differences between SE and AE were less where the mean differences for voiceless stops were 3.3 ms. On the other hand, for voiced stops, British English showed longer VOT durations than American English, where for labial /b/, the difference was 14 ms and alveolar /d/ was 16 ms. In contrast with the voiceless velar /k/, /g/ had the least difference at 6 ms. Furthermore, SBE had shorter VOT durations for voiceless stops than SE, where differences for /p/,/t/,/k/ were 21 ms, 8 ms and 15ms respectively. Interestingly the SE results revealed negative leads for /b/ at -17 ms and /d/ at -32 ms, which might show that voicing categories are dependent on the English dialect spoken, although /g/ had similar results through all English dialects spoken.

5.5.2 Other Varieties of English

Table 5.3 lists a few studies on a range of English dialects and varieties of the English language.

Syrdal (1996) found no significant effect from dialect or sex or interaction between them for VOT durations for /p/ and /b/. In her study, the low number of participants and identification of the dialect based on place rather than dialect (p.438) were confounds that had not been controlled.

In a study by Fowler et al. (2008), they compared Canadian English and American English, in addition to French, where they found no sex or dialect differences between the dialects of English (see Table 5.3). However, the study was restricted to voiceless stops /p, t, k/, and the age range was wide (between 18 and 57 years). Interestingly, the results from Robb et al. (2005), where they collected the data from the same state

(Connecticut) for their American English participants, found sex differences for voiceless stops. This might be due to methodological differences.

A study on another variety of American English, Indian English (IE), which is a recognised dialect of American English (AE) (Lawler, 2005), was carried out by Awan and Stine (2011) (see Table 5.3). In their study, the results showed a significant difference in which IE exhibited shorter VOT durations than AE. In addition, a significant interaction between sex and dialect was found, where IE and AE males showed shorter VOT durations than IE and AE females. Interestingly, sex showed a significant effect only in AE for /p/ and /t/ in initial and medial potions, where males had shorter VOT durations than females. This supported the results of studies showing differences between sexes in relation to voiceless stops.

In a study of another variety in British English (Indian British English (IBE)) (Kirkham, 2011), results showed a significant difference between male Asian British English and male British English (BE) speakers for the voiceless stop /t/. The IBE speakers showed shorter VOT durations than the BE speakers. In addition, female IBE speakers showed shorter VOT durations than BE females. The author attributed this difference to the fact that Asian females spoke more rapidly. However, for the voiced stop /d/, the results did not show any significant differences between the varieties of British English. This study was limited in terms of sample size, as only eight participants were chosen, but it still offers insight into differences in VOT between British English varieties.

5.5.3 Studies on dialects in other languages

A few studies have focused on VOT differences between dialects in different languages such as French (Fowler et al., 2008; Caramazza & Yeni-Komshian, 1974), Spanish (Lain, 2009; Rosner et al., 2000), and Greek (Jong Kong et al., 2012).

VOT studies in French dialects showed some contrasting results where Caramazza and Yeni-Komshian (1974) investigated differences between Canadian French (CF) and speakers from France (FF). All participants were monolingual French speakers of their dialects. The results showed a significant difference between CF and FF, where in both voiced and voiceless stops, FF had shorter VOT durations than CF. In contrast in a more recent study by Fowler et al. (2008) showed no differences between CF and FF. It is possible that the differences between the FF dialects (Nantes for Caramazza and Yeni-Komshian (1974) and Paris for Fowler et al. (2008)) might have been cause for differences between the studies.

Studies VOT in Spanish dialects, Williams (1977) did not find any differences amongst Peruvian, Guatemalan, and Venezuelan Spanish dialects. Rosner et al.'s (2000) recently compared Castilian Spanish with the dialects reported in Williams (1977), he found differences between Castilian and Peruvian, Guatemalan, and Venezuelan Spanish dialects where durations for voiced stops in Castilian being shorter than in the Guatemalan and Peruvian dialects. Differences related to voiceless stops /p,t,k/ between Castilian Spanish and Latin American dialects were more complex; for /p/, Castilian had statistically longer VOT duration than Guatemalan but had statistically shorter VOT duration than Peruvian and Venezuelan. In addition, for /k/ Guatemalan showed a significantly shorter VOT lag than Castilian.

In a study of two Greek dialects (Jong Kong et al., 2012), between speakers from Thessaloniki (North Central Greece) and Crete. The results showed that dialects interacted significantly with place of articulation, where the Cretan dialect showed a shorter mean duration difference for voiced stops than the Thessalonikan dialect. In addition, place of articulation and sex showed a significant interaction, where males exhibited longer voicing leads than female speakers amongst Thessalonikan speakers, while female Cretan speakers exhibited a longer VOT lead duration than males.

Study	Dialects	Results		Comments and limitations
		Dialects	Gender	
Syrdal (1996)	10 American dialects	No differences found between dialects in /p/ and /b/ VOT duration.	No sex differences	Restriction to labial stops /p, b/ Low number of participants
Fowler et al. (2008)	Canadian English and American English (Connecticut)	No differences between dialects	No sex differences	Restriction to voiceless stops /p, t, k/ Wide age range (18-57 years)
Awan & Stine (2011)	Indian English (IE) and American English	Significant differences, in that IE was shorter than AE for /p/ and /t/ in initial and medial position. Significant interaction between dialect and gender wherein AE and IE males had shorter VOT than females in both dialects.	AE males had shorter VOT than females. No sex differences for IE.	Attributed differences to effects from Indian language Restriction to voiceless stops /p, t/ Language of participants from India not restricted (Punjabi, Guajarati, Marathi, Nepali, Kanaada, Bengali, and Telgu)
Kirkham (2011)	Indian British English (IBE) and British English (BE)	For /t/, IBE showed shorter duration than BE. For /d/, there were no statistical differences but tended to show shorter duration for IBE than BE.	NA	Attributed differences to faster speech rate for IBE Limited number (4 participants from each dialect and gender) Restriction to alveolar stops

Table 5.3 Results on VOT from different studies on varieties and dialects of English (Awan & Stine, 2011; Kirkham, 2011; Fowler et al., 2008; Syrdal, 1996).

5.6 Studies of VOT in Arabic

5.6.1 Plain stops

In this section, published studies on VOT for Arabic are reviewed. Following this, a section on emphatic stops is provided; the emphatic stop is a distinctive feature in Arabic involving a secondary articulation (Khattab et al., 2006; Heselwood, 1996), as described in more detail in the next section.

In a study on Iraqi Arabic, (Al-Ani, 1970) himself participated in one of the first studies on stops in this language. He used isolated words with voiceless stops /t, k/ in initial position. Results showed that values for /t/ were 40–60 ms, and those for /k/were 60–80 ms. As there was only one informant, the results cannot be generalised to all Iraqi dialects because there are differences in the productions of speakers from different religions (Blanc, 1964), as well as regional variance (Alghamdi, 1990). However, in terms of place of articulation, the study showed VOT durations were shorter for /t/ compared to /k/. The subject in this study was male and an experienced phonetician; although the study gives insight into the Arabic language, the use of only one subject limits the wider applicability of these results.

Lebanese Arabic was the focus of a study by Yeni-Komshian et al. (1977), who used words in a text for the voiceless stops /t, k/, and the voiced stops /b, d/, as well as emphatics /tˤ, dˤ/ in initial position. Results generated from eight adult participants in different vowel contexts were shown. The findings demonstrated that the VOT values for voiced /b, d, g/ were all negative. However, the words used were not minimal pairs and varied in the number of syllables. Voicing was absent for voiceless stops, and VOT values were shorter in the anterior position of articulation in the order of /t/

< /k/. In addition, emphatic /tˤ/ was reported to have a shorter VOT value (23 ms) than that of /t/ (25 ms). The syllables were not matched in the analysis; therefore, the comparison between the syllables is limited. For voiced stops (/b, d/), results showed they had leads (negative values) with values for /b/ (-70 ms) and /d/ (67 ms); for emphatic /dˤ/, it was -68 ms. These results showed that Arabic has lead and lag values on the voicing continuum. In the Yeni-Komshian et al. (1977) study, significant statistical results for VOT duration in high vowels /i, u/ were found in comparison to the lower vowel /a/. The study had limitations in that the lengths of syllables varied across the words chosen for analysis. Although the origins of the speakers in this study were Lebanese, they were instructed to speak standard Arabic rather than their dialect. Furthermore, the study had only male participants, so the effects of gender could not be investigated. In addition, no statistical tests were performed for place of articulation.

Flege (1982) took a similar approach in his study of the production of voiceless /t, k/ and voiced /b, d/ stops in initial position in words that were minimal pairs but consisted of nonsense words and real words. His subjects were six Saudi male speakers that originated from the central and northern parts of Saudi Arabia. The results showed that voicing was absent in their production of the stops and demonstrated long voicing lead VOT values for both the voiced stops /b/ (-85 ms) and /d/ (-82 ms), compared to short voicing lags for the voiceless stops /t/ (36.8 ms) and /k/ (52.4 ms). It was from these results that Flege claimed Arabic is neither from group 2a or group 2b but is considered to lie between them (refer to Table 5.1), proposing that each language is distinct in its representation on the voicing continuum. However, the effects from bilingualism on voicing might be the reason for the results, as was mentioned in other studies (e.g. Caramazza & Yeni-Komshian, 1974), and this may have affected the results. In addition, the results are limited firstly by the low number of speakers and secondly by their coming from different parts of Saudi Arabia, raising the issue of potential dialectical difference that might have been the reason for their proposal of where Arabic lies in the VOT category .

Northern speakers from Saudi Arabia have similar characteristics to speakers from Jordan, where Mitleb (2009) conducted a study on four male undergraduate students in the North of Jordan (Al Mafraq) related to voiced /d, g/, and voiceless /t, k/ stops in initial position for minimal pair words in two vowel contexts (Cam and Ca:m), where C represents the stop consonant chosen in the study. The words were embedded in carrier sentences. For voiced consonants, the results for /d/ were 10 ms in the short vowel environment and 23 ms in the long vowel environment, while for /g/ they were 15 ms in the short vowel environment and 20 ms in the long vowel environment. For voiceless consonants, the results for /t/ were 37 ms in the short vowel /a/ environment and 64 ms in the long vowel /a:/ environment, while for /k/ they were 39 ms in the short vowel /a/ environment and 60 ms in the long vowel /a:/ environment. The main results showed significant differences between /t/ and /d/ in the long vowel environment, while differences were significant for both the short and long vowel context for /t/. For /k/ and /g/, the results showed a significant difference in voicing contrast for both short and long vowels. The length contrast between the vowels was also significant. Mitleb's (2009) results were not significant for place of articulation for both voiced and voiceless stops. The study showed a significant difference between voiced and voiceless stops but showed VOT results were all lags, but placed Arabic in category 2a rather than 2b (see Table 5.1), in accordance with Al-Ani (1970). In addition, this study reported contrasting results to those found in the literature on place of articulation effects on VOT durations, as velars /k/ and /g/ were no different from alveolars /t/ and /d/ in this study. An interesting finding was the long and short vowel effect, as this showed length factor on VOT duration because long vowels had longer VOT duration than short vowels.

A study on Kuwaiti Arabic focused on voiceless stops (/t, k/) in initial position in words embedded in a carrier phrase (Mabrouk, 1981). The results revealed that /t/ had a VOT duration of 30 ms, while that of /k/ was 35 ms. Although the author did not indicate his methodology, VOT for /t, k/ results are similar to those of Mitleb's (2009) study, where only a 5 ms difference was evident in /t/ and /k/ VOT durations. However, results for Mabrouk (1981) share a common limitation with (Al-Ani, 1970) as only they themselves were the informants used in their studies. Furthermore, vowel context was not indicated as another limitation related to the use of his results.

Hussain (1985) performed a study using two informants, himself (from Qatar) and another male participant (not specified). His research was on the Gulf dialect that is spoken by Arabs from around the Arabian Peninsula[8]. He focused on voiced stops /b, d/, and voiceless stops /t, k/ in initial position in the vowel context of /a, a:, i:/ that were in minimal word pairs embedded in a carrier phrase that included real and nonsense words. The results showed that /b/ and /d/ indeed had a voicing lead, with VOT durations of -113.5 ms and -83 ms, respectively. On the other hand, the voiceless stops, /t/ and /k/ had a lag duration of a 16 ms and 26 ms, respectively. Different vowel contexts did show variations in the results for voiceless stops. Yet, this research shares the same limitations as the previous studies, in that few

[8] Gulf dialect is a general term for the all dialects in the Arabian Peninsula except for Yemeni dialects which is distinctive in its features compared to Arabian Peninsula dialects.

informants were recruited, and therefore the results might not be representative of the dialect. Furthermore, the *Gulf dialect* is a general term indicating all speakers from the Arabian Peninsula as indicated in Chapter 2; therefore, the results were confined to a dialect that is shared by many speakers with different dialectal patterns within the region.

In his study of the Ghamdi dialect, which is spoken in Saudi Arabia by the tribe of Ghamd in the southern region, Alghamdi (1990) recruited 22 participants between the ages of 18 and 32 years. He selected voiced stops /b/, /d/, and voiceless stops /t, k/ as a focus of study, as he claimed that these are the most consistent between dialects, in addition to the emphatic alveolar /tˤ/. The vowel context was /a, a:, i:/. Stops were in initial position in a carrier phrase spoken by participants in Riyadh. The words chosen ended with a geminate consonant for the short vowel /a/ and had the structure CVCC. In addition, words were not minimal pairs and sometimes had an ending consonant structure of CV:C, where the endings /b/, /d/, /m/, /n/, and /l/ were interchangeable. For the voiced stops, /b/ had a voicing lead, where the order of VOT values by vowel context for /a, a:, i:/, were -64.4, -73.3, and -77.5 ms, respectively. For /d/, with the same order of VOT magnitude by vowel context was observed; the values were -69, -70.5, and -78.3 ms, respectively. Meanwhile, results for the voiceless stops /t/ and /k/ were: 25, 27.8, and 38.1 ms for /t/ and 30.3, 34.5, and 50.3 ms for /k/ for the vowels /a/, /a:/, and /i:/, respectively. Alghamdi (1990) made conclusions regarding the factors affecting VOT in his study. First was place of articulation, where the further back the point of articulation, the longer the VOT duration, as seen in both voiceless and voiced cases where voiced /b/ was shorter than /d/ and voiceless /k/ was longer than /t/. The second was vowel context, where high and long vowels showed a longer VOT duration for both leads and lags. These results are in line with those reported for place of articulation (Cho & Ladefoged, 1999; Whiteside & Irving, 1997, 1998; Klatt, 1975; Lisker & Abramson, 1964) and vowel context (Whiteside & Irving, 1997, 1998; Nearey & Rochet, 1994).

A few issues limited this study. For instance, the criteria for inclusion of participants were that they had to have lived in the southern region until the age of 17 years, but the data were collected in Riyadh, mainly from students and colleagues. As proposed by AlAwaji and Alshahwan (2012), the dialect that these participants adopted might have shifted from their native dialect to the White dialect or Najdi dialect, thereby limiting the applicability of the results to those participating in the study or who had similarly shifted from the Ghamdi to the Najdi dialect. Furthermore, in terms of the tests words, although syllables used for comparison were matched. However, remaining context of the words were different. The results may also have been affected by the final geminate consonant at the end of the words. Furthermore, only male participants were included.

Another study of Saudi participants who spoke modern standard Arabic (MSA), (AlDahri & Alotaibi, 2010) recruited 10 male participants. They were selected carefully by the authors because they were masters in reciting the Quran[9] (refer to chapter 2); they were also instructed in using MSA in their production for their study. The choice of stops was voiceless /t/ and voiced /d/ in medial position followed by the vowel /a/ in two words with a CVCVCV structure. The words /natara/ and /nadara/, meaning *exaggerate* and *fell* respectively, were embedded in a carrier phrase. The

[9] A Master of Recitation of the Holy Quran is a person who has memorised the Quran in the different readings.

results were that voiceless /t/ had a voicing lag of 56 ms and voiced /d/ had a 16 ms voicing lag. These results can be compared with those of Miltleb’s (2009) study, although the focus of the current study was on initial position stops, with the intention of showing different results for voiced and voiceless stops from informants within the same region. Furthermore, it is hard to claim that purely MSA was spoken, and whether the dialect of the participants had an effect on their speech in MSA form needs to be determined.

A further study on Iraqi Arabic (Rahim & Kasim, 2009) focused on Mosuli Arabic, which is a variety of Iraqi Arabic spoken by people in Mosul. In one part of the study, the researchers included four female and six male participants aged 21–52 years. The voiceless stops were /p, t, k/, while the voiced stops were /b, d, g/. All words were monosyllabic words except one, which was multisyllabic. The vowel /e:/ was used in words for the bilabial voiced/voiceless contrast for /p, b/, while the vowel /i:/ was used in words for the alveolar and velar voiced /d, g/ and voiceless /t, k/ contrast. Although no statistical results were used in their study, the findings showed differences in voicing contrast, where voiced stops had voicing leads (negative) in VOT durations, while voiceless stops had lags (positive). Furthermore, for voiceless stops, in terms of place of articulation, it was confirmed that the more posterior the place, the longer the VOT duration in the order of /p/ (16.85 ms) /< t/ (41 ms) /< k/ (56.5 ms). The same pattern was seen in voiced stops, where /b/ (-57.83 ms) /< g/ (-78.1 ms); however, voiced /d/ showed the longest VOT duration at -98.3 ms.

One of the objectives of this study (Rahim & Kasim, 2009) was to compare the results between voiced and voiceless stops (/p, t, k/ and /b, d, g/) with a high vowel /i:/ and a low vowel /a;/. Minimal pair words were selected for /b, g, k/, while for the remaining words, minimal pairs were not used and differed in both syllable length and the consonant ending the word. The results for vowel context were confirmed from the literature, where the higher the vowel, the longer the VOT duration for all words. In addition, the results further supported the claim that the more anterior the place of articulation is, the shorter the VOT duration will be. One of the limitations in this study was the lack of statistical tests, which would have confirmed differences between the VOT results. In addition, it did not investigate gender differences between males and females for VOT. Furthermore, the age of participants had a wide range. Although the effects of age are still inconclusive, it should have been more controlled, as this could have affected the VOT results. Finally, results were compared between different contexts and different lengths because the ending consonants were different.

5.6.2 Emphatics in Arabic

Arabic is distinctive in its productions of emphatics which are /tˤ, dˤ, sˤ, ðˤ/, although /dˤ/ is not used for the Arabic dialects investigated in this study as described in chapter 2. The secondary articulation that is involved in the production of emphatics is described as follows: The tongue dorsum is retracted into the upper pharynx, with a lowered palatine dorsum and mildly retracted tongue root and epiglottis. The effects on formants are a rise in the first formant frequency (F1) and a lowering in the second formant frequency (F2) (Abudalbuh, 2010; Khattab et al., 2006). A few studies have focused on the VOT values for emphatic stops (Abudalbuh, 2010; Almbark, 2009; Bellem, 2008; Khattab et al., 2006; Rifaat, 2003; Heselwood, 1996; Jesry, 1996; Yeni-Komshian et al., 1977), and this literature will be reviewed here.

In a study of a variety of Arabic, Rifaat (2003) studied colloquial Egyptian Arabic in five males and five females aged 19–25 years. The voiced stops were /d, g/, the voiceless stops were /t, k/, and the emphatics /tˤ, dˤ/ were investigated in minimal word pairs. The author did not specify the vowel context except that long and short vowels were used and had not specified the words used in his study. In one of the few studies that have investigated gender statistically, the results showed no differences between male and female VOT durations for voiced and voiceless stops and no significant results between long and short vowel contexts. The key aspect was that no significant differences were found between plain and emphatic stops. Rifaat (2003) reported that voicing had an effect where voiced consonants had leads (negative) while voiceless ones had lags. He reported a significant difference between places of articulation, where for voiceless stops, velar /k/ had a longer VOT duration (40 ms) than alveolar /t/ (20 ms), while for voiced ones, /d/ had a longer lead (-80 ms) than velar /g/ (-70 ms). One of the main limitations of this study was that the methodology was not specified. Furthermore, colloquial Egyptian Arabic is a general term that encompasses more than one dialect, including the Cairene, Nubian, and southern (Saaidi) accents (Bellem, 2008).

Syrian Arabic was the focus of the Jesry (1996) study, which included three participants who spoke Syrian Arabic and were tested on initial voiceless stops /t, tˤ, k, q/ in a carrier phrase that had short vowels /a, i, u/. The results showed the following in the three environments: for /t/, the VOT lengths were 24, 29, and 23 ms; for /k/ they were 32, 30, and 33 ms; and for uvular /q/, the results were 33, 31, and 22 ms and for /tˤ/, 24 ms in all three vowel environments. The following can be concluded for voiceless stops: VOT duration increased with place of articulation and emphatics, while the vowel environment did not show a consistent effect when vowels were short. The order was /tˤ < t < q < k/, which is in line with a longer VOT for more posterior articulation. The emphatic /tˤ/ was shorter in duration than the remaining voiceless stops; the differences between stops did not show a consistent significance. These can be considered short lags, as shown in the results for English voiceless stops. However, for voiced stops, VOT durations were in the order of short vowels /a, i, u/ as follows: for /b/, -67, -67, and -75 ms; for /d/, -65, -67, and -68 ms; and for /dˤ/, -69, -62, and -74 ms. It can be deduced that voiced stops did not show a significant difference in place of articulation or emphatics, while vowel context showed a slight increase in voicing lead when followed by high back vowel /u/. With respect to voicing lead in Jesry's study, the voicing lead order was /b < dˤ < d/. In this study of Syrian Arabic in the context of short vowels, VOT showed minor differences in duration between voiced and voiceless phonemes. It would be interesting to observe the difference in long vowel context to see if it had any effects. The number of participants in the study was low, and the dialects of participants in the study were not controlled or described by the author.

In another study of Syrian Arabic, Almbark (2009) investigated the difference between two Syrian dialects, specifically the Aleppian (speakers from Aleppo, north Syria) and Damascene (speakers from Damascus, south Syria) dialects. She recruited four speakers (two males and two females) from each dialect and compared initial emphatic stops (/tˤ, dˤ) to their nonemphatic cognates (/t, d/) in addition to fricative emphatics. The results showed no significant differences between gender and region; although females showed greater VOT lag durations than males for /t, tˤ/, the difference did not reach a significant level. Voiced stops showed a lead while voiceless stops exhibited a lag, which was consistent with the Jesry (1996) study.

To further elaborate on the results for emphatic stops, Yeni-Komshian et al. (1977) used emphatic /tˤ, dˤ/ and plain /t, d/ in CV sequences with the short vowels /a, i, u/. Voiced stops were negative, where emphatic /dˤ/ exhibited values of -65, -50, and -65 ms, and /d/ exhibited -60, -40, and -75 ms, for /a, i, u/, respectively. For voiceless stops, the results for emphatic /tˤ/ were 20, 35, and 30 ms, while for /t/ they were 20, 30, and 25 ms. The findings for voiceless stops showed that values in the /i/ context has the longest duration, while /a/ has the shortest. In addition, the shortest duration was shared between emphatic /tˤ/ and /t/. However, voiced stops showed that /i/ had the shortest lead (- 45 ms) compared to /a/ (- 62.5 ms) and /u/ (-70 ms). With respect to the order of voiced and voiceless stops, there seems to be an overlap between emphatic and nonemphatic ones, which supports Jesry (1996). Bellem (2008) pointed out that the results from the above studies are not uniform between Arabic dialects. She raised the issue whereby a pattern between Levantine urban dialects might be observed when compared with Bedouin origin dialects.

Heselwood (1996) discussed the contrast between Muslim Baghdadi (spoken in Baghdad, Iraq) and Cairene Arabic (spoken in Cairo, Egypt) productions of voiceless plain /t/ and emphatic /tˤ/ in initial and medial positions amongst four males from each dialect. His approach was based on a synchronic and diachronic analysis of the two dialects selected for his study, which is one of two studies to the knowledge of the researcher that compared dialects of Arabic in a systematic approach (the other study was Almbark, 2009). In his study, the words chosen were /taha/ ‘to go astray’ for /t/ and /tˤahin/ ‘a cook’ for /tˤ/ in initial position, and /t/ in /ʃitat/ ‘scattered’ and /tˤ/ in /χatˤatˤ/ ‘calligrapher’ for medial position. Words were said once in isolation and again embedded in a carrier phrase. The results are given in Table 5.4, which shows the VOT duration for initial and medial position for voiceless emphatic and plain stops.

	Baghdadi		Cairene	
	Initial	Medial	Initial	Medial
t	/taha/	/ʃitat/	/taha/	/ʃitat/
	39.86	35	31.5	35
t^{ʕ}	/t^{ʕ}ahin/	/χat^{ʕ}a:t^{ʕ}/	/t^{ʕ}ahin/	/χat^{ʕ}a:t^{ʕ}/
	15.13	15.87	39.62	29.65

Table 5.4 Mean VOT durations for voiceless emphatic (t^{ʕ}) and plain (t) voiceless alveolar stops in initial and medial position for Heselwood (1996).

Heselwood (1996) found that Cairene participants produced emphatic and plain stops as voiceless and aspirated and that the VOT values between them were similar, thereby showing a similar pattern to previously reported ones (Almbark, 2009; Rifaat, 2003; Yeni-Komshian et al., 1977), in which no differences were shown between plain and emphatic stops. However, for the Baghdadi Muslim dialect, there was a clear distinction between emphatic and plain stops, where plain /t/ was produced with aspiration, while emphatic /t^{ʕ}/ showed a short lag, with the values almost half those for plain /t/; these results were similar to those of the Jesry (1996) study. In essence, Heselwood (1996) had described this in his paper where he transcribed the aspirated emphatic /t^{hʕ}/ for Cairene while for Muslim Baghdadi, it was transcribed as /t^{ʕ}/, highlighting the differences stemmed from what might be Bedouin origin and sedentary origin differences. Furthermore, Heselwood (1996) highlighted that it would not be surprising that this might have an effect on modal voice phonation difference between dialects (p.37).

Bellem (2008) had later noted these differences and highlighted that in some dialects of Arabic, such as in the Iraqi dialect; descriptive grammars show /t/ as aspirated while /tˤ/ is not, while other dialects such as Cairene and Damascene do not show this distinction. Her interpretation was that speakers of Bedouin origin such as those in Iraq showed this distinction; she went on to examine another dialect of Bedouin origin in the study on Saudi Arabic discussed below.

Bellem (2008) selected seven speakers from Saudi Arabia from the King Abdulaziz City for Science and Technology (KACST) database, which was recorded between 1986 and 1987 in Riyadh. Target consonants were presented in different positions (initial, medial, final) within a carrier frame, including three short vowels /a, u, i/. Only word initial and medial consonants were analysed for voiceless stops in relation to stops /t, tˤ, k, q/, while initial was chosen for the voiced consonants /b, d, dˤ/. In addition, geminate and single words were included in the study. Results for voiceless stops were as follows for short vowels: /t/ 35 ms, /tˤ/ 16 ms, /k/ 44 ms, and /q/ 18 ms. The voiceless stops /tˤ/ and /q/ were almost half of /t/ and /k/. However, for voiced stops /b, d, dˤ/, the VOT values were -63, -66, and -84 ms, respectively. The results showed similarity to the findings from Heselwood's (1996) Baghdadi participants. However, Bellem (2008) observed differences in two participants for voiceless stops, where she observed that /t/ and /k/ VOT values were lower than those of the other participants. In her analysis, she viewed these discrepancies as resulting from the effect of the participant's birthplace on dialect. However, from a different point of view, they may have emerged due to individual variation between speakers. Furthermore, the recordings of these individuals were made in Riyadh, and the effects of one dialect may have transferred to their speech, as previously mentioned in relation to Alghamdi's (1990) study. It would be interesting to interpret these results from a statistical standpoint, but as in Heselwood's (2006) work, no statistical results were offered. As Bellem (2008) described in her thesis, it is possible that Arabic has a three-voicing category, with the emphatic /tˤ/ and voiceless uvular stop /q/ showing a short lag, while /t, k/ show a long lag, and voiced stops /b, d, g/ are prevoiced and have leads in Arabic.

Khattab et al. (2006) studied emphasis by examining the t/tˤ opposition in initial position using monosyllabic and disyllabic words. In their study, they recruited five males and two females from Irbid (north of Jordan), as well as three females from Amman (capital of Jordan). They found that VOT durations for emphatic consonants were shorter than plain consonants for both male and female participants. It is worth noting that they reported significant difference between sexes where males showed shorter VOT duration in their emphatic stops than females did (see Table 5.5).

	Male	Females
t	36.4	39.6
tˤ	18.2	26.4

Table 5.5 Mean VOT durations (ms) for plain and emphatic /t/ for Jordanian males and females: Males showed shorter VOT duration than females. In addition, plain /t/ had shorter VOT duration than emphatic /tˤ/ for Khattab et al. (2006).

In addition, they found a significant difference in that males had shorter VOT duration for plain /t/ than females. In their analysis of the results, they attributed differences between males and females to other factors such as gender differences rather than emphasis. As female data had discrepancies related to interdialectal differences, the researchers did not draw a conclusion related to the interaction between gender and emphasis. However, they considered that the differences might result from interaction amongst emphasis, gender, and social class. Finally, Khattab et al. (2006) mentioned that some Arabic dialects might have a three-voicing category based on a sociophonetic construct as described by Cho and Ladefoged (1999) with voice leads, short voice lags, and long voice lags (p.28).

In another study of Jordanian Arabic, Abudalbuh (2010) recruited 22 native speakers of this language (12 males and 10 females) aged 19–23 years from the northern part of Jordan. Voiced /d/ and voiceless stop /t/ and their emphatic counterparts voiced /dˤ/ and voiceless /tˤ/ were in initial position in minimal pair words with the following vowels /æ, i, u/. The results showed that both voiced and voiceless sounds were all positive for voicing lags; however, voiced stops /d, dˤ/ were shorter at 14 ms than voiceless stops /t, tˤ/ at 44 ms. Emphasis showed a significant effect, where plain stops (37 ms) were longer than emphatic stops (21 ms). Significant interaction was found between voicing and emphasis, where only voiceless stops showed VOT durational difference between plain /t/ 59 ms and emphatic /tˤ/ 28 ms, while no differences were found between /d/ 15 ms and /dˤ/ 13 ms. Gender did not reach significance; furthermore, there were no significant interactions between gender and emphasis or voicing. Vowel context played a significant role, where front vowel /i/ had a longer duration (36 ms) than the vowels /u/ (30 ms) and /æ/ (22 ms). Furthermore, Abudalbuh (2010) found a significant interaction between vowel quality and voicing, where for only voiceless stops, vowels /æ/ and /u/ were statistically significant, while for voiced stops no significance was found between vowels. He found no significant interaction between vowel quality and emphasis but did find a significant interaction between vowel quality and gender, where females tended to show statistical VOT difference between vowel /i/ and /u/ but not males. Finally, a significant interaction amongst gender, vowel quality, and voicing was observed, where for voiceless stops, /i/ was longer (64 ms) than /u/ (46 ms) for females, but this effect was not found for males, where /i/ was 41 ms and /u/ was 45 ms. Results from Egyptian Arabic (Rifaat, 2003) and Syrian Arabic (Almbark, 2009) showed no differences between emphatics and plain stops while Saudi results (Bellem, 2008), Baghdadi Muslim (Heselwood, 1996) and Jordanian Arabic (Abudalbuh, 2010; Khattab et al., 2006) showed differences between emphatic and plain stops. These results support Bellem's (2008) hypothesis that was originally made by Heselwood (1996) that emphasis might be dependent on Arabic origin where Bedouin-origin Arabic presents differences between emphatic and plain, while that of the non-Bedouin origin does not. However, results on Lebanese Arabic (Yeni-Komshian et al. ,1977), which might not be considered of Bedouin origin, showed differences between emphatic and plain stops.

To summarise, there seem to be differences between mean VOT values for voiceless and voiced stops in Arabic in a number of studies that have been addressed in this section (see Figure 5.2 and Figure 5.3), and emphatic stops (see Figure 5.4). However, in the absence of a consistent and systemic methodology, comparing the results between dialects in any language is difficult. Focus on Arabian Gulf dialects is even less with studies limited by a low number of participants or not controlling the dialects of their participants (AlDahri & Alotaibi, 2010; Bellem, 2008; Alghamdi, 1990; Hussain, 1985; Flege, 1982; Mabrouk, 1981). In addition, the previous studies have focused on male participants only. Studies on gender difference in VOT in Arabic are few (Abudalbuh, 2010; Almbark, 2009; Khattab et al., 2006; Rifaat, 2003), and they share the common limitations to studies on VOT in dialects in Arabic. Therefore, one of the main focuses in this study is an exploration of differences between two dialects of Arabic (Najdi and Bahraini) using a consistent methodology.

In addition, this work will assess differences between sexes as the second main question. Voicing, place of articulation, vowel context, and emphasis will be studied for voiceless stops /t, k/; voiced stops /b, d/; and emphatics /tˤ/. The research questions are laid out in the next section.

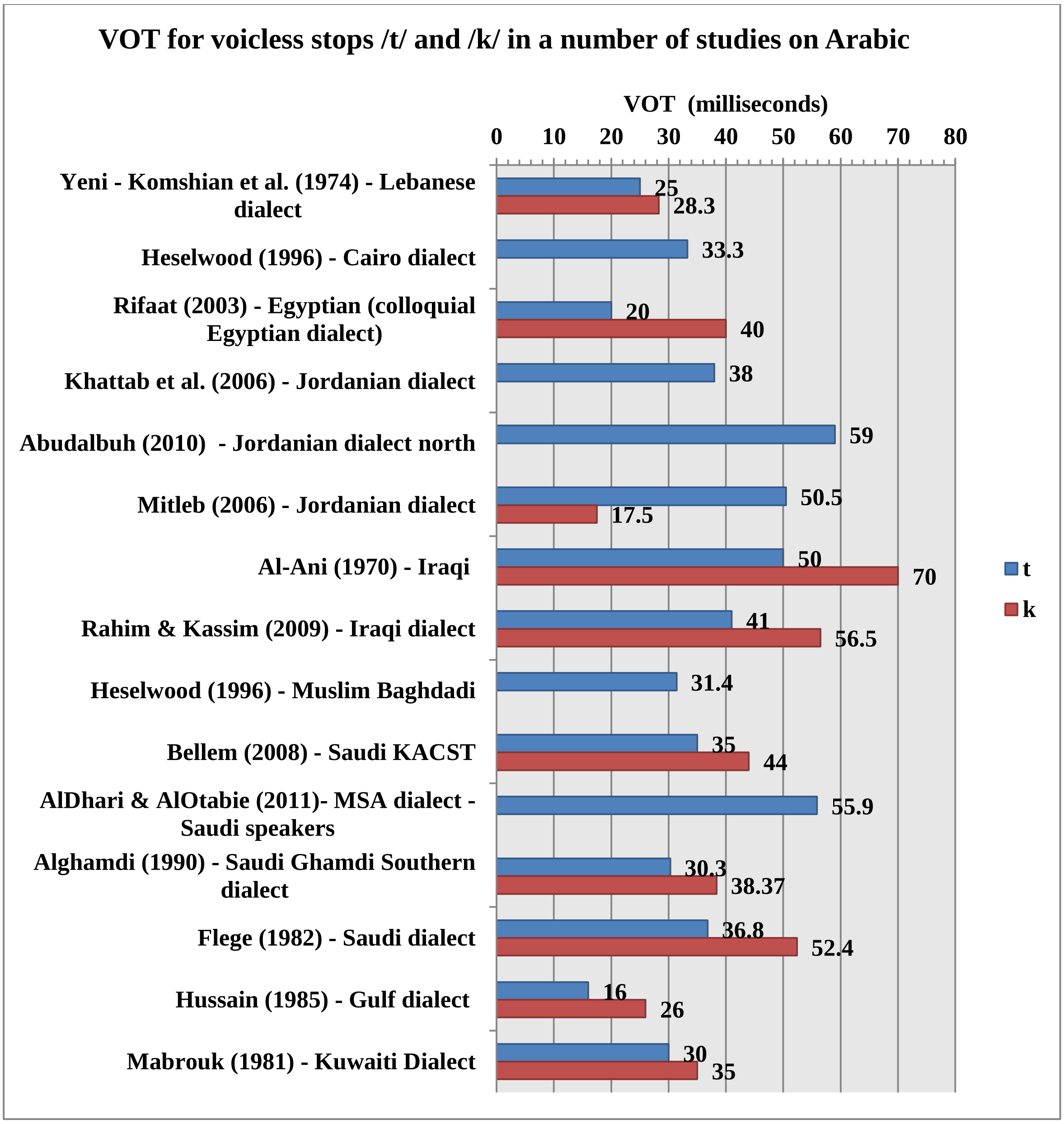


Figure 5.2 Mean VOT duration in milliseconds for voiceless stops (/t, k/) as presented in different dialects of Arabic (Abudalbuh, 2010; AlDahri & Alotaibi, 2010; Mitleb, 2009; Rahim & Kasim, 2009; Bellem, 2008; Khattab et al., 2006; Rifaat, 2003; Heselwood, 1996; Alghamdi, 1990; Hussain, 1985; Flege, 1982; Mabrouk, 1981; Yeni-Komshian et al., 1977; Al-Ani, 1970).[10]

[10] KACST= King Abdulaziz City for Sciences and Technology (Bellem, 2008); MSA = Modern Standard Arabic (AlDahri & Alotaibi, 2010).

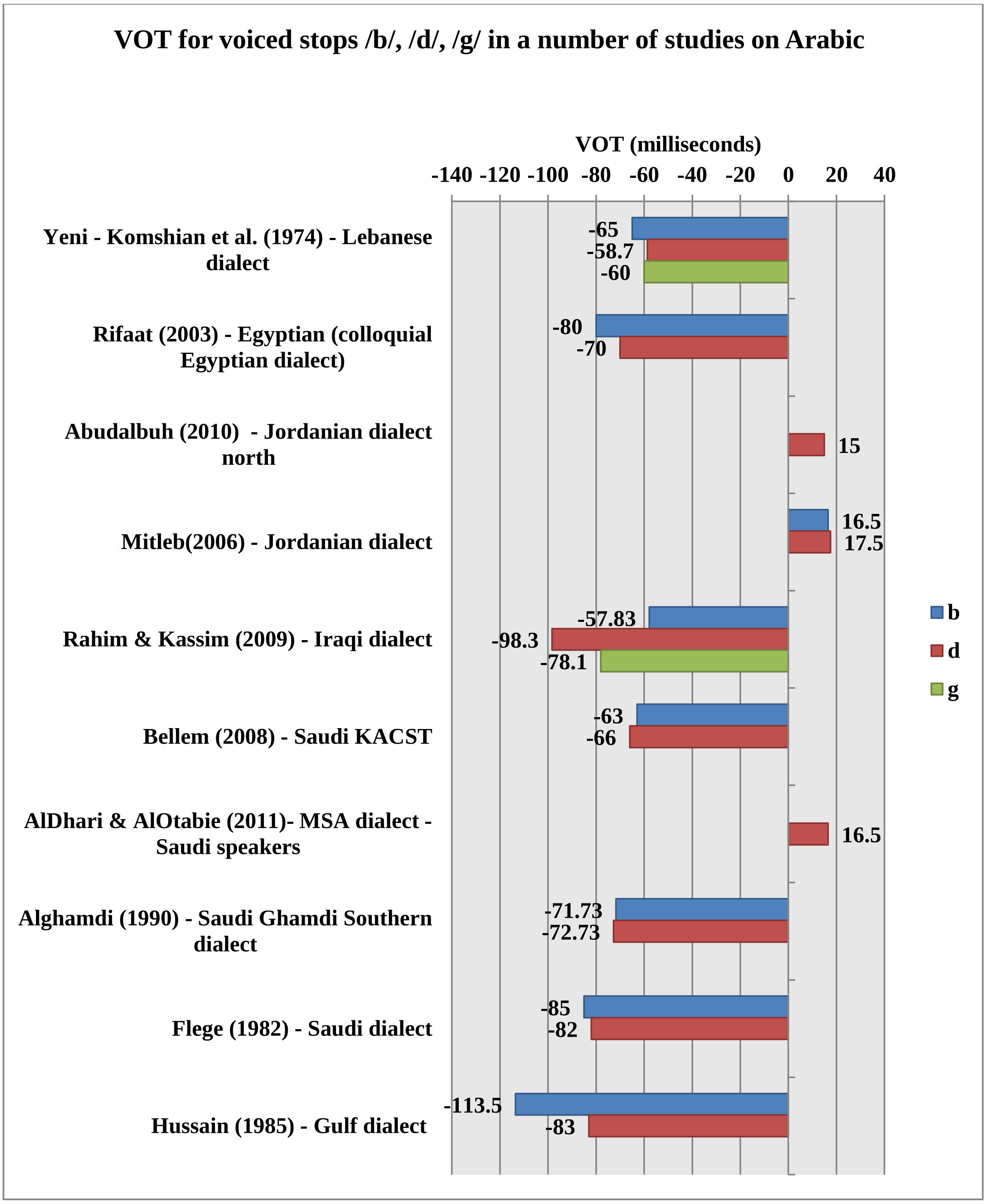


Figure 5.3 Mean VOT duration in milliseconds for voiced stops (/b, d, g/) as presented in different dialects of Arabic (Alotaibi & AlDahri, 2011; Abudalbuh, 2010; Rahim & Kasim, 2009; Bellem, 2008; Rifaat, 2003; Alghamdi, 1990; Hussain, 1985; Flege, 1982; Yeni-Komshian et al., 1977).

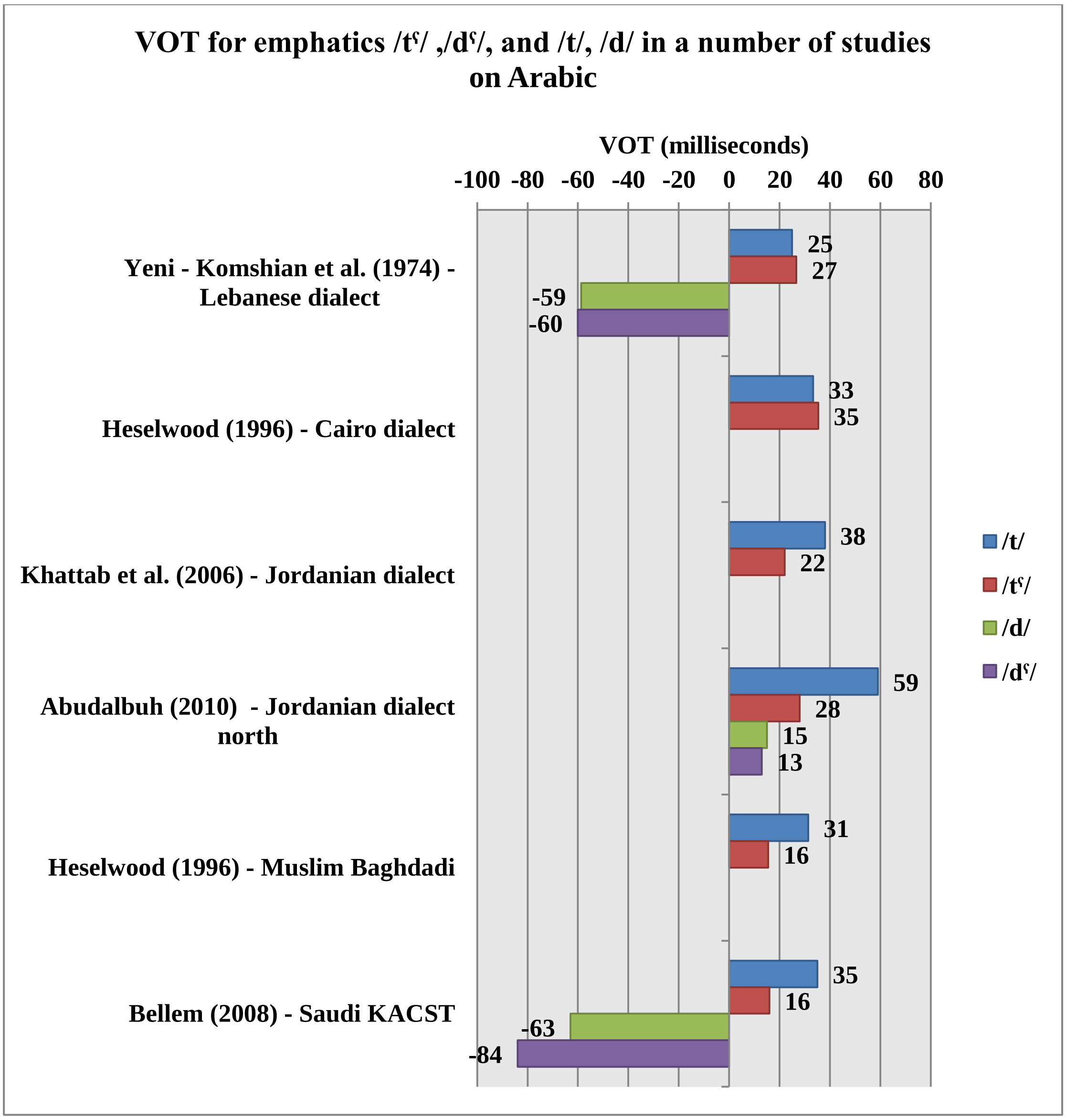


Figure 5.4 Mean VOT duration in milliseconds for plain stops (/t, d/) and emphatic stops (/tˤ, dˤ/) as presented in different dialects of Arabic (Abudalbuh, 2010; Bellem, 2008; Khattab et al., 2006; Heselwood, 1996; Yeni-Komshian et al., 1977).

5.6.3 Research aim, questions and hypotheses

5.6.3.1 Research aim and questions

5.6.3.1.1 Research Aim

To establish VOT normative data for words with initial voiced /b,d/, voiceless /t,k/ and plain/emphatic /t,tˤ/ for male and female Saudi and Bahraini speakers.

5.6.3.1.2 Main research questions

1. Are there differences in VOT values between the dialects Najdi and Bahraini?
2. Are there differences in VOT values between sexes in both Arabic dialects?

5.6.3.1.3 VOT-specific questions

5.6.3.1.3.1 *Plain stops*

a) Voicing: Are there differences in VOT values between voiced and voiceless stops (/t, d/)?
b) Place of Articulation: Are there effects of place of articulation of the stop on VOT—bilabial versus alveolar versus velar?
c) Vowel context: Would there be differences between vowel contexts – high versus low, and front versus back vowels?

5.6.3.1.3.2 Emphatic versus plain

a) Emphatic versus plain: Would there be a difference in VOT values between emphatic and plain alveolar stops (/tˤ, t/)?
b) Voicing: Would there be differences in VOT values between emphatic and plain alveolar stops (/tˤ, t/)?[11]
c) Vowel context: Would there be effects of vowel context on VOT values—the front high vowel /i:/ versus the back high vowel /u:/ ?

5.6.3.2 Hypotheses

The results from Heselwood (1996) and Almbark (2009) offered an insight into the expected differences found in Arabic dialects. Where differences occurred between sedentary and Bedouin-origin Arabic dialects (Heselwood, 1996), differences did not occur between sedentary dialects (Almbark, 2009). In addition, Bellem (2008) supported the argument by Heselwood (1996) based on origins of Arabic. The dialects chosen in this study are geographically proximate and are of Bedouin origin; therefore, the first hypothesis is that no differences in VOT durations will be found between the Najdi and Bahraini Arabic dialect for voiced (/b, d/), voiceless (/t, k/), voiced/voiceless (/d, t/), and plain/emphatic stops (/t, tˤ/).

In addition, research on sex differences in Arabic studies are scarce (Abudalbuh, 2010; Almbark, 2009; Khattab et al., 2006) where males tended to show shorter VOT durations than females for voiceless stops /t/; however, for voiced stops, research from studies (Abudalbuh, 2010; Almbark, 2009; Rifaat, 2003) did not find differences

[11] This was to ascertain if they were short or long lag on the voicing continuum as seen in Figure 5.1.

between males and females. In addition, research in English (Whiteside & Irving, 1997) found no difference between sexes for voiced stops; however, sex differences were evident in voiceless stops where females tended to have longer VOT values than males. Therefore, the second hypothesis is that males will have shorter VOT durations than females for voiceless and emphatic stops, while no sex differences will be found for the voiced stops /b, d/.

Khattab et al. (2006) had stated that some dialects of Arabic might be a three-voicing category. Only two studies (Bellem, 2008; Yeni-Komshian et al., 1977) have included the voiced, voiceless, and emphatic /tˤ/ stops. Bellem's study was done on Saudi dialect participants, which showed that voicing in Arabic might be a three-category voicing. Therefore, the third hypothesis is that Arabic in both dialects (Najdi and Bahraini) will display a three-category voicing (lead, short lag, and long lag).

The effect of place of articulation for voiced stops /b,d/ has shown inconsistencies in Arabic, where a number of studies (Yeni-Komshian et al., 1977; Flege, 1982; Hussain, 1985; Rifaat, 2003) showed bilabials had longer VOT duration than alveolars. Whereas, others (Alghamdi, 1990; Bellem, 2008; Rahim & Kasim, 2009) that had directed their analysis on Arabic dialects of Bedouin origin (Saudi and Iraqi) in a more controlled methodology with regards to sample size and inclusion , showed an opposite trend where bilabials had shorter VOT duration than alvealors. Meanwhile, for voiceless stops /t,k/ has shown in a number of studies on Arabic (Al-Ani, 1970; Yeni-Komshian et al., 1977; Mabrouk, 1981; Flege, 1982; Hussain, 1985; Alghamdi, 1990; Rifaat, 2003; Bellem, 2008; Rahim & Kasim, 2009; Abudalbuh, 2010) to be that the further back the place of articulation, the longer the VOT duration. Therefore, the fourth hypothesis is in that the further back in the vocal tract the place of articulation of a plosive, the longer the VOT duration for both voiced and voiceless stops.

The emphatic stops have been shown in a number of studies on Arabic to have shorter VOT duration than plain stops (Bellem, 2008; Khattab et al., 2006; Heselwood, 1996). Therefore, the fifth hypothesis is that the emphatic stop /tˤ/ in Najdi and Bahraini Arabic dialects will have shorter VOT duration that their plain stop cognate /t/.

In the studies on Arabic (Abudalbuh, 2010; Rahim & Kasim, 2009; Alghamdi, 1990; Yeni-Komshian et al., 1977), high front vowel /i:/ had a longer VOT duration than high back vowel /u:/, which had a longer duration than low vowel /a:/. Therefore, the sixth hypothesis is that for voiced, voiceless, and emphatic stops, high vowels have a longer VOT duration than low vowels while high front vowels have a shorter duration than high back vowels.

5.7 Methods

5.7.1 VOT acoustic analysis

The first area of investigation in this study was DDK. The second area, was VOT, and to explore the differences between the speech characteristics of two Arabic dialects: Saudi Najdi (spoken in the central region of Saudi Arabia) and Bahraini (spoken mainly by Bahraini Arabs in the islands of the Kingdom of Bahrain). In addition, sex differences will be explored in the contexts which will be described in the following sections

5.7.1.1 Stimuli

The stimuli in the present chapter consisted of monosyllabic minimal pairs containing the target plosives in Arabic in initial position. The target plosives were voiced /b, d/ and voiceless /t, k/, and the emphatic /tˤ/ was in word-initial position. The words were all real words and the voiced stops were followed by three long vowel contexts /a:, i:, u:/, while the remaining voiceless and emphatic plosives were followed by the two long vowels /i:, u:/ (See §3.3.3.3, Table 3.3).

5.7.1.2 Procedure and preparation for acoustic analysis

The procedure was previously described in §3.3.3.3. In addition, preparation for acoustic analysis was described earlier in §3.4.3.3.

5.7.2 Acoustic analysis

VOT measurements were taken for words for voiced stops /b, d/, and voiceless stops /t, k/ and emphatic /tˤ/. Boundary markings were different depending on whether they were voiced or voiceless stops as described below. All words, as described previously, were stops in initial position. Each participant repeated the 12 words twice, and each dialect by gender group had 20 participants (12 × 2 × 80), meaning the total number of words produced was 1,920. Only 1,837 words were analysed due to distortion or background noise; therefore, 83 words (4.33 %) were excluded from the analysis, and the remaining 1,837 (95.67%) were analysed. All participants were represented in the analysis of their stops.

5.7.2.1 *Voiced stops*

VOT was analysed for /b, d/ as the temporal interval between the onset of voicing, where the first boundary was set, and the release of the stop, where the second boundary was set. The voicing for voiced stops /b, d/ are negative (voicing leads), as illustrated in Figure 5.5 with the analysed word /ba:r/ annotated.

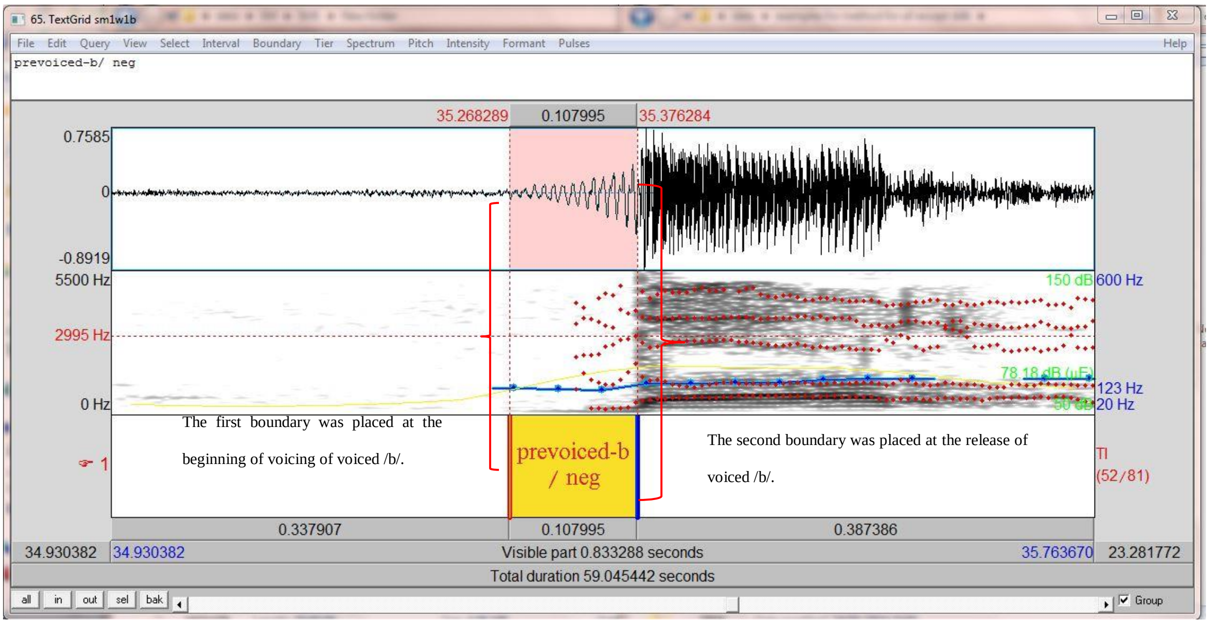
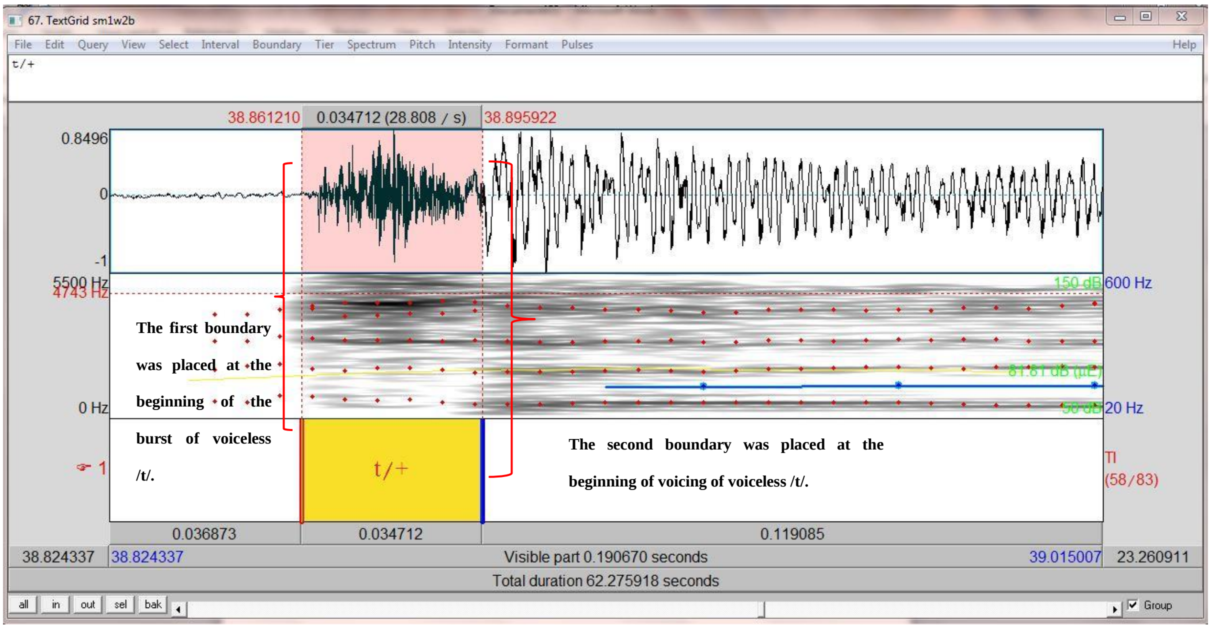


Figure 5.5 An example of VOT for voiced /b/ in initial position in the word /ba:r/ where the boundaries were placed at the beginning of voicing and the release of voiced /b/.

5.7.2.2 *Voiceless stops*

VOT was analysed for /t, k, tˤ/ as the temporal interval between the release of the consonant where the first boundary was set at the beginning of burst, and the second boundary was set at the onset of voicing of the following vowel. This is illustrated in Figure 5.6 (a) with the analysed word /ti:r/ annotated. Another example is for the voiceless emphatic /tˤ/, which can be seen in Figure 5.6 (b) for the word /tˤir/.

(a)



(b)

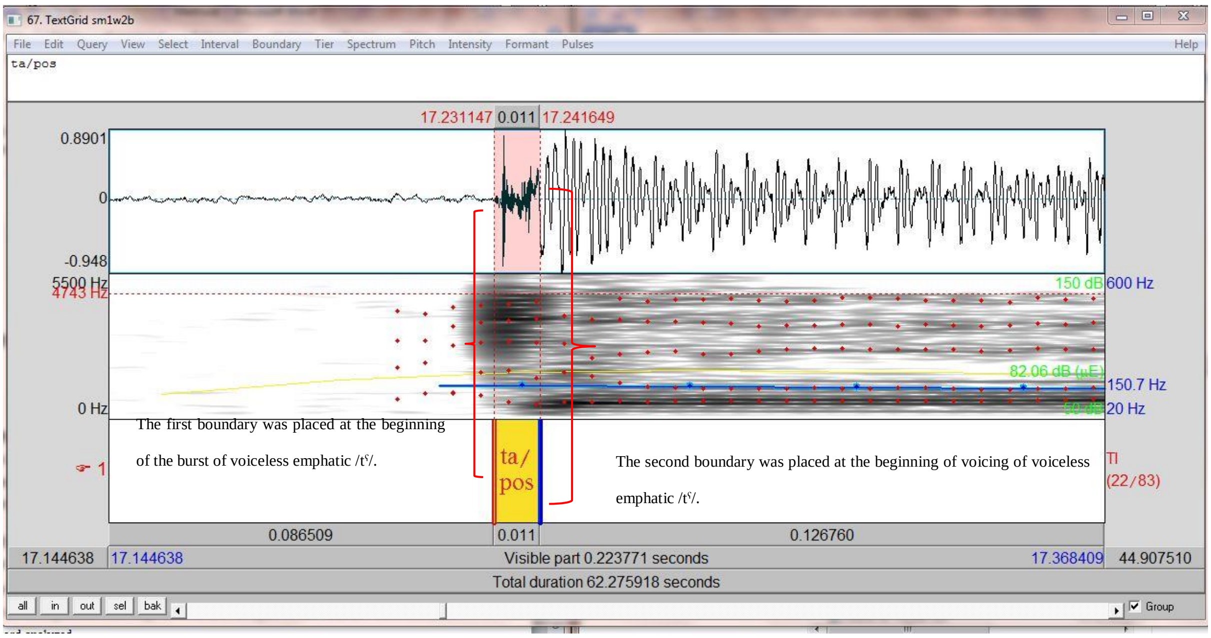


Figure 5.6 (a) An example of VOT for voiceless alveolar /t/ in initial position in the word /ti:r/, where the boundaries were placed at the beginning of the burst and the release of voicing of /t/. (b) An example of VOT for voiceless alveolar emphatic /tˤ/ in initial position in the word /tˤi:r/, where the boundaries were placed at the beginning of the burst and the release of voicing of /tˤ/.

5.7.3 Analysis and transfer

A Praat (Boersma & Weenink, 2012) script (see Appendix 4.1) written by Katherine Crosswhite and modified by Mark Antoniuo (2007) was also modified for this research to extract the syllable duration in milliseconds from the marked iteration for all syllables from the sound files in WAV format and text grids for each participant. Output of the script was then transferred to a Microsoft Excel (2010) spreadsheet. Results for all participants were compiled into one Excel spreadsheet that was transferred to the Statistical Package for the Social Sciences version 19 (SPSS, Inc., Chicago, IL) for statistical analysis.

5.7.4 Reliability

5.7.4.1 Inter-rater reliability

The task of annotating the syllables is a manual one undertaken by a single researcher. As a result, a degree of error can be expected. Therefore, to ensure optimum reliability, an independent speech and language pathologist familiar with acoustic phonetic analysis of VOT repeated the analysis. Annotation of text grids for these samples were then acoustically processed by Praat (Boersma & Weenink, 2012).

A total of 11 participants were randomly selected (5 Bahraini and 2 Saudi females and 2 Saudi and 2 Bahraini males). The number of words for these participants was 234, excluding 32. This made a final total of 264 analysed words, which represented 12.78% of the total sample.

5.7.4.2 Intra-rater reliability

At least seven months later, VOT duration markings were carried out a second time to further assess intra-rater reliability. The selected files were those used in inter-rater reliability. The researcher compared the first set of ratings with those obtained in the second period.

The inter-rater and intra-rater reliability files were the same files and were estimated for 12.78% of the measurements. Pearson correlation coefficients were calculated as shown in Table 5.8.

5.7.4.3 Results

	Intra-rater Reliability	**Inter-rater Reliability**
VOT duration (ms)	r =.984, n = 234, p<.001	r =.964, n = 234, p<.001

Table 5.8 Pearson correlation results for inter-rater and intra-rater reliability

The intra-rater reliability levels were used to assess the reliability of the VOT measurements. There was a strong positive correlation between the two measurements taken by the researcher, (r =.984, n = 234, p<.001). In addition, the second measurement (inter-rater reliability), taken by a colleague, revealed a strong positive correlation, (r =.964, n = 234, p<.001). Overall, there was a strong positive correlation between the measurements revealing a high level of reliability for the acoustic analysis of VOT duration in milliseconds.

5.7.5 Design and data analysis

This study's primary aim was to establish normative data and to answer two main research questions. First, it sought to determine whether differences exist between the two dialects of Arabic—Najdi and Bahraini—and, second, whether differences exist between sexes in speaking Arabic. In addition, the study was designed to examine VOT differences between voiceless (/t, k/) and voiced (/b, d/) stops in initial position in CV:C Arabic words. Also, an emphatic voiceless stop /$t^ʕ$/ was added to examine the effect of emphasis on VOT. Statistical analysis were performed in a series of repeated measures where dialect and gender were the between-subjects factors, while the within subject factors were the effects of place of articulation, voicing, and vowel context. The results section will be presented for voiced /b, d/, voiceless /t, k/, voiced contrast /t, d/, and emphatic /t, $t^ʕ$/ as dialect, gender, and the within subject factors.

5.8 Results for VOT analysis

5.8.1 Voiced stops /b, d/

For voiced stops, place of articulation (bilabial vs. alveolar) was assessed in monosyllabic words in three vowel contexts (/ba:r/ /bi:r/ /bu:r/) × (/da:r/ /di:r/ /du:r/). Mean VOT durations and standard values for sounds /b/ and /d/ in three different vowel contexts are shown in Table 5.6 by dialect and gender.

	Vowels	/ba:r/	/da:r/	/bi:r/	/di:r/	/bu:r/	/du:r/
Gender	Dialect (number)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Male	S (20)	-73.10 (26.84)	-82.52 (18.28)	-77.59 (25.18)	-92.21 (33.45)	-80.61 (24.77)	-83.32 (24.11)
	B (20)	-77.17 (24.59)	-79.05 (21.80)	-80.72 (24.98)	-85.93 (25.21)	-76.62 (19.89)	-85.79 (25.95)
	Mean (40)	-75.14 (25.49)	-80.78 (19.93)	-79.15 (24.81)	-89.07 (29.41)	-78.62 (22.27)	-84.55 (24.75)
Female	S (20)	-79.45 (22.41)	-75.96 (14.83)	-83.07 (26.28)	-92.32 (22.19)	-76.07 (25.27)	-90.42 (15.80)
	B (20)	-73.58 (26.57)	-73.53 (25.21)	-80.46 (24.01)	-82.98 (28.28)	-69.26 (15.20)	-81.61 (18.80)
	Mean (40)	-76.52 (24.45)	-74.74 (20.45)	-81.76 (24.88)	-87.65 (25.53)	-72.67 (20.87)	-86.02 (17.71)
Total	Saudi (40)	-76.27 (24.61)	-79.24 (16.76)	-80.33 (25.56)	-92.27 (28.02)	-78.34 (24.81)	-86.87 (20.44)
	Bahraini (40)	-75.37 (25.37)	-76.29 (23.43)	-80.59 (24.18)	-84.46 (26.48)	-72.94 (17.87)	-83.70 (22.46)
	All (80)	-75.83 (24.82)	-77.76 (20.29)	-80.46 (24.72)	-88.37 (27.37)	-75.64 (21.65)	-85.29 (21.40)

Table 5.6 Mean VOT duration (ms) and standard deviation for stops /b/ and /d/ in three different vowel contexts (/bar, dar/ /bir, dir/ /bur, dur/) for Saudi and Bahraini Arabic speakers

A mixed model ANOVA was conducted with mean VOT durations of prevoicing for stops /b/ and /d/ in initial position in three different vowel contexts (/ar/, /ir/, /ur/), with sex (male–female) and dialect (Saudi–Bahraini) as the between-subjects factors. Place of articulation, voicing, and vowel context were the within-subjects factors. Results showed Mauchly's test non significant ($p > .05$), therefore, sphericity has been assumed.

5.8.1.1 Dialect and sex

For voiced stops, results for between-subjects factors showed that there was no significant effect of dialect ($F(1, 76) = .824$, $p = .376$) and no significant effect of sex ($F(1, 76) = .131$, $p = .719$), and no significant interaction between sex and dialect ($F(1,76) = .522$, $p = .47$).

5.8.1.2 VOT patterns for /b,d/

Averaged mean VOT values were leads (negative) where /b/ and /d/ results can be viewed in Table 5.6 in three vowel contexts (/a:/, /i:/, /u:/) as a function of sex and dialect. All speakers produced voiced stops (/b, d/) with prevoicing regardless of gender and dialect effects.

5.8.1.3 Place of articulation

Results showed a significant main effect for place of articulation for voiced plosives /b/ and /d/ ($F(1, 76) = 8.792$, $p < .05$). Post hoc test using Bonferroni correction revealed significance ($p < .001$), where mean VOT durations for voiced plosive bilabial /b/ had shorter negative VOT durations (-77.31 ms) than VOT values (-83.81

ms) for voiced plosive alveolar /d/; values showed that the more posterior the place, the longer the voicing lead (see Figure 5.7 and Table 5.6).

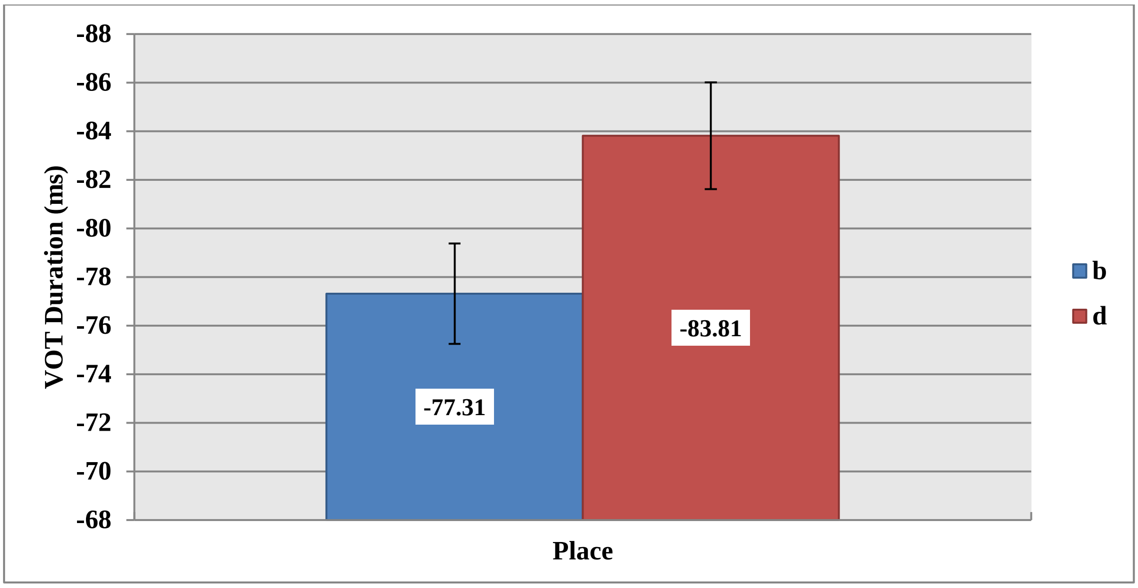


Figure 5.7 Mean ± standard errors for VOT durations (ms) of voiced bilabial /b/ and alveolar /d/; bilabial shows shorter VOT durations than alveolar.

5.8.1.4 Vowel context

Results showed that there was a main significant effect of vowel context ($F(1, 152) = 7.914$, $p<.001$). Post hoc Bonferroni tests revealed significant differences between VOT durations for the high vowel /i:/ (-84.41 ms) and lower vowel /a:/ (-76.79), ($p<.001$), while no significant differences were found between /u:/ and /a:/ ($p=.172$), or the high vowels /i:/ and /u:/ ($p=.118$) (see Figure 5.8).

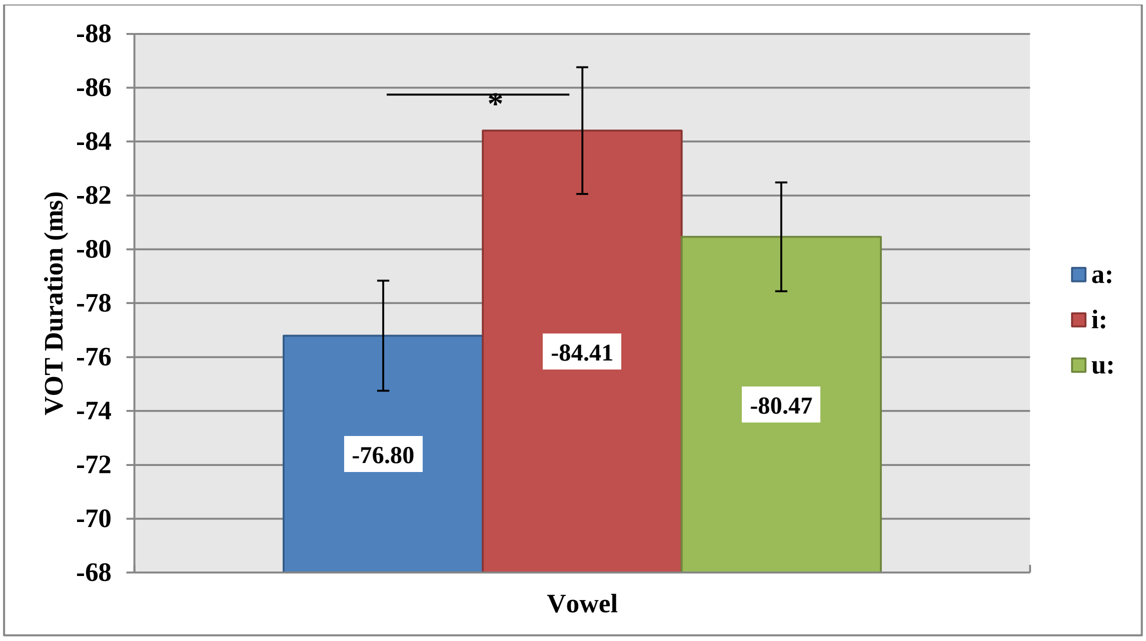


Figure 5.8 Mean ± standard errors for vowels (/a:/, /i:/, /u:/) produced for voiced stops.

However, there was no significant interaction between vowel context by gender (F(1,152) = .374, p =.686), no significant interaction between vowel context by dialect (F(1,152) = .216, p =.811), and no significant interaction between vowel context by gender by dialect (F(1, 152) = .079, p =.924).

Furthermore, no significant interaction was found between place of articulation for voiced plosives by vowel context (F (2, 152) = 2.174, p =.117). No significant interaction was found between place of articulation for voiced plosives by vowel context by sex F (2, 152) = 2.001, p =.137), between place of articulation by vowel context by dialect (F (2, 152)= .893, p =.412), or interaction between place of articulation by vowel context by sex by dialect (F (2, 152) = .789, p =.456).

5.8.2 Voiceless stops /t, k/

Voiceless alveolar /t/ followed by two vowels in the Arabic monosyllable words (/tir/ /tur/) was contrasted with voiceless alveolar /k/ followed by two vowels in the Arabic monosyllabic words (/kir/ /kur/). Mean VOT durations and standard values for the stops /t/ and /k/ in two different vowel contexts are shown in Table 5.7 by dialect and gender.

	Vowels	/ti:r/	/ki:r/	/tu:r/	/ku:r/
Gender	Dialect (number)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Male	S (20)	72.86 (24.55)	83.24 (23.69)	68.53 (20.15)	78.48 (17.98)
	B (20)	64.52 (14.78)	73.05 (17.17)	56.65 (13..57)	70.29 (13.94)
	Mean (40)	68.69 (20.44)	78.15 (21.06)	62.59 (17.99)	74.39 (16.41)
Female	S (20)	83.48 (16.43)	88.95 (15.94)	80.11 (198.05)	88.24 (17.39)
	B (20)	77.05 (18.16)	85.70 (13.60)	76.01 (13.92)	82.20 (12.79)
	Mean (40)	80.27 (17.40)	87.32 (14.72)	78.06 (16.60)	85.22 (15.38)
Total	Saudi (40)	78.17 (21.31)	86.10 (20.14)	74.32 (20.23)	83.36 (18.14)
	Bahraini (40)	70.79 (17.53)	79.37 (16.58)	66.33 (16.74)	76.25 (14.52)
	All (80)	74.48 (19.74)	82.73 (18.64)	70.33 (18.88)	79.81 (16.71)

Table 5.7 Mean VOT duration (ms) and standard deviation for voiceless sounds /t/ and /k/ in two different vowel contexts (/tir, kir/, /tur, kur/) for Saudi and Bahraini Arabic speakers.

A mixed-model ANOVA was conducted with mean VOT durations of voicing lags for sounds /t/ and /k/ in initial position in two different vowel contexts (/ir/, /ur/) with gender (male–female) and dialect (Saudi–Bahraini) the between-subjects factors.

Place of articulation, voicing, and vowel context were within-subject factors. Results showed Mauchly's test nonsignificant ($p > .05$), therefore, sphericity was assumed.

5.8.2.1 Dialect and sex

Dialect showed a main effect for the voiceless stops /t, k/, ($F(1, 76) = 5.682$, $p < .005$). A post hoc test using Bonferroni correction revealed significance ($p < .05$), where Saudis had generally longer mean VOT duration (80.49 ms) than Bahraini speakers (73.19 ms) (see Figure 5.9).

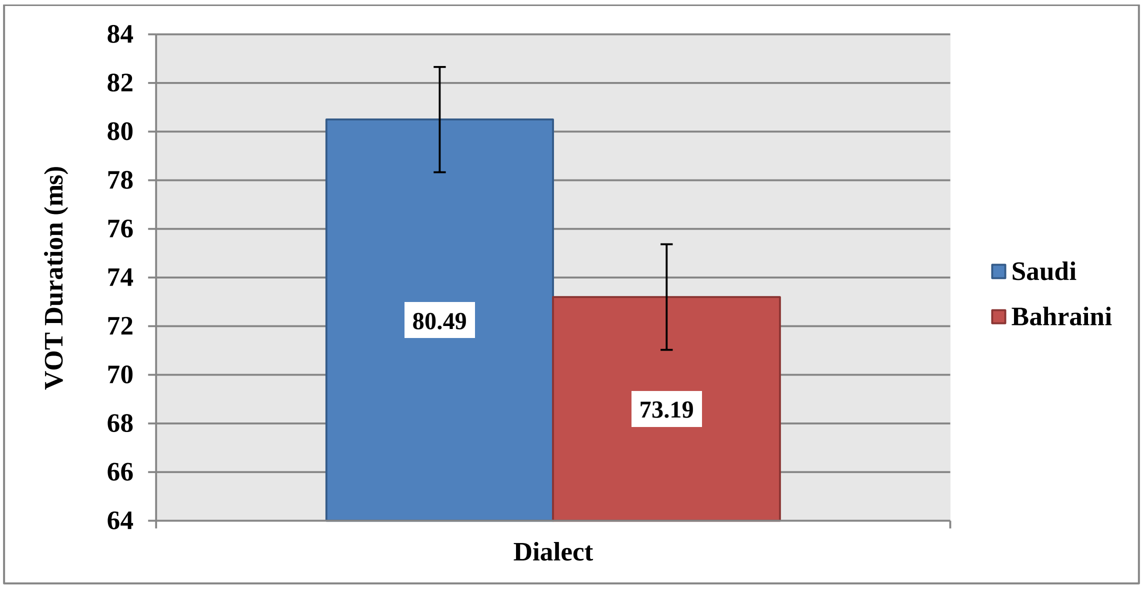


Figure 5.9 Mean ± standard errors for VOT durations (ms) for Saudis and Bahrainis for voiceless plosives /t, k/, where Saudis showed longer VOT durations than Bahrainis.

Sex also showed an effect for voiceless plosives (/t,k/) ($F(1, 76) = 14.738$, $p < .001$). A post hoc test using Bonferroni correction revealed significance ($p < .001$), where males had generally shorter mean VOT duration (70.96 ms) than females (82.72 ms) (see Figure 5.10).

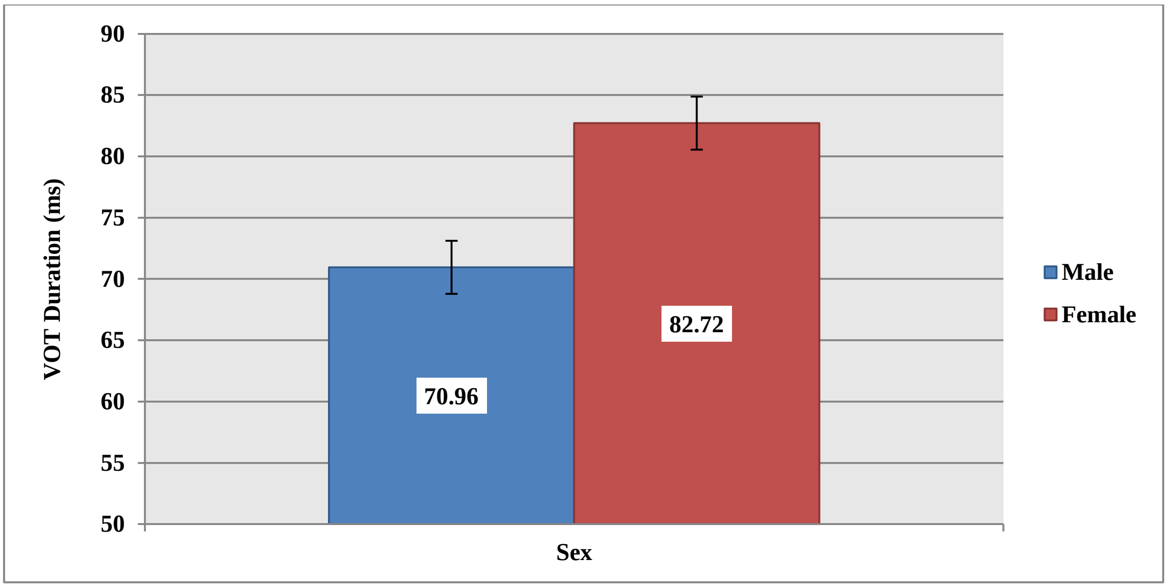


Figure 5.10 Mean ± standard errors for VOT durations (ms) for males and females for voiceless plosives /t, k/, where males showed lower VOT durations than females.

However, no significant interaction was found between sex by dialect (F (1.76) =.586, p=.446) as seen in Figure 5.11.

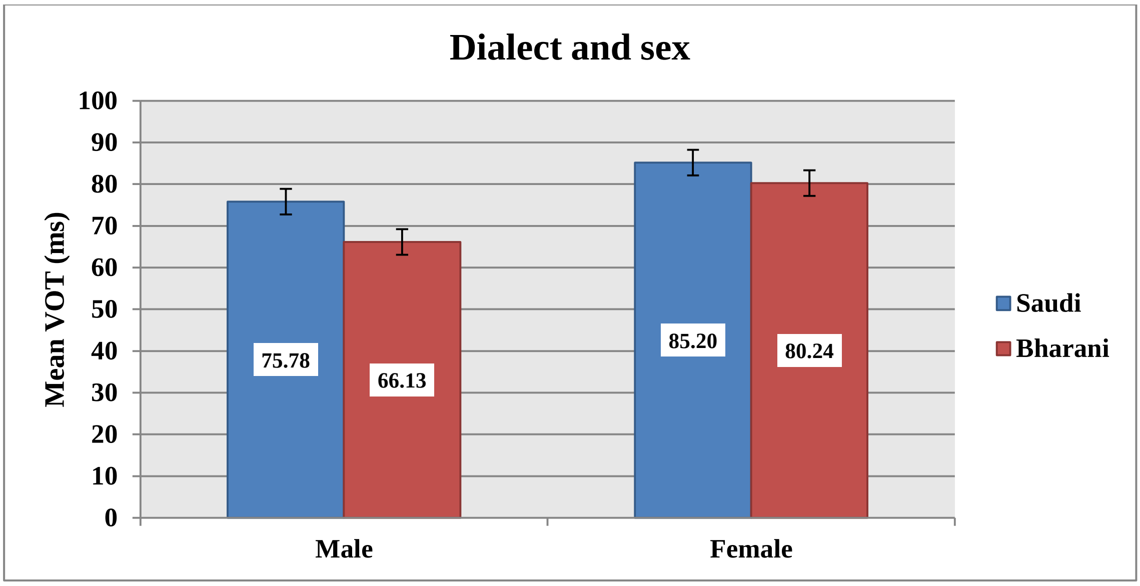


Figure 5.11 Mean ± standard errors for VOT durations (ms) for diaelct and sex interaction for voiceless plosives /t, k/ for male and female Saudi and Bahraini speakers.

5.8.2.2 VOT patterns for /t,k/

Mean VOT values were long lags (positive), where /t/ and /k/ results can be viewed in Table 5.7 in two vowel contexts (/i:/, /u:/) as a function of gender and dialect. All Arabic speakers produced their voiceless stops /t, k/ with absent voicing (lags) regardless of sex and dialect effects.

5.8.2.3 Place of articulation

For voiceless stops /t, k/, VOT values showed a significant main effect of place of articulation for voiceless plosives /t/ and /k/ ($F (1, 76) = 39.612$, $p < .001$). Post hoc tests using Bonferroni correction revealed significance ($p < .001$) where mean VOT durations for the voiceless plosive velar /k/ had longer VOT durations (81.27 ms) than the voiceless plosive alveolar /t/ (72.41 ms) (see Figure 5.12). Therefore, the more posterior the place, the longer the VOT duration.

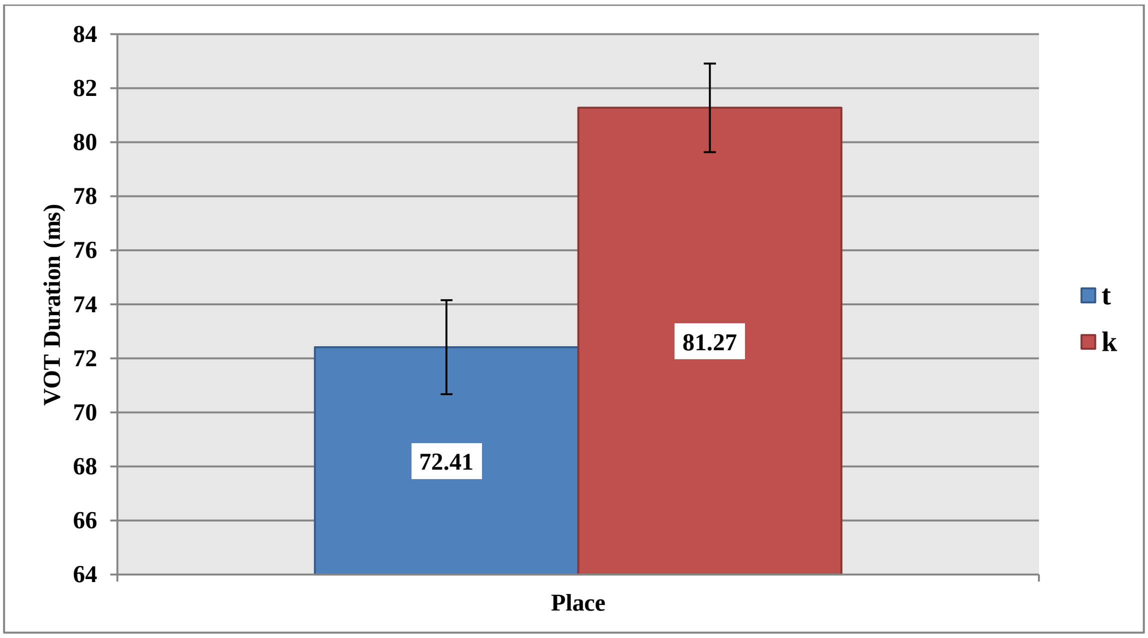


Figure 5.12 Mean ± standard errors for VOT durations (ms) of voiceless alveolar /t/ and velar /k/; alveolar stops shows shorter VOT durations than velar stops.

For the voiceless stops, there was no significant interaction between place of articulation and sex (F(1,76) = 1.561, p =.215), no significant interaction between place of articulation and dialect (F(1,76)=.074, p =.786), and no significant interaction between place of articulation by sex by dialect (F(1,76) = .003, p =.957).

5.8.2.4 Vowel context

For voiceless stops, results showed that there was a significant effect of vowel context (F(1, 76) = 6.836, p <.05). Post hoc Bonferrioni tests revealed significant differences between VOT durations for the high front vowel /i:/ (78.61 ms) and the high back vowel /u:/ (-75.07 ms), (p<.05), (see Figure 5.13).

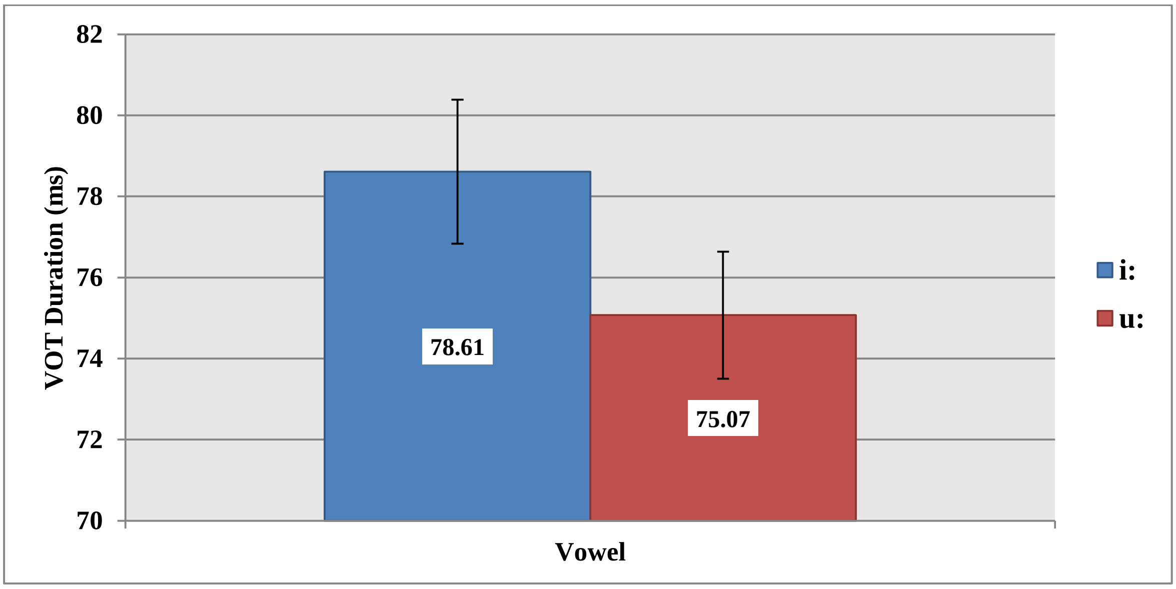


Figure 5.13 Mean ± standard errors for effect of vowel context on voiceless stops where /i:/ had longer VOT duration than /u:/.

However, there was no significant interaction between vowel context by sex (F(1, 76) = 1.052, p =.305), vowel context by dialect (F(1, 76) = .034, p =.853), or vowel context by sex by dialect (F(1, 76) = .010, p =.921).

Moreover, there was no significant interaction between place of articulation by vowel context ($F(1,76)= .193, p =.662$), place of articulation by vowel context by sex ($F(1, 76) = .161, p =.689$), place of articulation by vowel context by dialect ($F(1, 76) = .002, p =.969$), or place of articulation by vowel context by sex by dialect ($F(1, 76) = .918, p =.341$).

5.8.3 Voiced/voiceless plosives

Voicing was assessed in a voiced/voiceless contrast in two vowel contexts (/tir/ /tur/) × (/dir/ /dur/); voiceless alveolar /t/ followed by two vowels in Arabic monosyllable words (/tir/ /tur/) in contrast with voiced alveolar /d/ followed by two vowels in Arabic monosyllabic words (/dir/ /dur/).

	Vowels	/ti:r/	/di:r/	/tu:r/	/du:r/
Gender	Dialect (number)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Male	S (20)	72.86 (24.56)	-92.22 (33.45)	68.54 (20.16)	-83.33 (24.11)
	B (20)	64.53 (14.79)	-85.93 (25.21)	56.65 (13.57)	-85.79 (25.95)
	Mean (40)	68.70 (20.45)	-89.07 (29.41)	62.59 (18.00)	-84.56 (24.76)
Female	S (20)	83.49 (16.44)	-92.33 (22.19)	80.12 (19.06)	-90.43 (15.80)
	B (20)	77.06 (18.16)	-82.99 (28.28)	76.02 (13.93)	-81.62 (18.80)
	Mean (40)	80.27 (17.40)	-87.66 (25.53)	78.07 (16.61)	-86.02 (17.72)
Total	Saudi (40)	78.18 (21.32)	-92.27 (28.02)	74.33 (20.23)	-86.88 (20.44)
	Bahraini (40)	70.79 (17.53)	-84.46 (26.49)	66.33 (16.75)	-83.71 (22.47)
	All (80)	74.48 (19.75)	-88.37 (27.37)	70.33 (18.89)	-85.29 (21.40)

Table 5.8 Mean VOT duration (ms) and standard deviation for voiceless alveolar /t/ and voiced alveolar /d/ in two different vowel contexts (/tir, dir/ /tur,dur/) for Saudi and Bahraini Arabic speakers.

Mean VOT durations and standard values for sounds /t/ and /d/ in two different vowel contexts are shown in Table 5.8 by dialect and sex. A mixed-model ANOVA was conducted with mean VOT durations for alveolar sounds /t/ and /d/ in initial position in two different vowel contexts (/ir/, /ur/) with sex (male–female) and dialect (Saudi–Bahraini) as the between-subjects factors. Voicing, and vowel context were the within-subject factors. Results showed Mauchly's test nonsignificant ($p > .05$), therefore, sphericity had been assumed.

5.8.3.1 Dialect and sex

Results for the between-subjects factor of dialect for the voiced/voiceless plosives /t, d/ showed that there was no significant difference between dialects ($F(1, 76) =.173$, $p = .712$). In addition, no significant interaction was found between sex and dialect ($F (1.76) =1.025$, $p=.315$). However, results for between-subjects factors in voiced/voiceless plosives /t, d/ showed that there was significant effect from sex on mean VOT durations as ($F (1, 76) = 5.182$, $p < .05$). A post hoc test using Bonferroni correction revealed significance ($p <.001$) where males had generally longer VOT leads (-10.59 ms) than females (-3.83 ms), as shown in Figure 5.14. VOT values are the result of averaging voicing leads (negative) for /d/ and voicing lags (positive) for /t/ for each gender. Because females had longer voicing lags than males, results showed a shorter average voicing lead (negative) for females than males.

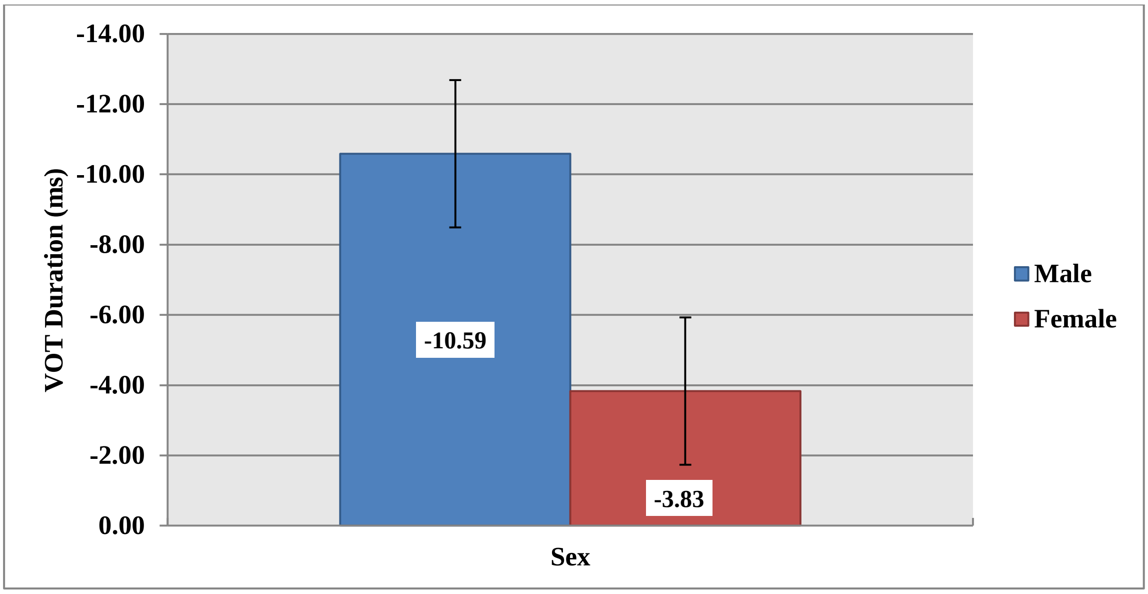


Figure 5.14 Mean ± standard errors VOT duration (ms) for males and females for voiced/voiceless plosives /d, t/ where males showed a longer VOT lead overall, than females.

5.8.3.2 Voicing

Voicing for voiceless /t/ and voiced /d/ values showed a significant main effect ($F(1, 76) = 2990.54$, $p < .001$). Post hoc tests using Bonferroni correction revealed significance ($p < .05$) where mean VOT durations for voiceless alveolar plosive /t/ had a voicing lag (72.41 ms), whereas the voiced alveolar plosive /d/ was prevoiced (-86.83 ms) (see Figure 5.15).

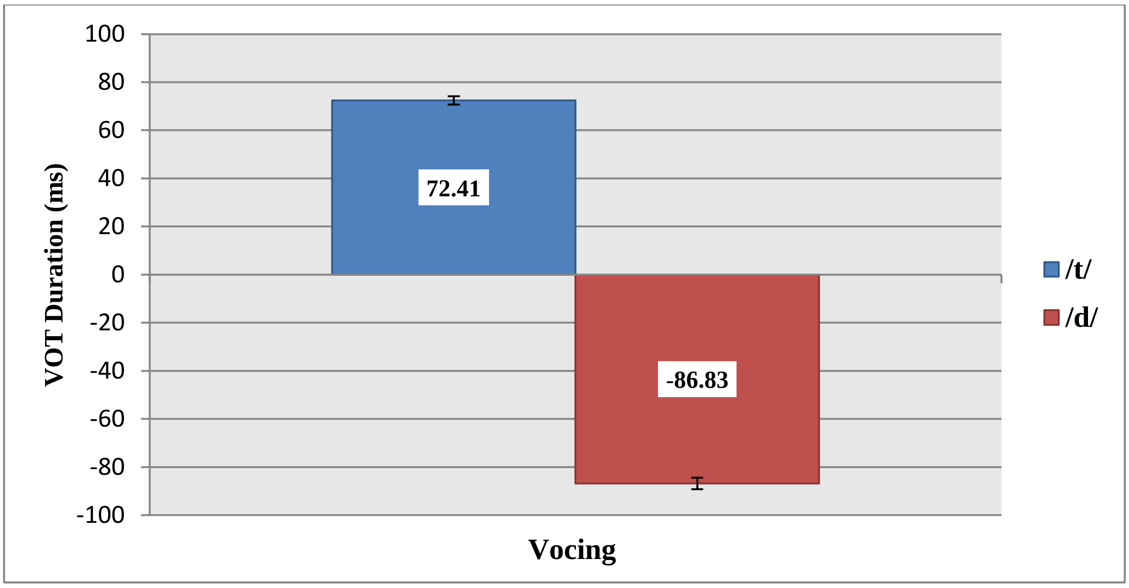


Figure 5.15 Mean ± standard errors bars where voiceless alveolar /t/ had a voicing lag while voiced alveolar /d/ was prevoiced.

Voicing and dialect showed a significant interaction ($F(1, 76) = 5.122$, $p < .05$). A mixed-model ANOVA was used with mean VOT durations for pooled alveolar voiced /d/ and pooled alveolar voiceless /t/ as the repeated measures with dialect as the between-subjects factor. Results showed a significant difference for dialect between Saudis and Bahrainis for /t/ ($F(1,76),=4.90,p<.05$), where mean VOT durations for Saudis (76.25 ms) were longer than for Bahrainis (68.56 ms). However, no significant differences were seen between Saudis and Bahrainis for voiced /d/ ($(F1,76)=1.34$, $p=.251$),however, Saudis tended to show shorter voicing leads for /d/ (-84.08 ms) than Bahrainis (-89.57 ms), (see Figure 5.16).

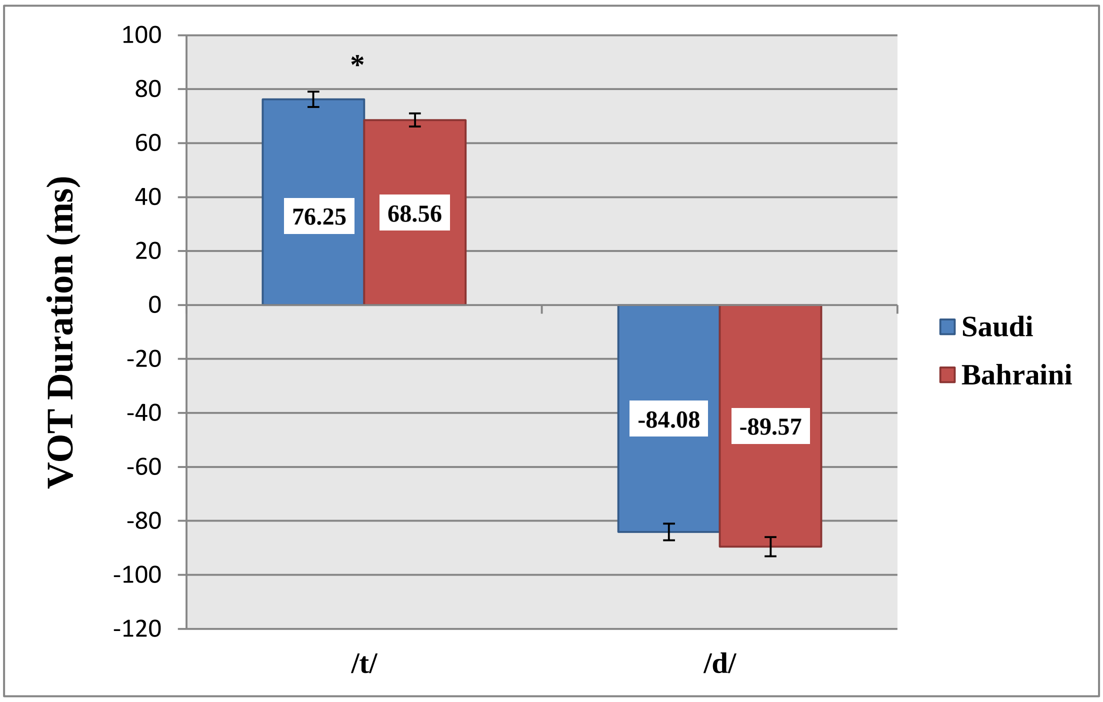


Figure 5.16 Mean ± standard errors for significant interaction between voicing and dialects, where mean VOT duration (ms) for Saudis showed longer VOT durations than Bahrainis for voiceless /t/. No significant differences were found between the two dialects in voiced /d/.

There was a significant interaction between voicing and sex ($F(1, 76) = 5.412$, $p < .05$). A mixed-model ANOVA was used with mean VOT durations for pooled alveolar voiced /d/ and pooled alveolar voiceless /t/ as the repeated measures with sex as the between-subjects factor. Results showed significant differences between sexes for /t/ ($F(1,76)=15.187, p<.001$), where males tended to show shorter /t/ VOT values (65.65 ms) compared to females (79.17 ms) (see Figure 5.17). However, no significant differences were observed between males and females for voiced /d/ ($F(1,76)=0$, $p=.996$).

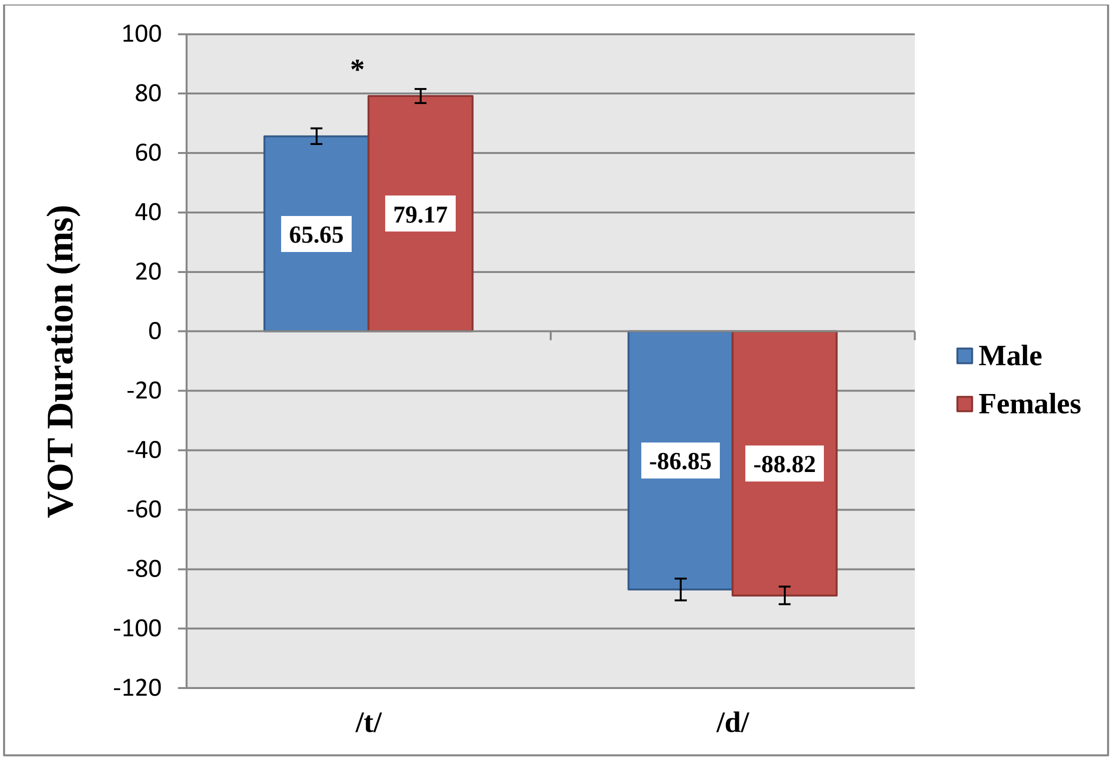


Figure 5.17 Mean ± standard errors for significant interaction between voicing and gender, where mean VOT duration (ms) shows males at lower VOT durations than females for both voiced /d/ and voiceless /t/.

5.8.3.3 Vowel context

Results showed no significant effect of vowel context (F(1,76) = .115, p =.736). There was no significant interaction between vowel context by sex (F(1,76) = .025, p =.874), vowel context by dialect (F(1,76) = .678, p =.413), or vowel context by sex by dialect (F(1,76) = 1.224, p =.272).

There was an interaction which approached significance found for voicing contrast by vowel context (F(1, 76) = 3.684, p =.059). For the voiceless stop /t/, longer mean VOT durations (74.48 ms) for front high vowel /i:/ than the front high vowel /u:/ (70.33 ms). For voiced /d/, no difference were observed between vowels /i:, u:/ , (see Figure 5.18).

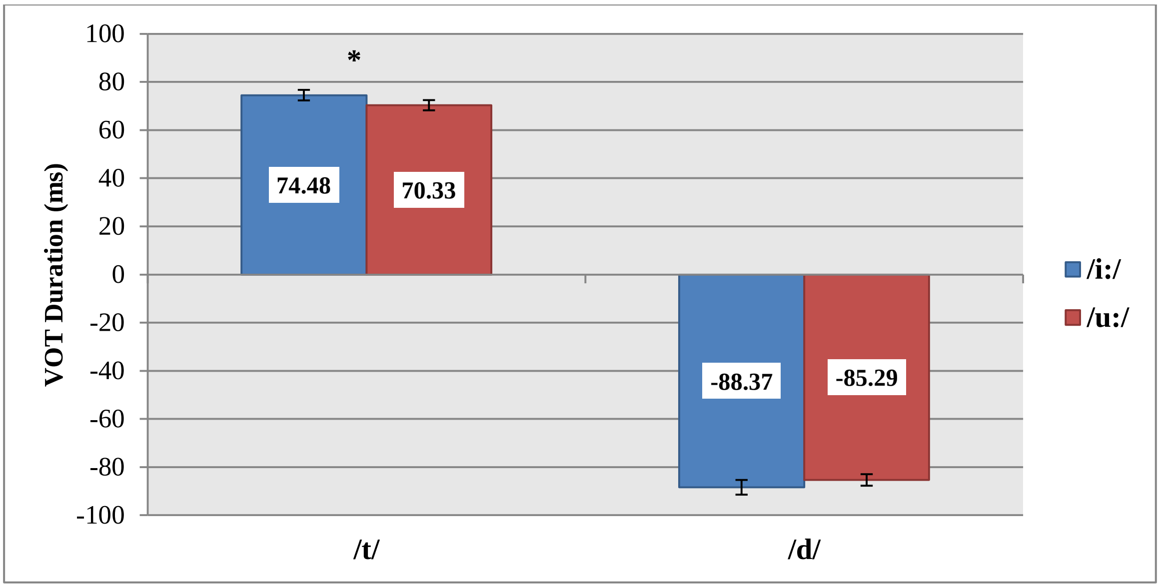


Figure 5.18 Mean ± standard errors for significant interaction between voicing and vowels where mean VOT duration (ms) showed front high vowel /i:/ had longer VOT durations than back high vowel /u:/ for voiceless /t/ and voiced /d/.

In addition, there was no significant interaction between voicing contrast by vowel context by sex ($F(1, 76) = .810$, $p = .371$), voicing contrast by vowel context by dialect ($F(1, 76) = .286$, $p = .595$), or voicing contrast by vowel context by sex by dialect ($F(1, 76) = .024$, $p = .877$).

5.8.4 Plain/emphatic stops

The emphatic voiceless alveolar plosive /tˤ/ followed by two vowels in the Arabic monosyllable words (/tˤir/, /tˤur/) was contrasted with the plain voiceless alveolar /t/ followed by two vowels in the Arabic monosyllabic words (/tir/, /tur/). Mean VOT durations and standard deviation values for /tˤ/ and /t/ in two different vowel contexts are shown in Table 5.9 by dialect and sex. A mixed-model ANOVA was conducted with mean VOT durations of voicing lags for plosives /tˤ/ and /t/ in initial position in two different vowel contexts (/ir/, /ur/). The between-subjects factors were dialect (Saudi–Bahraini) and sex (male–female) and the within-subject factors were emphasis and vowel context. Results showed Mauchly's test nonsignificant (p > .05), therefore, sphericity had been assumed.

	Vowels	/ti:r/	/tˤi:r/	/tu:r/	/tˤu:r/
Gender	Dialect (number)	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
Male	S (20)	72.86 (24.55)	20.25 (5.99)	68.53 (20.15)	21.92 (7.40)
	B (20)	64.52 (14.78)	21.84 (7.59)	56.65 (13..57)	20.99 (4.51)
	Mean (40)	68.69 (20.44)	21.04 (6.79)	62.59 (17.99)	21.46 (6.06)
Female	S (20)	83.48 (16.43)	17.93 (3.80)	80.11 (198.05)	17.58 (5.03)
	B (20)	77.05 (18.16)	18.35 (4.43)	76.01 (13.92)	20.09 (6.90)
	Mean (40)	80.27 (17.40)	18.14 (4.08)	78.06 (16.60)	18.84 (6.10)
Total	Saudi (40)	78.17 (21.31)	19.02 (5.09)	74.32 (20.23)	19.75 (6.62)
	Bahraini (40)	70.79 (17.53)	20.09 (6.38)	66.33 (16.74)	20.54 (5.77)
	All (80)	74.48 (19.74)	19.59 (5.75)	70.33 (18.88)	20.15 (6.18)

Table 5.9 Average VOT duration (ms) means and standard deviation for plain voiceless alveolar plosive /t/ and for emphatic voiceless plosive /tˤ/ in two different vowel contexts (/tir, tˤir/ /tur,tˤur/) for Saudi and Bahraini Arabic speakers.

5.8.4.1 Dialect and sex

Results for between-subjects factors for dialect in plain/emphatic /t, tˤ/ showed there was no significant difference between dialects but the results displayed a trend (F(1, 76) =.3.14, p = .08), where Saudi speakers tended to show longer VOT duration (47.84 ms) than Bahraini speakers (44.44 ms) (see Figure 5.19). In addition, no significant interaction was found between sex and dialect (F (1,76) =610, p=.437).

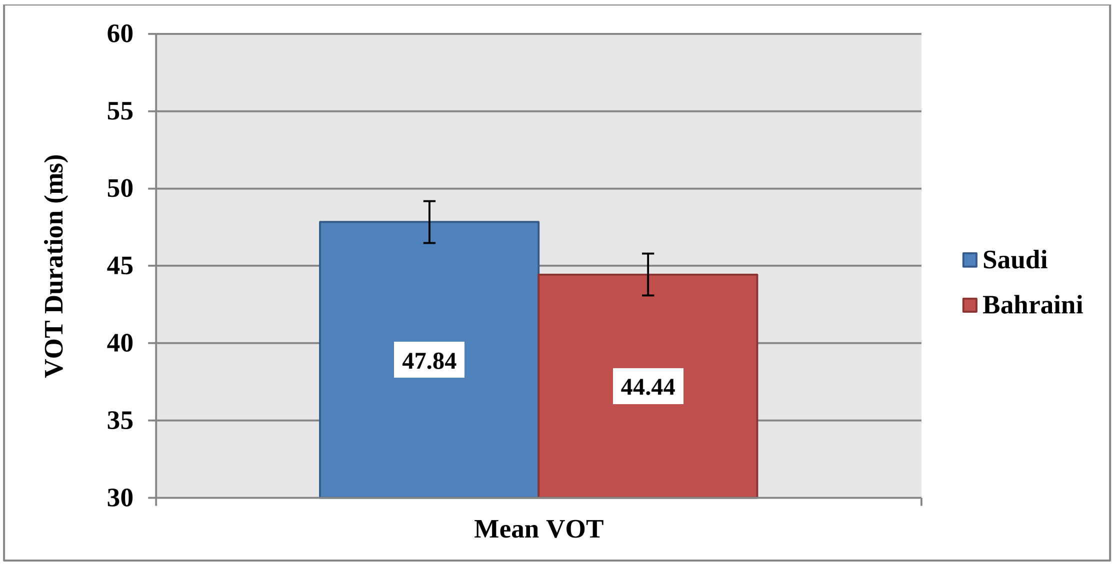


Figure 5.19 Mean ± standard errors bars for voiceless plain/emphatic /t, tˤ/ where Saudi speakers tended to show longer VOT duration than Bahraini speakers.

However, sex showed a significant difference between male and females for plain/emphatic voiceless plosives /t, tˤ/ ($F(1, 76)= 7.904, p < .05$). A post hoc test using Bonferroni correction revealed significance ($p <.001$), where males had shorter mean VOT durations (43.45 ms) than females (48.83 ms) (see Figure 5.20).

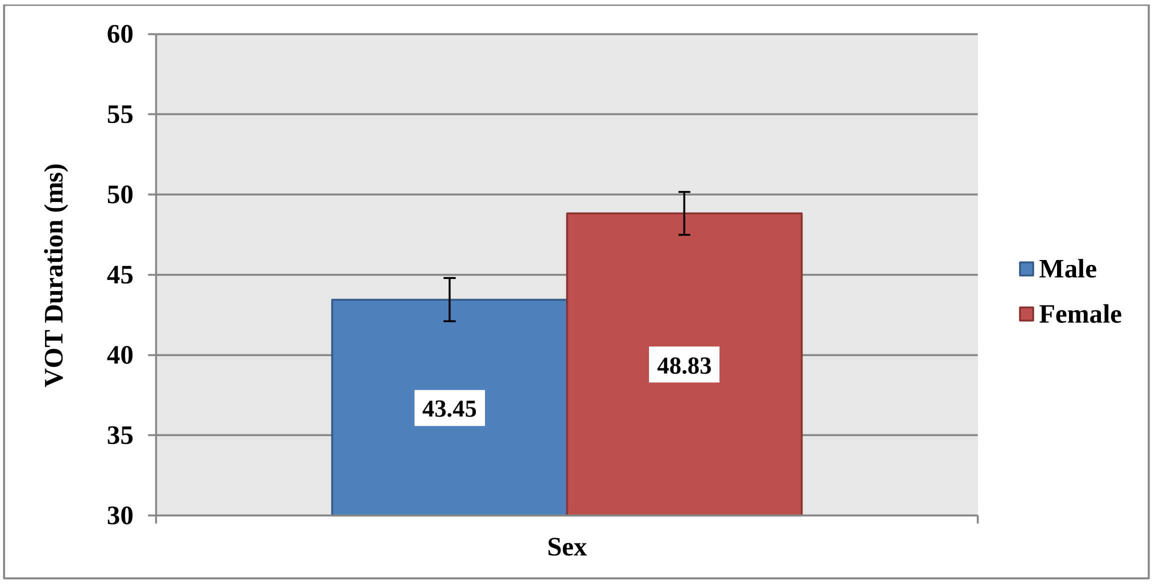


Figure 5.20 Mean± standard errors for VOT duration (ms) for males and females for plain/emphatic /t, tˤ/ stops, where males showed lower VOT durations than females.

5.8.4.2 VOT patterns and emphasis

With regards to VOT patterns, results given in Table 5.9 showed that both the plain voiceless stop /t/ and emphatic /tˁ/ displayed voicing lags. However, the voiceless emphatic alveolar /tˁ/ had a shorter mean VOT duration (19.87 ms) than the plain voiceless alveolar /t/ (72.41 ms). These differences were found to be significant ($F(1, 76) = 911.68$, $p < .001$), (see Figure 5.21).

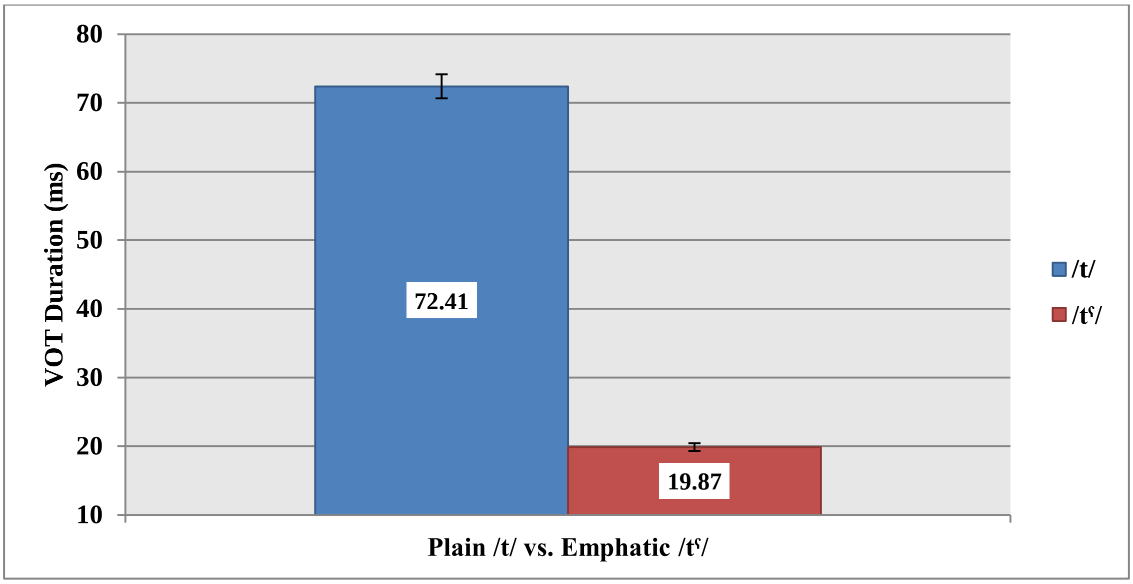


Figure 5.21 Mean± standard errors for VOT duration (ms) for the plain/emphatic alveolar /t, tˁ/ contrast, where /t/ showed longer VOT durations than /tˁ/.

There was a significant interaction between emphasis for voiceless plosives and dialect ($F(1, 76) = 6.085$, $p < .05$) , which is displayed in Figure 5.21. A mixed-model ANOVA was used with mean VOT durations for pooled plain alveolar voiceless /t/ and pooled emphatic alveolar voiceless /tˁ/ as the repeated measures, with dialect as the between-subjects factor.

Results showed a significant difference in VOT duration for /t/ between Saudis and Bahrainis ($F(1,76)$,$=4.908$,$p<.05$), where mean VOT values for Saudis (76.25 ms) were longer than for Bahrainis (68.56 ms). However, no significant differences were found between Saudis and Bahrainis for the voiceless emphatic /tˤ/ (F1,76)=.597, p=.422). Although no significant dialect differences were found in the production of emphatic /tˤ/, Saudi speakers produced the emphatic /tˤ/ with a marginally shorter VOT than Bahraini speakers (see Figure 5.22).

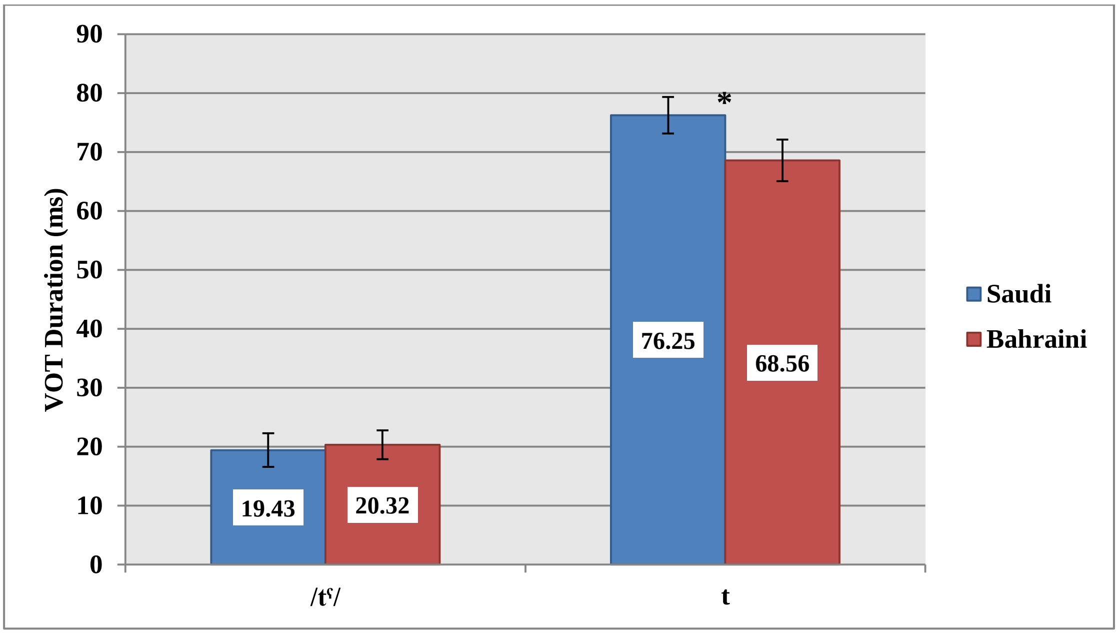


Figure 5.22 Mean ± standard errors for significant interaction between emphasis and dialect, where mean VOT duration (ms) for Saudis showed a trend with shorter VOT durations than Bahrainis for voiceless emphatic / tˤ/, while significant differences were found between the two dialects in voiceless /t/, where Saudi speakers had longer VOT durations than Bahraini speakers.

In addition, there was a significant interaction between emphasis for voiceless plosives by sex ($F(1, 76) = 21.90$, $p < .001$), as shown in Figure 5.23. A mixed-model ANOVA was used with mean VOT durations for pooled plain alveolar voiceless /t/ and pooled emphatic alveolar voiceless /tˤ/ as the repeated measures, with sex as the between-subjects factor. Results showed a significant differences in emphatic /tˤ/ between males and females (F(1,78),=5.762,p<.05), where males showed higher VOT durations (21.25 ms) than females (18.5 ms). In addition, a significant difference emerged for /t/ between the sexes (F (1,78),= 15.187,p < .001), where males showed shorter VOT values (65.65 ms) than the females (79.17 ms).

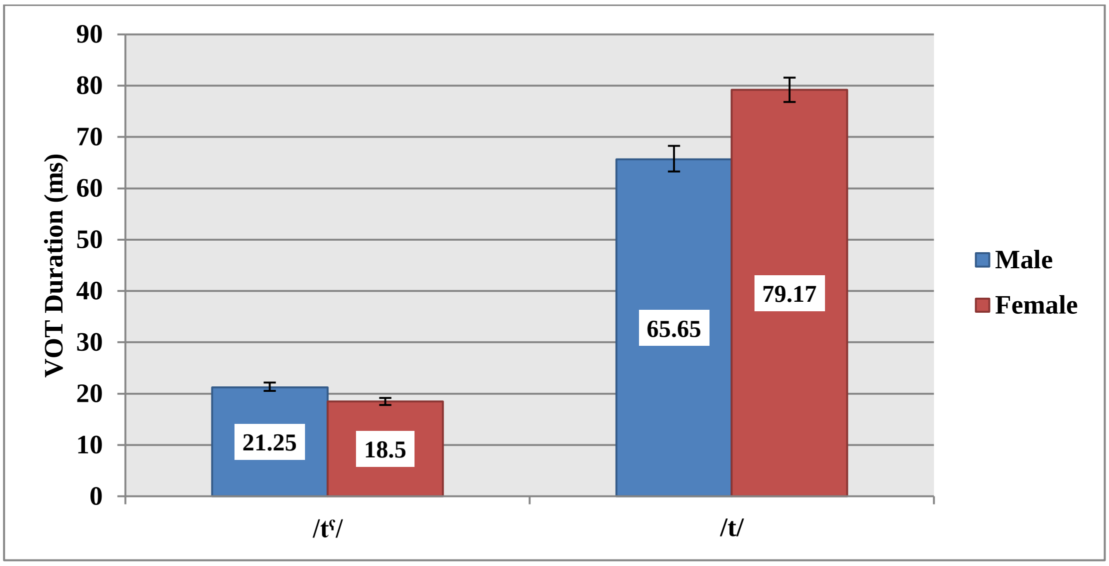


Figure 5.23 Mean ± standard errors for significant interaction between emphasis and sex where significant differences were found in VOT durations that were significantly longer for males than females for the emphatic /tˤ/. In addition, voiceless /t/ showed males had shorter VOT values than females.

5.8.4.3 Vowel context

Results showed that there was no significant effect of vowel context (F(1, 76) = .2.854, p =.095). However, there was a significant interaction found between emphasis for voiceless plosives by vowel context (F(1, 76) = 5.208, p <.05). A post hoc paired t-test revealed that for the voiceless alveolar stops /t/, the front high vowel /i:/ had longer mean VOT durations (74.48 ms) than back high vowel /u:/ (70.33 ms) (t(79)=2.09,p<.05). However, for the voiceless emphatic alveolar /tˤ/, no significant difference was found between the vowels /i:, u;/ (t(79)=-.891,p=.376) (see Figure 5.24).

No significant interaction was found between emphasis for voiceless plosives by vowel context by sex (F(1, 76) = .769, p =.383), emphasis by vowel context by dialect (F(1, 76) = .009, p =.924), or between emphasis by vowel context by sex by dialect (F(1, 76) = .024, p =.878).

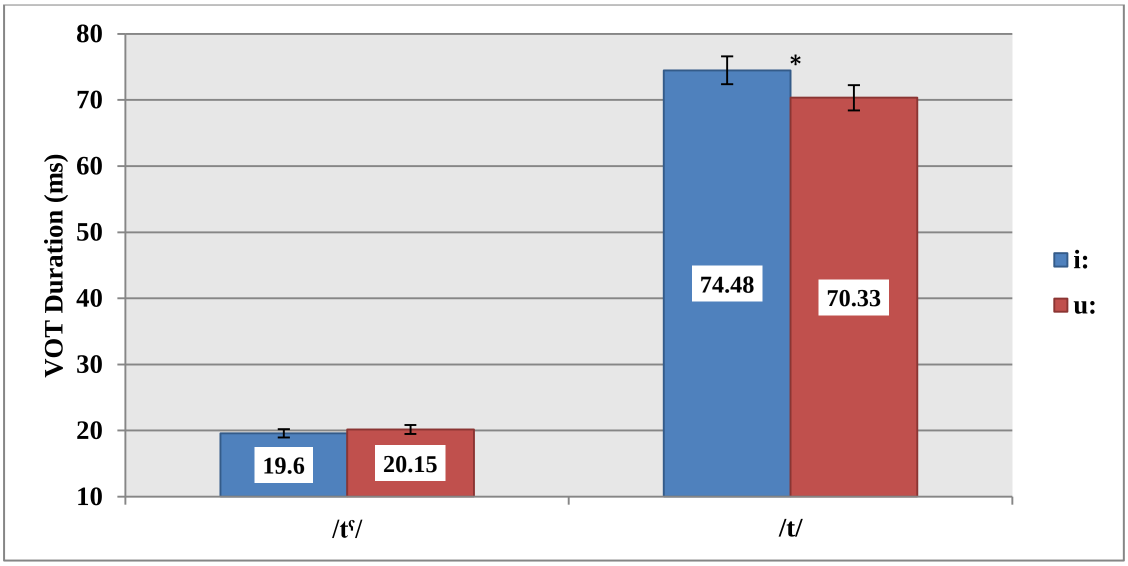


Figure 5.24 Mean ± standard errors for the significant interaction between emphasis and vowels where /u:/ showed longer VOT durations than /i:/ for voiceless /t/. No significant differences were found between vowel context for the voiceless emphatic /tˤ/.

In summary, VOT patterns showed ,voicing leads for voiced stops /b,d/ ,long lags (> 60 ms) for voiceless stops /t,k/ and short lags (< 22 ms) for the emphatic /tˤ/ as seen in Tables 5.6 – 5.9.

Significant results and interactions are shown in Table 5.10 where for voiced stops /b, d/, sex and dialect were not significant. Place of articulation showed significant differences where the more posterior the place of articulation was, the longer the VOT durations (b<d) were. For vowel contexts, the front high vowel /i:/ showed longer VOT duration than the back high vowel /u:/, which showed longer VOT duration than lower vowel /a:/ (see Table 5.6).

For the voiceless stops /t, k/, dialect was significant where Saudi speakers had longer VOT durations than Bahraini speakers. In addition, gender was significant where males had shorter VOT duration than females. Place of articulation showed significant differences similar to voiced stops where the more posterior place of articulation was, the longer the VOT duration (t<k) was. Also, vowel context showed significant differences where the front high vowel /i:/ had longer VOT durations than the back high vowel /u:/ (see Table 5.7).

For the voiced/voiceless stops /t, d/, dialect showed a significant interaction with voicing where Saudi speakers had longer VOT durations than Bahraini speakers for the voiceless plosive /t/. In addition, significant differences were evident between the sexes, where males had shorter VOT durations than females. Also, voicing had a significant interaction with sex where for /t/ males had shorter VOT durations than females. Voicing was significant where /d/ displayed voicing leads (negative) whereas /t/ displayed long voicing lags (positive), with significant differences also shown for place of articulation. Vowel context showed an interaction with voicing where significant differences were found for /t/, the high front vowel /i:/ had longer VOT durations than the back high vowel /u:/. No statistical significant differences were found between vowel contexts for /d/. However, the front high vowel /i:/ tended to show longer VOT durations than the back high vowel /u:/ (see Table 5.8).

For plain/emphatic /t, tˤ/, there was a significant interaction between dialect and emphasis where for the plain /t/, with Saudi speakers displayed significantly longer VOT duration than Bahraini speakers. While, for the emphatic /tˤ/, Saudi speakers displayed a marginally shorter VOT duration than Bahraini speakers. Sex showed a significant difference where males had shorter VOT duration than females. In addition, emphasis and gender had a significant interaction where for the plain stop /t/, males also showed shorter VOT durations than females, while for the emphatic stop /tˤ/, males tended to show longer VOT duration than females. Vowel context approached significant difference where the front high vowel /i:/ tended to show a longer VOT duration than the back high vowel /u:/. Further analysis showed the differences were significant for plain plosive /t/, whereas no significant difference for the emphatic stop /tˤ/, which showed a slightly shorter front high vowel /i:/ than the back high vowel /u:/ (see Table 5.9).

	Voiced /b,d/	Voiceless /t,k/	Voiced/voiceless /d,t/	Plain/Emphatic /t,tˤ/
Dialect	n.s	/t,k/: (S>B) (p<.05)	Voicing Interaction /t/ (B<S) (p<.05)	Approached significance (S>B) (p=.08) Interaction with emphasis (p<.05) t(B<S) (p<.05) tˤ(S<B) n.s
Sex	n.s	/t/k/,(M<F) (p<.001)	Sex (M<F) (p<.05) Voicing interaction (p<.05) /t/,(M<F) (p<.001)	t/tˤ(M<F) (p<.05) interaction with emphasis (p<.001) t(M<F) (.001) tˤ(M>F) (p<.05)
Voicing	Lead	Lags above 60 ms	Lead and long lags (p<.001)	Emphatic /tˤ/ < 30 ms /t/> 60 ms (p<.001)
Place	/b/</d/ (p<.05)	/t/</k/ (p<.001)	Lead and long lags (p<.001)	Lags /tˤ/</t/ (p<.001)
Vowel	/i:/>/u:/>/a:/ (p<.001)	/i:/>/u:/ (p<.05)	Approached significance interaction (p=.059) /t/,/i:/>/u:/ (p<.05) /d/ n.s	Approached significance (i:>u:) (p=.095) /t/(i:>u:) (p<.05) /tˤ/ n.s

Table 5.10 Significant results and interactions for voiced /b, d/; voiceless /t, k/; voiced/voiceless /t, d/; and plain/emphatic /t, tˤ/ for dialect, gender, voicing, place of articulation, and vowel contexts. (S and B denote Saudi and Bahraini speakers while M and F denote male and female).

5.9 Discussion

This first aim of this study was to establish normative VOT data for words with initial voiced /b,d/, voiceless /t,k/ and plain/emphatic /t,tˤ/ for male and female Saudi and Bahraini speakers which was successfully achieved and results are displayed in Tables 5.6 ~ 5.9. In addition, the second aim was to determine the effects of dialect (Saudi and Bahraini) and sex (male and female) on VOT for plain stops /b, d, t, k/ amongst Arabic speakers. This chapter also examined the effects of voicing, place of articulation, and vowel context for the voiced /b, d/ and voiceless /t, k/ stops. Furthermore, it discusses the effects of emphasis and vowel context for the emphatic /tˤ/ compared to the plain /t/. It begins with a discussion of dialect and gender differences identified in the study and the hypotheses that have been postulated, followed by a discussion of the within measures of voicing, place of articulation, emphasis, and vowel context as well as the hypotheses proposed for them (see Table 5.11). Finally, a summary of the findings is provided.

	Dialect		Sex		Voicing		Place/emphasis		Vowel	
	Hypothesis	**Results**	**Hypothesis**	**Results**	**Hypothesis**	**Results**	**Hypothesis**	**Results**	**Hypothesis**	**Results**
Voiced	Differences will not be found between dialects.	S=B	Differences will not be found between sexes.	M=F	Lead	Lead	The more posterior the place of articulation the longer VOT duration.	/b/</d/	/i:/>/u/>/a:/	/i:/>/u/>/a:/
Voiceless	Differences will not be found between dialects.	S>B	Males will have shorter VOT than females.	M<F	Long lags	Long lags	The more posterior the place of articulation the longer VOT duration.	/t/ < /k/	/i:/>/u/	/i:/>/u/
Emphasis	Differences will not be found between dialects.	S=B	Males will have shorter VOT than females.	M>F	Short lags	Short lags	Emphatic will have shorter VOT than plain.	/tˤ/ </t/	/i:/>/u/	/i:/=/u:/

Table 5.11 Comparisons of hypotheses predicted for the study of voiced, voiceless, and emphatic stops and the outcomes of the statistical analysis.

5.9.1 Dialect

As there were words with voiced, voiceless and emphatic stops in this study, this section will discuss dialect effects on voiced stops followed by voiceless stops and emphatics and finally concluding this section with reference to the hypothesis proposed.

Referring back to Tables (5.6, 5.10, 5.11), the Bahraini and Saudi dialects did not show differences between the voiced stops (/b, d/). Results supported the hypothesis that differences would not be found between the Arabic dialects included in the study. Studies on voiced stops in dialects are scarce in Arabic; however, in comparison with other dialects of Arabic, although using different methods, results for voiced stops in this study were similar to a number of others on voiced stops in dialects (see Figure 5.25) except for those published by Abudalbuh (2011), AlDahri and Alotaibi (2010), and Mitleb (2009). The results from Jordanian Arabic for Mitleb (2009) and AbuDalbuh (2011) indicated voicing lags, and the results for Khattab (2002) showed that a few participants in her study for Lebanese Arabic produced voiced /b, d/ with lags similar that might have affected Jordanian Arabic which might highlight characteristics of Levantine dialects. Results from AlDahri and Alotabi (2009) were on Saudi Arabic, which also showed lags for the alveolar voiced stop /d/. This is the only study that showed this pattern amongst dialects of Bedouin origin. The methodology used for this study was vague; therefore, it would be unproductive to compare it to other studies. Remaining studies used different methodologies, so no firm conclusion can be drawn from the comparison of the results of this study to other dialects in Arabic.

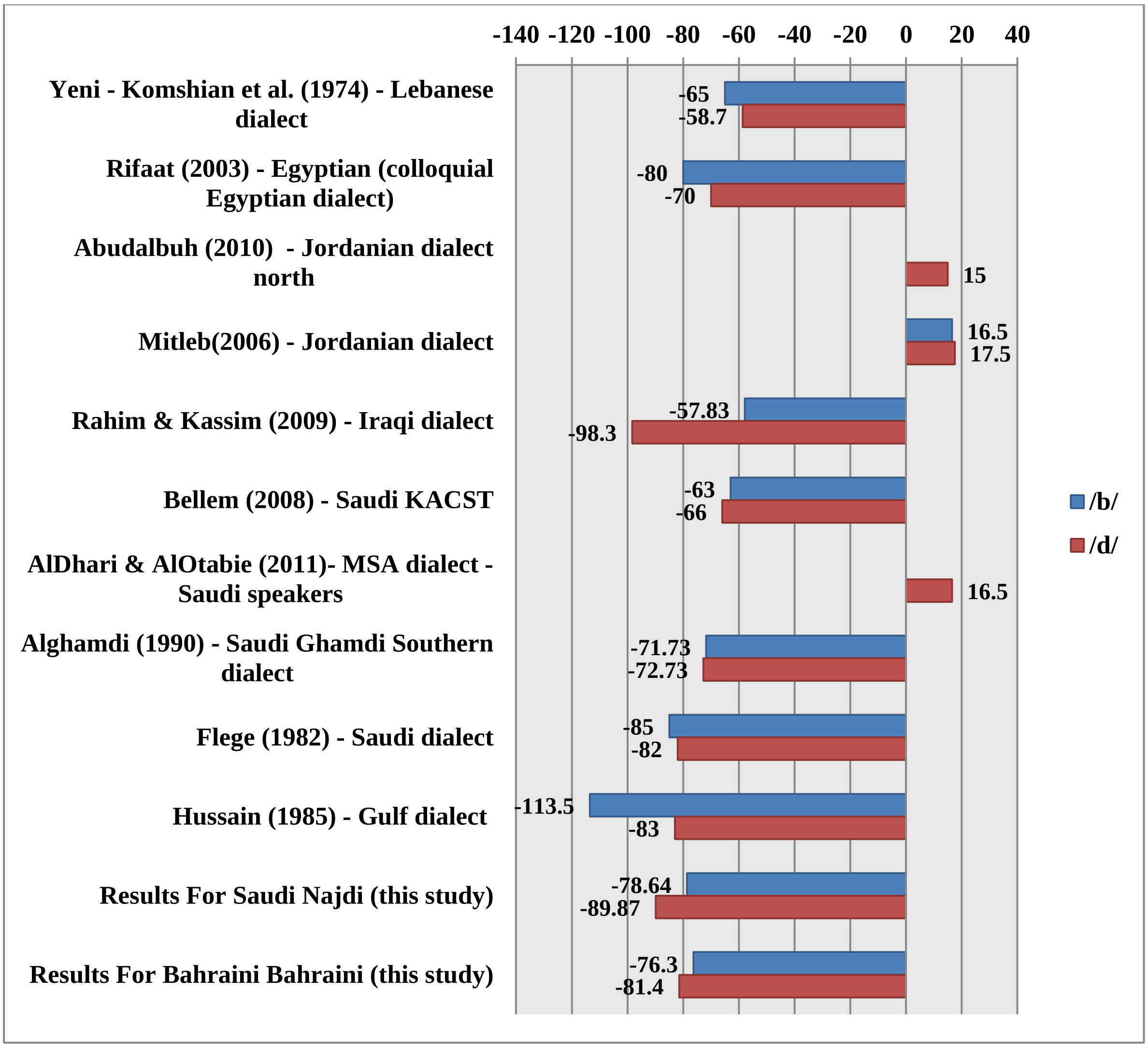


Figure 5.25 Mean VOT results for voiced stops (/b, d/) in a number of dialects of Arabic, including this study for Saudi and Bahraini speakers (Alotaibi & AlDahri, 2011; Abudalbuh, 2010; Rahim & Kasim, 2009; Bellem, 2008; Rifaat, 2003; Mitleb, 1992; Alghamdi, 1990; Hussain, 1985; Flege, 1982; Yeni-Komshian et al., 1977).

However, the picture is different for the voiceless stops /t, k/, where Saudi speakers had longer VOT durations than Bahraini speakers. This did not support the hypothesis made previously that differences would not be found between dialects. Comparing the voiceless stops /t, k/ VOT values from this study exhibited differences between Saudi Najdi and Bahraini speakers. Furthermore, when comparing the results from the two dialects to other studies from different Arabic dialects, they had the longest VOT durations for voiceless stops /t,k/,further supporting differences between dialects (see Figure 5.26).

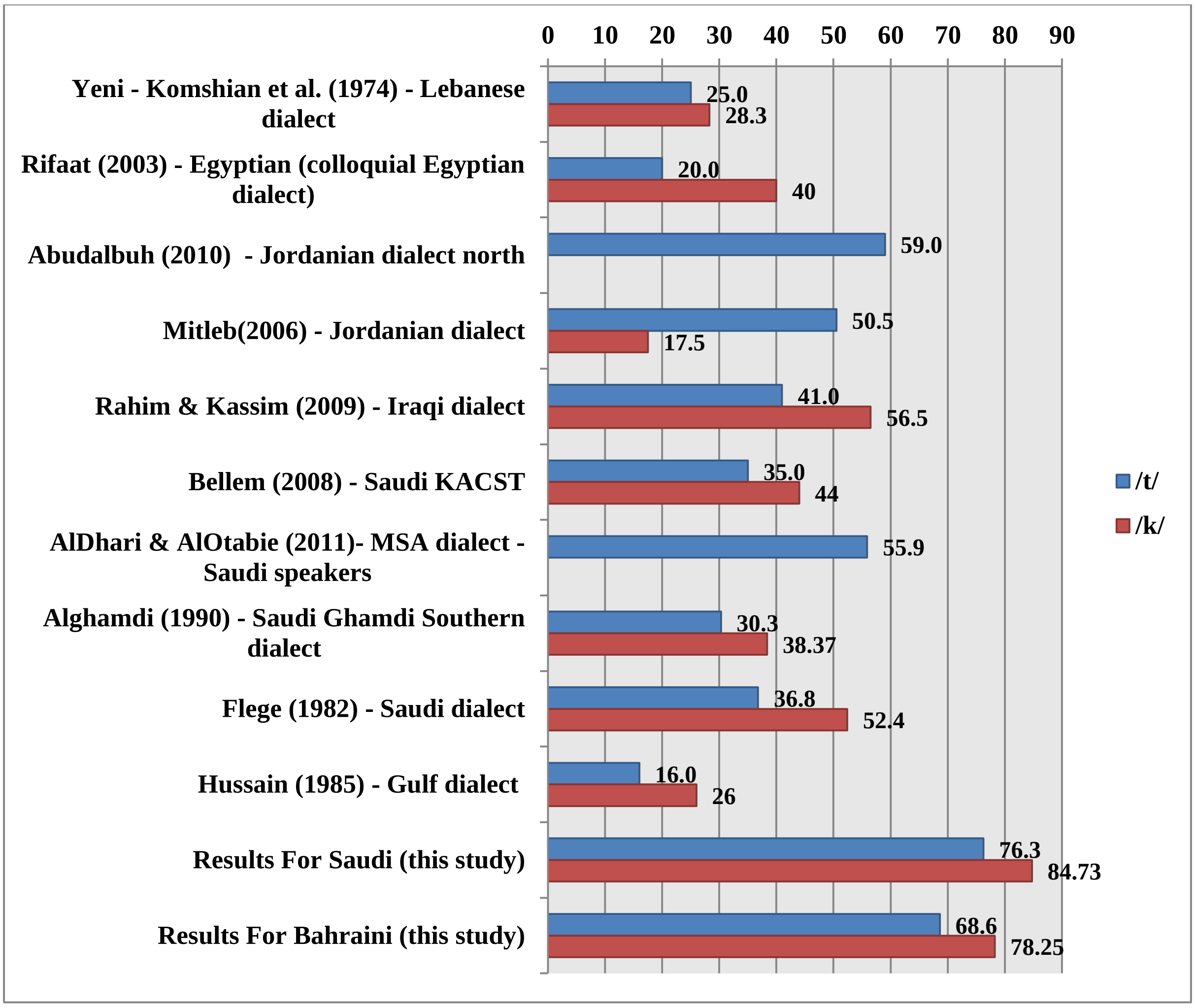


Figure 5.26 Mean VOT results for voiceless stops (/t, k/) in a number of dialects of Arabic, including this study for Saudi and Bahraini speakers (Abudalbuh, 2010; AlDahri & Alotaibi, 2010; Rahim & Kasim, 2009; Bellem, 2008; Rifaat, 2003; Mitleb, 1992; Alghamdi, 1990; Hussain, 1985; Flege, 1982; Yeni-Komshian et al., 1977).

In addition, when observing results from other studies in Arabic (see figure 5.26), variations do appear and are more consistent for voiceless stops than those observed for voiced stops (see figure 5.25). An example might be seen in comparing the results from Hussain (1985) for the Gulf dialect and Rahim and Kasim for the Iraqi dialect (2009), in which both can be considered to be of Bedouin origin where the difference between their results for voiceless stops /t, k/ were more than 30 ms as well as the results from this study for both dialects. This further support dialectical difference for VOT values for Bedouin and non-Bedouin origin Arabic speakers. In addition, results from Mitleb (2009) on Jordanian dialect where alveolar

/t/ showed longer VOT durations than velar /k/ which may imply that certain Jordanian dialects might have different VOT patterns.

For the emphatic /tˤ/, results were not significant statistically, which agreed with the hypothesis proposed that differences would not be found between Saudi and Bahraini Arabic dialect (see Figure 5.27). This result shows similarities between the Bahraini and Saudi dialects, this might be as Bellem (2008) indicated that Saudi speakers and in this study, Bahraini speakers are conservative in their production of the /tˤ/. The results show similarities with other studies (Khattab et al., 2006; Bellem, 2008; Abudalbuh, 2010) and Iraqi dialect from Heselwood's study (1996) where the plain stop /t/ showed longer VOT durations than the emphatic /tˤ/. Indeed , VOT results for /tˤ/ within these studies (Khattab et al., 2006; Bellem, 2008; Abudalbuh, 2010) are similar. Although, Abudalbuh (2010) showed marginally higher VOT value /tˤ/ which might be as a results of dialect. However, results from Lebanese (Yeni-Komshian et al., 1977) and Egyptian (Heselwood, 1996) showed a different pattern where VOT values between plain /t/ and emphatic /tˤ/ were similar, although, VOT values for the emphatic /tˤ/ were similar to those from the other studies, highlighting differences between VOT production for /t/. The Egyptian and Lebanese dialects are of non-Bedouin origin which might highlight that these dialects might neutralise their production of /tˤ/ as Heselewood’s study (1996) described the Egyptian results. This might imply further differences between Western and Eastern Arabic dialects. Although, this further should be examined in future studies.

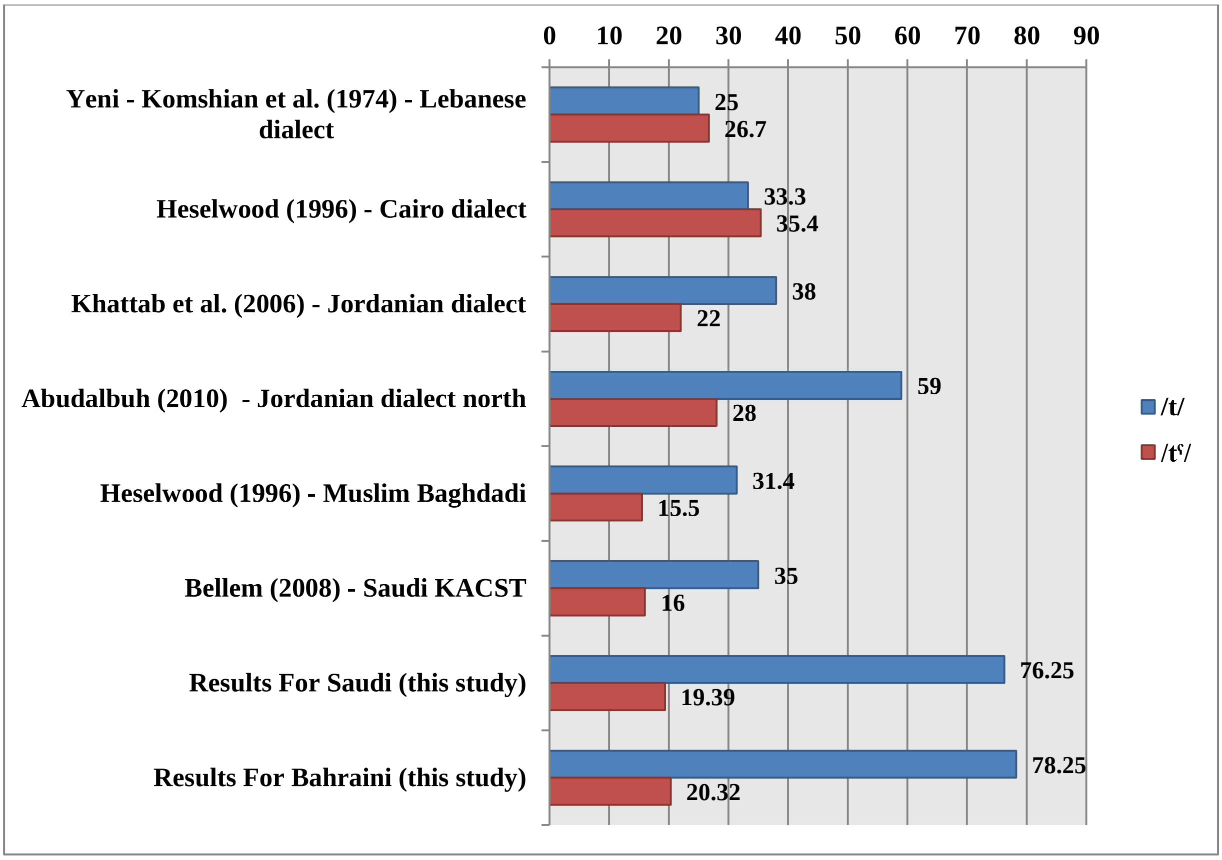


Figure 5.27 Mean VOT results for voiceless stops /t/ and emphatic /tˤ/ in a number of dialects of Arabic, including this study for Saudi and Bahraini speakers (Abudalbuh, 2010; Bellem, 2008; Khattab et al., 2006; Heselwood, 1996; Yeni-Komshian et al., 1977).

Looking at the results for this study for the voiced /b, d/; voiceless /t, k/; and the emphatic /tˤ/; the first hypothesis was supported for the voiced /b,d/ and the empathic /tˤ/ where no differences occurred between the Saudi and Bahraini dialects. However, for the voiceless stops /t,k/, results showed that Saudis had longer VOT duration than Bahraini speakers which does not agree with first hypothesis. Therefore, the results from this study show that dialect differences might appear depending on the stimulus type (i.e. voiceless stops in this study). Future studies are recommended when examining dialects and languages to expand stimulus type used in them to fully comprehend differences if they exist.

5.9.2 Sex

For VOT durations, sex did not show any effect for the voiced stops which were prevoiced. Results for VOT production for the voiced stops /b, d/ support the second hypothesis, i.e. that no differences would be found in the linguistic production of males and females. To the knowledge of the researcher, only a few other studies of Arabic have examined the difference between voiced stops between sexes. In the Abudalbuh (2010) study for /d/, he did not find differences of VOT values between male and female. Likewise, the study by Almbark (2009) did not find statistical differences for voiced /d/ between sexes. In addition, Rifaat (2003) did not find differences between sexes for voiced stops /d, g/. This seems to be in line with a number of other studies in English (Awan & Stine, 2011; Robb et al., 2005; Whiteside & Irving, 1997, 1998).

For the voiceless stops /t, k/, males and females exhibited differences where males showed shorter VOT durations than females, which is similar to what is shown for (/t, tˤ/) as seen in Khattab et al. (2006). However, Almbark (2009) and Rifaat (2003) demonstrated no difference between sexes in their studies, which may indicate that sex differences might be dialect-specific in Arabic. Although not statistically significant, Almbark (2009) had indicated that males tended to show shorter VOT values for stops emphatic and plain stops /tˤ,t/ than females. This also supports the second hypothesis that males would have shorter VOT duration than females for voiceless stops /t, k/.

Results for emphatic and plain stops showed that males had shorter VOT durations than females. However, the interaction between emphasis and sex showed that VOT results for voiceless stop /t/ supported the hypothesis that males had shorter VOT durations than females. However, results for the emphatic /tˤ/ demonstrated that males had significantly longer VOT durations than females, which is different from the results reported by Khattab et al. (2006), and also different from those reported for Arabic dialects from sedentary origins (Almbark, 2009; Rifaat, 2003). An explanation for this difference is that males' production of the emphatic /$t^ʕ$/, which produces a slighter longer delay than females, may be dialect-/gender-specific. In the next paragraphs, possible reasons will be discussed.

Another possible explanation for the differences found in the production of the emphatic /$t^ʕ$/ between males and females derives from a sociolinguistic point of view. Gender-related differences may occur in the production of emphatics, where some researchers have found that Arab women tend to avoid fully producing them with emphasis or pharyngealisation (Kahn, 1975; Royal, 1985; Wahba, 1996; Masri & Jongman, 2004; Khattab et al., 2006; Almbark, 2009). This was particularly the case in three specific Arabic dialects: Cairene Arabic (Kahn, 1975; Ahmed, 1979; Royal, 1985; Wahba, 1996; Masri & Jongman, 2004), Jordanian (Khattab et al., 2006) and Syrian (Almbark, 2009). The results were specifically inconclusive in Khattab et al. (2006), where two participants from Irbid produced their emphatic /$t^ʕ$/ with less emphasis than those from Amman while one participant from Amman produced her emphatic /$t^ʕ$/ with full emphasis; the interviewer in the study identified the latter participant as being from a high-class area in Amman and from a modern urban culture. This may also be the case with the females in the present study whose production of /$t^ʕ$/ has a greater degree of emphasis than that of the males; these female participants are from urban areas, as Riyadh and Manama are the capital cities in Saudi Arabia and Bahraini, respectively.

There results suggest there might be an interplay between the extra-linguistic factors of gender/dialect and social class in the production of emphatics. Considering the dialects (Saudi Najdi and Bahraini) examined in the present study, it seems that gender/dialect differences may play a major role in the production by females of emphatic /$t^ʕ$/, where they tend to fully produce their emphatic /tˤ/, in contrast to the production of the males. This is supported by Holes (1987) who reported a study on Bahraini populations on a number of social variables, including gender. He stated that socio-sectarian differences had greater significance in their realisations. However, he reported that women “tended towards extremes of dialectness” (p. 22) in their speech. Furthermore, Ismail's (2008) work on gender differences identified that females displayed a significantly more non-standard phonological form than males, with the exception of /q/ realisations. In her study on Saudi Arabic, Ismail (2008) agreed with Holes (1987) that Saudi females share with Bahraini females a tendency to use more dialectal speech than males. Therefore, male speech is characterised by their use of the more standard form (i.e. MSA) of Arabic.

The results for the voiceless emphatic /tˤ/ from the present study support the presence of more sex-related linguistic differences as females produced significantly shorter VOTs than males, therefore highlighting that dialect/gender interaction might be the reason for production of emphatics differently. It would be interesting to analyse the production of dialects among females from other regions in Saudi Arabia and from the Baharanh dialect (Shiia dialect) to assess their sex differences are also present. As studies remain scarce on sex-related differences in speech characteristics, future studies are needed in this area.

The results from this study supported the second hypothesis for the voiced stops where no differences existed between males and females. For the voiceless stops, males showed shorter VOT duration than females supporting the second hypothesis. However, males showed longer VOT durations than females; therefore VOT pattern between sexes for emphatics might play a role in identifying differences between dialects.

5.9.3 Voicing

In voicing, Arabic speakers of both dialects (Saudi and Bahraini) and sexes showed a consistent pattern irrespective of place of articulation, where in the production of the voiced stops /b, d/, the voiced plosives showed negative values (voicing leads). In the production of the voiceless stops /t, k/, positive values (voicing lags) were observed. The results showed a long lag, exceeding 30 ms, for both (/t, k/). In addition, the emphatic /tˤ/displayed a mean short lag values of 19.87 ms, which is less than 30 ms. In view of this information, this study supports the claim initially made by Khattab et al. (2006) that some Arabic dialects might have a three-voicing category, which was supported by the results presented in Bellem (2008) on Saudi Arabic, and is in agreement with the third hypothesis proposed for this study.

The two voicing categories claimed by others were formed on the basis of two stop categories rather than including all stops, for example, the examined stops were only voiced and voiceless stops (AlDahri & Alotaibi, 2010; Mitleb, 2009; Rahim & Kasim, 2009; Khattab, 2002; Alghamdi, 1990; Hussain, 1985; Flege, 1982). Others only examined the voiceless plain/emphatic stops (Heselwood, 1996; Khattab et al., 2006) or voiced/voiceless plain/emphatic stops (Rifaat, 2003; Almbark, 2009; Abudalbuh, 2010), which showed no significant differences between the voicing categories of the plain and emphatic stops. For example, Abudalbuh (2010) showed voicing lags in voiced alveolar plain /d/ and emphatic /dˤ/, further supporting the presence of dialectal differences in VOT values in Arabic.

To the knowledge of the researcher, the only studies that have examined the voicing categories in Arabic with the inclusion of the voiced, voiceless, and emphatic stops were Bellem (2008) and Yeni-Komshian et al. (1977). Results from Bellem (2008) and Yeni-Komshian et al. (1977) for Lebanese Arabic showed that the emphatic /tˤ/ and plain /t/ had 27 ms and 25 ms VOT duration, respectively. These findings are also in agreement with studies of sedentary Arabic dialects as found in Heselwood's (1996) Cairene Arabic study, where no differences were found that might have misled researchers to label Arabic as a two-voicing category.

Therefore, the third hypothesis was supported where Saudi and Bahraini Arabic dialects showed that these dialects had a three voicing category. Further studies are warranted for dialects in the Gulf area and other dialects of Arabic.

5.9.4 Place of articulation

The results revealed that for the voiced stops (/b, d/) and the voiceless stops (/t, k/), the more posterior the place of articulation, the longer the duration of VOT values. The voiced bilabial /b/ had a shorter voicing lead than the alveolar /d/. Furthermore, the results for this study are in agreement with a number of studies in Arabic where the further the place of articulation, the longer the VOT duration. The voiced bilabial stop /b/ having a shorter VOT duration than the alveolar /d/ as can be observed in a number of studies on Arabic, specifically Bedouin-origin Arabic (Rahim & Kasim, 2009; Bellem, 2008; Alghamdi, 1990). These studies are in agreement with studies for voiced stops in the Armenian language (Lisker & Abramson, 1964), which is considered to be a three-voicing category similar to the proposed voicing categories for this study.

The voiceless alveolar stop /t/ was shorter than the velar /k/ similar to a number of Arabic studies from both sedentary and Bedouin origins (Rahim & Kasim, 2009; Bellem, 2008; Rifaat, 2003; Alghamdi, 1990; Hussain, 1985; Flege, 1982; Mabrouk, 1981; Al-Ani, 1970). In addition, it follows the results for voiceless stops in English and other languages (Cho & Ladefoged, 1999; Docherty, 1992; Klatt, 1975; Lisker & Abramson, 1964). In the view of

Cho & Ladefoged (1999), regarding characteristics of the effects of place of articulation on VOT for voiceless stops, one of the explanations is that for velars it takes longer to release the intraoral pressure in comparison with alveolar stops.

The results for the voiced and voiceless stops support the fourth hypothesis where the further back the place of articulation the longer the VOT duration.

5.9.5 Emphasis

Results from this study showed that the emphatic alveolar stop /tˤ/, when compared to its plain alveolar cognate /t/, had shorter VOT duration than the /t/, therefore, the fifth hypothesis was supported. These results are consistent with a number of studies on different Arabic dialects, including results from Saudi (Bellem, 2008), Jordanian (Abudalbuh, 2010; Khattab et al., 2006), and Muslim Baghdadi (Heselwood, 1996) Arabic. However, Cairene Arabic spoken in Egypt (Heselwood, 1996) did not show differences between emphatic alveolar and plain alveolar stops, further supporting the claim made in this study that Arabic is complicated in its realisations of emphatics. The reason for differences in VOT duration between plain and emphatic is a result of the articulatory configuration of the emphatic stops where they are characterised by an increased contraction of the pharyngeal muscles (Lehn, 1963). Furthermore, Khattab et al. (2006) add that the shorter delay in the onset of voicing strongly indicates that the forces of tension around the glottis are stronger during the hold phase of the stop and the vocal folds are closer, thereby taking a shorter time to come together for commencing of voicing.

Results for the voiced emphatic /dˤ/ in three studies (Abudalbuh, 2010; Almbark, 2009; Rifaat, 2003) showed that differences were not found with its plain voiced alveolar cognate /d/. The inclusion of the voiced emphatic /dˤ/ would have been important to explore whether differences were found between dialects, whether it would have followed the asymmetry rule for voiced stops (Kessinger & Blumstein, 1997) proposed in the dialect section (see section 5.9.1), or whether the effects from emphasis for dialects of Arabic from Bedouin origin would be different.

5.9.6 Vowel context

For vowel context, only the voiced stops (/b, d/) had the three long vowels of Arabic (/a:/, /i:/, /u:/), while the remaining stops (voiceless and emphatic) had two high vowels, the high front vowel /i:/ and back front vowel /u:/. The results for three-vowel context in voiced stops are in agreement with a number of studies in Arabic such as Abudalbuh's results on Jordanian Arabic (2010) and in English and French (Nearey & Rochet, 1994), amongst others. Voiced stops followed by the high front vowel /i:/ had a longer VOT duration than the high back vowel /u:/, which had a longer VOT duration than the low vowel /a:/. Therefore, the results support the sixth hypothesis for voiced stops.

For voiceless stops, results showed that the front high vowel /i:/ had longer VOT duration than the back high vowel /u:/, which is in agreement with Nearey and Rochet's study of English and French (1994) and Abudalbuh's research on Jordanian Arabic (2011). Therefore, the results support the sixth hypothesis for voiceless stops.

Interestingly, for the emphatic stop /tˤ/, no statistical difference was found between the front high vowel /i:/ and the back high vowel /u:/. This had been reported elsewhere in the Jesry (1996) study where results for both vowel contexts were 24 ms. It is possible that emphasis spread is restricted in the higher front vowel /i:/ as in /tˤi:r/, thereby resulting in a similar duration to the back vowel /u:/. The result does not support the sixth hypothesis offered in this study. It might be an effect from the Arabic dialects in this study, as Herzallah (1990) observed in her analysis of Palestinian Arabic (Bedouin origin Arabic) that emphasis spread is restricted to following of low vowels in Arabic, which might also be the case in this study.

It would be interesting to view the emphatic production of /tˤ/ preceding all vowel contexts and in particular the lower vowels /a,a:/, in addition to production of emphatic /dˤ/ preceding all vowels to see if differences exist between the full set of vowels and show the effects of pharyngealisation for voiced and voiceless emphatics.

5.10 Summary

Results from this chapter revealed that dialect and gender play a major role for voiceless stops /t, k/. For dialect, Saudi speakers showed longer VOT durations than Bahraini speakers; and for gender, males showed shorter VOT durations than female speakers. However, gender and dialect did not show significance for voiced stops /b, d/. The results for the voiceless alveolar emphatic stop /tˤ/ also did not show significance for dialects. However, the result for sex for the emphatic stop /tˤ/ was unexpected because it contrasts with the second hypothesis proposed that males produced longer VOT duration than female speakers, underlining a more gender/dialect effect on the production the emphatic /tˤ/ whereby Arabic dialects differ in their production of the emphatic /tˤ/. Therefore, the voiceless emphatic stop appears to play a role in differentiation between dialects and gender in the Najdi and Bahraini speakers investigated in this study.

In addition, this research showed in the third hypothesis that Arabic may have a three-voicing category, as suggested by Bellem (2008), rather than a two-voicing category, as might be suggested by other studies (Rahim & Kasim, 2009; Khattab, 2002; Alghamdi, 1990). Place of articulation showed that the more posterior the place, the longer the VOT duration for voiced /b, d/ and voiceless /t, k/, similar to Arabic studies (Al-Ani, 1970; Alghamdi, 1990; Bellem, 2008; Flege, 1982; Hussain, 1985; Mabrouk, 1981; Rahim & Kasim, 2009). Emphatic stops demonstrated shorter VOT duration than their plain counterparts (Abudalbuh, 2010; Bellem, 2008; Khattab et al., 2006; Heselwood, 1996; Yeni-Komshian et al., 1977). For voiced and voiceless stops, vowel context had a significant effect on VOT patterns where high vowels were longer than low vowels and high front vowels were longer than high back vowels. This supports results from the Arabic study by Abudalbuh (2010) and studies on different languages (Nearey & Rochet, 1994; Volaitis & Miller, 1992; Weismer, 1979; Klatt, 1975). Whereas, for the emphatic stop /tˤ/, no significant results were found between VOT duration for /i:/ than /u:/, which is similar to Jesry (1996).

Chapter 6. Fundamental Frequency (F0)

6.1 Introduction

The previous chapter examined VOT, including the effects of dialect, sex, place of articulation and vowel type on VOT duration. The focus in this chapter is on the parameter of Fundamental Frequency (F0), in order to determine if dialectical and sex differences are present for Arabic speakers of two dialects (Najdi and Bahraini).

Baken & Orlikoff (2000) describe F0 as being reflective of the biomechanical characteristics of the vocal folds including laryngeal structure, applied muscle forces and how they interact with translaryngeal airflow. In other words, F0 is the vibration rate of the vocal folds and is expressed in hertz (Hz) (Johnson & Jacobson, 2011). F0 is an important aspect of assessment of voice in the field of acoustic phonetics, and for speech and language pathologists and clinicians. Studies have established normative data for English (e.g. Stoicheff, 1981; Hollien & Shipp, 1972; Saxman & Burk, 1967). Studies on the Arabic language are scarce (Natour et al., 2011; Natour & Wingate, 2009; Alghamdi, 1998), and studies on sex differences for mean F0 in Arabic are more scarce (Natour et al., 2011; Natour & Wingate, 2009; Malki et al., 2009). Different types of stimuli have been shown to have differences in F0 (Zraick et al., 2000; Murry et al., 1995); therefore this study will explore the differences between dialects and sexes in different stimuli types for Arabic speakers from two dialects (Saudi and Bahraini).

The structure of the chapter is as follows. First it presents the speaker related and non-speaker related factors that affect F0, followed by a review of studies on the effect of dialects on F0.

After a review of the Arabic studies available on F0, research questions and hypotheses will be presented, followed by the methodology. Results and discussion will be presented finally.

6.2 Factors affecting F0

In recent years, numerous studies have attempted to determine the multiple factors that have an effect on F0. In this section, a review of the factors is presented. These factors are divided into two categories: speaker-related and non-speaker related.

6.2.1 Speaker non-related

6.2.1.1 Stimuli type

A few studies have examined the effects of stimuli type on F0. Murry et al. (1995) examined F0 in the sustained phonation of /a/ and reading passage and prompted speech data in response to participants being presented a picture. They found that sustained phonation had a lower F0 than reading and spontaneous speech. While females had a higher F0 than males, females displayed a different pattern, where sustained phonation produced higher F0 values compared to reading samples and spontaneous speech, while the reading passage data had a higher F0 than spontaneous speech.

In a more recent study, Zraick et al. (2000) had added counting from 1-10, two filler words and counting 1-3, then a sustained vowel /i/ in addition to reading from The Rainbow Passage (Fairbanks, 1960). The results were similar to Murry et al. (1995) for sex where males had lower F0 than females. Results for males showed no statistically significant differences between tasks; however, females' results showed statistical differences between all tasks, see Table 6.1.

	Zraick et al. (2000)		Murry et al. (1995)	
	Male	Female	Male	Female
Sustained /a/	124	201	123	209
Reading	136	192	137	195
Spontaneous speech	127	187	136	189

Table 6.1 Mean F0 (Hz) for different two studies in English (Zraick et al., 2000; Murry et al., 1995) for different stimuli type (numbers were rounded to the nearest decimal point).

There seem to be differences for F0 between the two studies (e.g. 8Hz difference between female speakers on sustained /a/ and 9 Hz difference between male speakers on spontaneous speech). Whether the differences are caused by methodological discrepancies or a product of different dialects remains uncertain.

6.2.1.2 Phonetic context effects

6.2.1.2.1 Effects of Vowels on F0

Differences between mean F0 in vowels have been documented in more than 30 languages from 61 studies by Whalen & Levitt (1995). In their study (Whalen & Levitt,1995), high vowels /i,u/ had a higher mean F0 than the vowel /a/. In addition, although not statistically significant, the high front vowel /i/ had a lower mean F0 than the high back vowel /u/. In addition, a number of studies on sustained phonation (Table 6.2) and words (Table 6.3) showed a similar pattern to that seen by Whalen and Levitt (1995).

6.2.1.2.2 Effects of Voicing and place of articulation on F0

A few studies have reported that mean F0 for vowels following voiced stops had a lower mean F0 than those following voiceless stops (Van Alphen & Smits, 2004; Kingston & Diehl, 1994; Umeda, 1981; Löfqvist, 1975; Mohr, 1971; Lehiste & Peterson, 1961; House &

Fairbanks, 1953). However, other studies reported no differences between mean F0 for vowels after voiced and voiceless stops (Fox et al., 2013).

6.2.1.2.3 Elicitation Style

In one of the few studies that looked at the effect of elicitation style, Zraick et al. (2006) examined the following simulation contexts (voice evaluation (formal), speaking in public, speaking to a peer, speaking to a superior, speaking to a subordinate – child, and speaking to a parent or spouse). The results showed that speaking to a subordinate resulted in the highest F0 while speaking to a superior resulted in the lowest F0; the results were statistically significant.

6.2.2 Speaker related

6.2.2.1 Age

The effects of age have been documented in many studies where male and female children have higher F0 than adults (Morris, 1997; Sorenson, 1989; Wheat & Hudson, 1988; Bennett, 1983; Hollien & Shipp, 1972; McGlone & McGlone, 1972).

After puberty, males and females develop their respective adult sex differences where males develop longer vocal folds and significant voice changes occur between the ages of 14-18 years (Curry, 1940). For females Duffy (1970) speculated that F0 is affected between the ages of 13-15 years. Sex differences in F0 between adult speakers will be elaborated on in the next section.

As age progresses, among older adults, older adult males increase their F0 (Harnsberger et al., 2008; Brown et al., 1991; Hollien & Shipp, 1972; Mysak, 1959). In addition, increase occurs in older adult females as well (Russell et al., 1995; Higgins & Saxman, 1991; Benjamin, 1986; Stoicheff, 1981).

6.2.2.2 Sex

Several studies have found that the differences between the membranous vocal fold length and laryngeal size contribute to the differences of F0 between males and females, where males have larger sized vocal length and laryngeal size than females (Fung, 1990; Williams & Eccles, 1990; Titze, 1989a; Hirano et al., 1981; Kent, 1976; Hollien, 1960). Moreover, females tend to have more tension in the vocal fold than males (Fung, 1990; Titze, 1989; Hirano et al., 1981) which leads to females having higher F0 than males (Titze, 1988, 1989).

However, in an interesting study on Wu dialect in Chinese (Rose, 1991), mean F0 for male speakers was 170 Hz while female speakers had 187 Hz which in comparison to other studies (see Table 6.2 in next section) shows that dialect may play a role in mean F0 as well as social convention (Traunmüller & Eriksson, 1995).

The next section on differences in F0 in race, ethnicity and cross-linguistic studies will demonstrate the differences between sexes.

6.2.2.3 Effects of vocal pathologies on F0

Diseases have exhibited differences in pathological disease (Hirano, 1989; Murry & Doherty, 1980). Hirano (1989) compared the results from 40 control participants to 1,563 speakers that had different pathologies (e.g. Reinke’s edema, chronic laryngitis, sulcus vocalis among other diseases) on sustained phonation. The results reported significantly high F0 for specific diseases (e.g. glottis, subglottic carcinoma, sulcus vocalis and mutational dysphonia) while others (e.g. laryngitis and Reinke’s edema) reported significantly lower F0. The reported differences were due to increased stiffness for high F0 pathologies or increased mass and decreased stiffness. Murry & Doherty (1980) analysed 5 controls with 5 pathologic voice patients. Stimuli were from recording a sentence from "The Rainbow Passage" (Fairbanks, 1960) and sustained phonation. The results showed differences between control and patients on the sentences where they had higher F0 while no differences were found between them for sustained phonation.

In contrast, Murry (1978) found no differences between 80 male participants between the ages 28 and 77 years with 4 groups (20 per group) with different types of pathologies (vocal fold paralysis for over a year, benign mass lesions, laryngeal cancer and controls). Stimuli used for analysis were sentences from "The Rainbow Passage" (Fairbanks, 1960). The results were not statistically significant but those with vocal pathologies tended to have higher F0 than control.

In addition to vocal pathologies, hearing has been reported to affect F0 where in a study by Nakamura et al. (2007), hearing impaired adults showed higher F0 than normal hearing adults.

6.3 F0 studies investigating race, ethnicity and cross-linguistic differences

It has often been claimed that the physical differences between many races may be attributed to differences between F0. However, most of the studies that show there were differences between African Americans and Caucasian Americans were on children (Wheat & Hudson, 1988; Hollien & Malcik, 1962) or older adults (Xue & Mueller, 1996). The studies on children and older adults may interact with other factors such as development and the effects of aging on F0; therefore, the studies on adults will be the focus in this section of the thesis.

Hudson & Holbrook (1981) compared the results of reading "The Rainbow Passage" (Fairbanks, 1960) between 200 African American (AA) and Caucasian American (CA) subjects between the ages of 18-29 years. Results showed that African Americans had lower F0 values; males and females had mean values of 110.00 Hz and 193.00 Hz, respectively compared to mean values of 116.00 Hz and 217.00 Hz for Caucasian American males and females; however no statistical tests were administered. In a follow-up study, Hudson and Holbrook (1982) compared the results from reading and spontaneous speech data. The reading speech results for AA speakers were from their previous study, and showed that in spontaneous speech males had a mean F0 value of 108.00 Hz while females had a F0 mean of 188.00 Hz. Spontaneous speech had a lower F0 than the reading speech data. In addition, although statistically supported, AA speakers had a lower F0 than CA when compared to the results of several studies (see Table 6.2).

Sapienza (1997) did not find any significant differences between 20 African Americans and 20 Caucasian Americans aged between 18-28 years for sustained vowels. The males that were African American and Caucasian American had values of 123.95 and 124.53 Hz respectively, and female African American and Caucasian American had values of 223.10 and 214.90 Hz, respectively (see Table 6.3).

Study	Language	Type	Male	Female
Hudson & Holbrook (1981)	American English (C)	Reading	116.65	217.00
	American English (AA)	Reading	110.15	193.10
Hudson & Holbrook (1982)	American English (AA)	Spontaneous	108.05	188.85
Chen (2007)*	Chinese (Mandarin)	Reading	110.00	196.00
Zhang et al. (1999)*	Taiwanese Chinese (Mandarin)	Counting	118.30	203.20
Pegoraro-Krook & Castro (1994)*	Portuguese (Brazilian)	Counting	130.50	×
		Reading	134.90	×
Guimarães & Abberton (2005)*	Portuguese (European)	Reading	109.60	190.30
		Spontaneous	109.20	186.60
Mennen et al. (2007)*	British English (Southern)	Reading	×	213.30
	German	Reading	×	208.60
Altenberg & Ferrand, (2006)	American English	Spontaneous	×	185.50
	American English	Spontaneous	×	190.12
	Russian			208.20
	American English	Spontaneous	×	182.31
	Cantonese Chinese			174.79
Andreeva et al. (2014)*	British English	Reading	127.00	218.00
	German		120.00	206.00
	Bulgarian		154.00	275.00
	Polish		157.00	259.00
	British English	Counting	119.00	213.00
	German		116.00	202.00
	Bulgarian		155.00	272.00
	Polish		165.00	260.00
Rose (1991)*	Chinese (Wu dialect)	Reading	170.00	187.00

Table 6.2 Mean F0 (Hz) for different types of stimuli using connected speech in a number of languages (Andreeva et al., 2014; Mennen et al., 2007; Chen, 2007; Altenberg & Ferrand, 2006; Guimarães & Abberton, 2005; Zhang et al., 1999; Pegoraro-Krook & Castro, 1994; Rose, 1991; Hudson & Holbrook, 1981, 1982). The results also show males have markedly lower mean F0 than females except for Rose (1991). (Note: * denotes that the results are disaplyed as in the releavent articles and an additaional decimal point was added to match other studies).

A study by Andrianopoulos et al. (2001) compared 4 different ethnic/race groups with 10 participants per group (5 male and 5 female); groups were Caucasian, African American, Indian and Chinese. Age, sex and educational background were matched between participants. In measurements of F0 for the three sustained vowels /a/, /i/ and /u/, Chinese males and females produced statistically higher fundamental frequencies for all three vowels than the other three groups. The results from this study suggest race might have an effect on F0. In another study of Mandarin Chinese (Zhang et al., 1999) comparing F0 for sustained phonation of vowel /a/ in Taiwanese speakers (45 males and 45 females between 20-49 years). Their study showed F0 values consistent with the results from Andrianopoulos et al.'s study (2001) (seeTable 6.3).

However, in another study on Taiwanese Chinese Mandarin speakers (Wang & Huang, 2004), results (see Table 6.3) were similar for sustained phonation /a/ to those of Caucasian Americans and African Americans (Sapienza, 1997), and also Indian speakers (Andrianopoulos et al., 2001). In addition, Wang & Huang (2004) had results for counting similar to those of a study on Mandarin Chinese by Chen (2007). Furthermore, comparing these results to studies from other languages (Table 6.2) shows some similarities to results for English (Hudson & Holbrook, 1981, 1982) and European Portuguese (Guimarães & Abberton, 2005).

Guimarães & Abberton (2005) performed a study on European Portuguese speakers between the ages of 19-67 years on sustained vowels /a,i,u/ and reading and spontaneous speech. The results showed females to have higher mean F0 than males. F0 varied depending on stimuli type where sustained vowels had generally statistically higher F0 than those in spontaneous speech, while no differences were exhibited between reading and spontaneous speech (see Tables 6.2 and 6.3). As previously explained the results were similar to other languages.

However, Pegoraro-Krook & Castro's (1994) results for male Brazilian Portuguese speakers between the ages of 17-30 years were higher for the reading passage (see Tables 6.2 and 6.3) which might highlight a difference between Portuguese dialects. However, no firm conclusion can be made as different methodologies were used and the age ranges in the two studies were different. In Guimarães and Abberton (2005), participants ranged from 20 to 67 years old in comparison to the age range that was much narrower in Pegoraro-Krook and Castro's study (1994).

In a study on female speakers of German and Southern British English on reading (Mennen et al., 2007), results showed similarities for F0 between German and British English. In another study (Andreeva et al., 2014) on British English and German (Germanic) and also Bulgarian and Polish (Slavic) languages (results see Tables 6.2 for all languages on reading sentences and counting) showed sex differences where males had lower F0 than females. In addition, differences between German and British English were not found but were lower than both Slavic languages (Polish and Bulgarian), which also had no differences in F0 between them. Upon visual inspection of the results (see Table 6.2), the Slavic languages (Polish and Bulgarian) appear to have higher F0 values for both tasks. On further inspection of the results of British English and comparing them to American English (Hudson & Holbrook, 1981, 1982), British English reading showed slightly higher F0 than American English for male speakers. However, it is difficult to affirm if the differences are due to dialect as methodological differences are apparent: different reading passages which might lead to diffrences in F0.

In a further cross-linguistic study, Altenberg & Ferrand (2006) examined F0 in monolingual American English and bilingual Cantonese Chinese/English and Russian/English females speakers aged between 18-24. The American English group had 10 participants while each bilingual group had 9 participants per group. Russian was considered to be the native language of eight participants from the Russian/English bilingual group and 3 participants with English and Cantonese considered both languages as native languages while the remaining 6 considered English their native language. F0 was gathered from spontaneous speech as reported in Table 6.2. The results showed no significant differences between all groups when speaking American English. However, F0 was significantly higher when speaking Russian, while no differences were found between Cantonese and American English. However, the authors considered that there might be an effect of one language on the other as exhibited in the slightly lower F0 in American English in Cantonese bilinguals and slightly higher F0 in American English for Russian bilinguals, which might imply an effect from bilingualism. Although, the study suggests the bilinguals adopt different F0 for each language.

Study	Language	Type	Male	Female
Sapienza (1997)	American English (C)	/a/	124.53	214.90
	American English (AA)	/a/	123.95	223.10
Andrianopoulos et al, (2001)	American English (C)	/a/	128.31	233.46
	American English (AA)	/a/	127.56	227.99
	Indian	/a/	137.60	251.64
	Chinese	/a/	154.21	266.73
	American English (C)	/i/	125.90	242.35
	American English (AA)	/i/	140.86	245.76
	Indian	/i/	139.60	262.17
	Chinese	/i/	162.36	280.92
	American English (C)	/u/	129.92	242.06
	American English (AA)	/u/	146.01	256.82
	Indian	/u/	143.09	263.78
	Chinese	/u/	162.25	295.03
Zhang et al. (1999)	Taiwan Chinese (Mandarin)	/a/	160.81	297.42
Wang & Huang, (2004)*	Taiwan Chinese (Mandarin)	/a/	121.30	213.40
Guimarães & Abberton (2005)*	Portuguese (European)	/a/	118.40	210.50
		/i/	127.60	221.00
		/u/	123.00	225.10

Table 6.3 Mean F0 (Hz) values for sustained phonation of vowels for different races and languages (Guimarães & Abberton, 2005; Wang & Huang, 2004; Andrianopoulos et al., 2001; Zhang et al., 1999; Sapienza, 1997) in a number of studies. Note the differences between sexes where males have generally lower mean F0 than females. (C = Caucasian and AA = African American). (Note: * denotes that the results are disaplyed as in the releavent articles and an additaional decimal point was added to match other studies).

6.4 Life Style, Speech Rate and Intensity on F0

6.4.1 Life style

Life style choices have been shown to affect F0. A study on the effects of fasting during Ramadan for Muslims showed that males had statistically significant lower F0 (Hamdan et al., 2010) while females had slightly lower F0 during fasting but this was not significant (Hamdan et al., 2007).

In addition to fasting, smoking had been reported to affect F0 where it lowered F0 for females in a study by Guimarães & Abberton (2005). Further to smoking, they reported even lower F0 when females were stressed and smokers.

6.4.2 Speech Rate and Intensity effects on F0

Fundamental frequency has been reported to vary with speech rate, where an increase in speech rate results in an increase in F0 (Black, 1961; Shanks, 1970). Moreover, in a recent study by Topbaş et al. (2012), speech rate was shown to have an effect on the mean F0 in syllables produced by 24 adults (12 males and 12 females); the syllables used were /pʌ/, /pʌtə/ and /pʌtəkə/. They found a significant increase between mean F0 for slow and maximum rate of speech. In addition, they found an increase in mean F0 between normal speech rate and maximum speech rate.

In a study by Dromey & Ramig (1998), F0 and intensity showed an increase for participants when they produced their sentences at double and four times the rate of their comfortable level. In addition, Watson & Hughes (2006) describe an increase in mean F0 with the increase of intensity in their subjects.

6.4.3 Research into varieties and dialect difference in F0 in English

As described earlier in cross-linguistic studies, comparing results between different studies can be problematic as methodologies and stimuli are different across studies. However, dialect differences have been explored with varying results. In this section, a review of studies on dialects in English will be dissccussed.

In one of the earliest studies on differences between dialects in English, Hanley (1951) reported a study on American English. He examined three dialects spoken by 27 male participants: the General American dialect was spoken by 9 participants, the Southern American dialect was spoken by 11 participants, and the Eastern American dialect was spoken by 7 participants. The stimuli were "The Rainbow Passage" (Fairbanks, 1960) and spontaneous speech. The first paragraph was read out loud; however, the first sentence was not used in analysis. The results showed that the Southern American dialect had a higher mean F0 than both the General American and Eastern American dialects but the results were statistically significant for only spontaneous speech (see Table 6.4).

In another study on American dialects, Fox et al. (2013) selected three American dialects: two Midwestern varieties, the Midland variety spoken in Ohio (OH) and an inland North variety spoken by Southeastern Wisconsin (WI), and a third Southern variety spoken in western North Carolina (NC). The researchers collapsed all the vowel results and divided them in terms of stressed and non-stressed words. The results (see Table 6.4) showed that stress had a significant effect; however, no significant differences were found between voiced/voiceless stops and dialects. Also, they found that differences between F0 contours for vowels were greater for the Southern American dialect than the Midwestern American dialect. It should be noted that this study focused on vowels only, which might have affected the mean F0. Another point is that sex was restricted to female participants who were also defined geographically rather than linguistically.

Language	Study	Dialects	Type	Males Mean F0 (Hz)	Females Mean F0 (Hz)
English	Hanley (1951)*	General American	Spontaneous Reading	119.40 111.10	×
		Southern American	Spontaneous Reading	134.60 136.20	×
		Eastern American	Spontaneous Reading	122.20 117.20	×
	Fox et al. (2013)*	OH	Vls stressed Vls unstressed Vd stressed Vd unstressed	×	253.60 187.40 252.90 184.90
		WI	Vls stressed Vls unstressed Vd stressed Vd unstressed	×	235.80 159.20 235.80 161.10
		NC	Vls stressed Vls unstressed Vd stressed Vd unstressed	×	235.30 164.20 235.10 164.80
	Vicenik & Sundara (2013)	Western American	Reading	×	211.97
		Australian	Reading	×	208.62
		German	Reading	×	195.03

Table 6.4 Mean F0 (Hz) for a number of English dialects (Hanley, 1951; Fox et al., 2013; Vicenik & Sundara, 2013). The results showed differences between American dialects in Hanley (1951) while no differences occurred in the other dialects (Fox et al., 2013; Vicenik & Sundara, 2013). ((OH) denotes Ohio, (WI) Southeastern Wisconsin and (NC) western North Carolina). (Note: * denotes that the results are disaplyed as in the releavent articles and an additaional decimal point was added to match other studies).

Another study that had pitch contours as its focus is Vicenik and Sundara's (2013) study, where they recruited females speaking three languages: 16 spoke two English dialects, 8 were Americans recruited from California, USA, and 8 were recruited from around Sydney, Australia. The remaining 8 were speakers that spoke central German. Stimuli were sentences that were read out loud; analysis was performed on all sentences. The results (see Table 6.4) showed that there were no differences between the English dialects for the mean F0; however, differences were found between American dialects for maximum F0. In addition, differences were found between American and German for mean F0, minimum F0 and maximum F0.

6.5 Studies of F0 in Arabic

Research on phonetics and voice registers in Arabic is relatively scarce. Alghamdi (2006) indicated that most recent studies were individual efforts from PhD students or individuals with an interest in one of the features of Arabic-like pharyngealisation (Heselwood, 1996, 2007; Khattab et al., 2006). Recently, there have been a few studies on Arabic (Natour & Wingate, 2009; Malki et al., 2009; Abu-Al-Makarem & Petrosino, 2007; Alghamdi, 1998). This review on Arabic studies is divided depending on stimuli type; firstly studies on F0 in vowels (Natour & Wingate, 2009; Malki et al., 2009; Natour et al., 2011), followed by studies on F0 in words (Alghamdi, 1998; Shoul, 2008), and finally concluding with studies on F0 in sentences (Natour & Wingate, 2009; Alshahwan, 2008; Abu-Al-Makarem & Petrosino, 2007).

6.5.1 Vowels

In a study by Natour & Wingate (2009), 300 participants from Jordan (100 adult males, 100 adult females,100 children) who were college students between 18-24 years old all produced a sustained phonation of the vowel /a: / and stated their names (first, second and third) using a carrier phrase. The author indicated that mean F0 for sustained values for the adult males and females were similar to those reported for sustained phonation F0 for adult Caucasian Americans and African-Americans reported in the literature. Furthermore, sex differences were observed in mean F0 for /a/ as males had lower a mean F0 (131 Hz) than females (231 Hz). The study was limited with one vowel /a/. Furthermore, as attested by the authors, the results might be utilized in clinics for neighbouring countries but with caution as differences in Arabic dialects have not been excluded, see Table 6.5.

Study	Dialect	Sex	Vowels					
			/a:/	/i:/	/u:/	/ɑ:/	/e:/	/o:/
Natour & Wingate (2009)	Jordanian	M	131	×	×	×	×	×
	Arabic	F	231	×	×	×	×	×
Malki et al. (2009)	General	M	127	×	×	×	×	×
	Saudi	F	211	×	×	×	×	×
Natour et al. (2011)	Jordanian	M	127	132	134	128	128	130
	Arabic	F	225	236	233	224	226	225

Table 6.5 Mean F0 (Hz) for Arabic studies (Natour & Wingate, 2009; Malki et al., 2009; Natour et al., 2011), results show sex differences where males showed lower mean F0 than females,(results were rounded to the nearst decimal point).

Malki et al. (2009) conducted a study on vocal registers including mean F0 for 100 participants (50 males and 50 females) that were Saudis between the ages of 18 and 60 years; 5 males were excluded from the study. Stimulus for this study was sustained phonation /a/ for the middle 3 seconds produced by participants. Results showed that males had significantly lower mean F0 127 Hz than females 211 Hz (see Table 6.5). The results were then compared to the MDVP database for English which showed differences between Saudi males and females which lower F0 than those from the database (males had 145Hz, females had 244 Hz).

In a study by Natour et al. (2011) on Jordanian Arabic for 200 participants (100 males and 100 females) aged between 18 and 24 years, the F0 was investigated in the sustained phonation of the vowels /ɑ:, i:, u:, a:, e:, o:/. However, no statistical analysis was conducted with regard to mean F0 as the purpose of the article was on formant frequency analysis, which will be reviewed in the next chapter. The results show clear differences between sexes where males have lower mean F0 than females for all vowels. An observation on mean F0 is that the high vowels /i:,u:/ might have slightly higher mean F0 than low vowels (see Table

6.5). Similar to the studies above (Natour & Wingate, 2009; Malki et al., 2009), there was no restriction to a specific dialect within the focused country of study. Establishing normative data for the Saudi population regardless of dialect might have been the concern of the researchers; however, not controlling the dialects was a limitation of the study.

6.5.2 Words

Alghamdi (1998) is one of the few studies that have compared dialects of Arabic. In his study, he compared vowels in CVC syllables between 5 Saudis, 5 Sudanese and 5 Egyptian males between the ages of 29-48 years. The consonants in the syllables were /s/, and the vowels were long (/a:,i:,u:/), which made meaningful words while syllables with short vowels /a,i,u/ were nonsense words. Measurements for F0 were from two points, 20 ms after the beginning of vowel and 20 ms before the end of the vowel. Results, seen in Table 6.6, were from the average from the two points made for mean F0. Results showed there were no significant differences between the dialects of Arabic in terms of mean F0. In addition, differences were not found statistically between F0 for the long and short vowels. Furthermore, the low vowels /a, a;/ showed a slightly lower mean F0 than the higher vowels /i, i:, u, u:/. Alghamdi (1998) found that there was a 15 Hz difference between the Arabic speakers in his study and the American speakers in Hillenbrand et al.'s study (1995), although he did not provide a statistical analysis. Criteria for inclusion for age were wide and the informants from Saudi were from two regions, Najdi and Southern Region. Furthermore, Sudanese and Egyptian participants had been living between 1-5 years in Saudi which might have affected their dialects. The study is restricted with male participants only while the number of participants might be considered low.

Study	Dialect	Vowels					
		/a/	/a:/	/i/	/i:/	/u/	/u:/
Alghamdi (1990)	Saudi Arabic	143	140	138	133	149	140
	Sudanese Arabic	149	138	137	134	152	142
	Egyptian Arabic	146	139	140	138	145	148

Table 6.6 Mean F0 (Hz) for male participants from three Arabic dialects (Saudi Arabic, Sudanese and Egyptian) in Alghamdi (1990) where no statistical differences were reported between dialects,(results were rounded to the nearst decimal point).

In one of the few studies that compared the effect of emphatics on F0, Shoul (2008) compared F0, amplitude and duration between emphatic /tˤ/ and plain /t/ in syllables in initial and intervocalic with the vowel /a/ for Moroccan Arabic. The results showed no differences in F0 values, duration and amplitude between the emphatic and plain contexts. The authors did not present the F0 values for their study. Interestingly, they also suggested that emphasized vowels in Moroccan Arabic might not require a narrowing of the supra-glottic cavity. The study's focus on one vowel /a/ is one of the limitations of the study.

6.5.3 Sentences

As previously mentioned, Natour & Wingate (2009) used the analysis of sentences for 200 Jordanian participants (100 males and 100 females). F0 results (see Table 6.7) showed F0 for Jordanian males were consistent with results from Caucasian males reported in the literature. However, female Jordanian participants showed F0 for sentences that were relatively higher than those reported from different studies on different languages (e.g. Brown et al., 1991; Altenberg & Ferrand, 2006). With regard to mean F0 and sex differences, males had lower mean F0 of 137 Hz than females 231 Hz.

Study	Dialect	Sex	Spontaneous	Reading
Natour & Wingate (2009)	Jordanian Arabic	Male	137	×
		Female	231	×
Abu-Al-Makarem & Petrosino (2007)	General Gulf Arabic	Male	146	147
		Female	×	×
Alshahwan (2008)	Saudi Najdi dialect	Male	126	124
		Female	×	×

Table 6.7 Mean F0 (Hz) for different stimuli in Arabic studies (Natour & Wingate, 2009; Alshahwan, 2008; Abu-Al-Makarem & Petrosino, 2007) ,(results were rounded to the nearest decimal point).

Abu-Al-Makarem & Petrosino (2007) reported comparisons of the measures of mean speaking fundamental frequency in bilingual (Arabic and English) Arabic men. The participants were 15 native speakers of Arabic with a Gulf dialect, who were considered to be proficient speakers of English. Mean F0 was obtained from each participant on two tasks, reading and spontaneous connected speech, in both languages. The reading task in English was “The Rainbow Passage” (Fairbanks, 1960), and in Arabic it was a passage that was of comparative length and complexity that was used solely for their research. The spontaneous speaking task involved responses to different questions posed by the researcher. Results showed there were no significant differences between languages and tasks between Arabic and English languages. The results for English were 149 Hz and 144 Hz for reading and spontaneous (not presented in Table 6.7), respectively, while for Arabic they were 147 Hz and 146 Hz. However, there was a significant difference between tasks in Arabic, where reading had statistically higher mean F0 than spontaneous speech (for results see table 6.7). There are several limitations in this study. The number of subjects was 15 participants thereby limiting the generalizability of the results. Also, the study was restricted to male participants only. The term ‘Gulf dialect’ is a general term that includes a large population from different geographical regions. As with Malki et al. (2009), it disregards the dialectal differences between participants from different regions with different dialects. Thus, the Arabic participants in the study might have had dialectical variations among them, which might have had an effect on the mean F0 values. In addition, the effects of bilingualism might have resulted in the absence of differences between the two languages.

In a similar study, Alshahwan (2008) compared the results of bilingual Arabic/English Saudi male speakers between the ages of 23 and 34 years. The researcher used Arabic and English passages and spontaneous speech. The reading passages for English and Arabic were “The Rainbow Passage” (Fairbanks, 1960) and an Arabic phonetically balanced passage used previously for Saudi population (Al-Shatti et al., 2008). Spontaneous speech samples were responses to questions on daily lives in both Arabic and English. Results for Arabic in both read and spontaneous were 126 Hz and 124 Hz, respectively, and for English results were 133Hz and 125 Hz (not presented in Table 6.7). Statistical results showed significant differences between Arabic and English in bilingual speakers where English samples had a higher F0 mean (129 Hz) than Arabic (124 Hz). In addition, there was a significant effect of task in both languages where reading had a higher mean F0 than spontaneous speech.

Alshahwan (2008) attributed the differences between his results and those from Abu-Al-Makarem & Petrosino (2007) to the fact that the dialect spoken by the Arabic speakers was confined to one specific dialect “Najdi’ rather than the general “Gulf dialect” which might have masked variations. Furthermore, the differences between the dialects of English might have played a role where speakers in Alshahwan (2008) were speakers of British English rather than the American English in Abu-Al-Makarem & Petrosino's study (2007). This study shares limitations with Abu-Al-Makarem & Petrosino (2007) in the low number of participants, in addition to the use of only reading and spontaneous speech, and finally the use of only male speakers to examine the differences in Arabic bilingual speakers.

In summary, there appear to be no differences between dialects of Arabic for F0; however, this is only based on the results of one study (Alghamdi, 1998) that covered a wide age range. In addition, a comparison of the results is not possible as stimuli and the methodologies used were different. Moreover, the few studies that were performed on dialects of Arabic were general;general Jordanian (Natour et al., 2011; Natour & Wingate, 2009), general Saudi dialect (Malki et al., 2009) and general Gulf dialects (Abu-Al-Makarem & Petrosino, 2007). Furthermore, the number of participants was low for the majority of the studies in Arabic (Shoul, 2008; Alshahwan, 2008; Abu-Al-Makarem & Petrosino, 2007; Alghamdi, 1998). Moreover, few studies have looked at sex differences in mean F0 (Natour et al., 2011; Natour & Wingate, 2009; Malki et al., 2009). Therefore, one of the main aims of this study is to establish normative mean F0 for males and females from both dialects and to explore differences between the two dialects of Arabic (Saudi Najdi and Bahraini Bahraini) using the same method of analysis. In addition, it will examine sex differences as a second main aim. Vowel context, voicing context, place of articulation, emphasis and sentence type will be assessed. In the next section, research questions and hypotheses will be presented.

6.5.4 Research aim, questions and hypotheses

6.5.4.1 Research aim and questions

6.5.4.1.1 Research Aim

To establish mean F0 normative data in different stimuli for male and female Saudi and Bahraini Arabic speakers**.**

6.5.4.1.2 Main research questions

1) Are there differences in mean F0 between Najdi and Bahraini Arabic dialects?
2) Are there differences in mean F0 between sexes in both Arabic dialects?

6.5.4.1.3 Mean F0 – specific questions

6.5.4.1.3.1 Sustained Phonation

a) Are there differences in the mean F0 between high /i, u/ versus low /a/, and front /i/ versus back /u/ vowels?

6.5.4.1.3.2 Plain stops

a) Voicing: Are there differences in the mean F0 of vowels with initial voiced and voiceless stops?
b) Place of articulation: Does the place of articulation (bilabial, alveolar and velar) of initial plosives affect the mean F0 of vowels?
c) Vowel context: Are there F0 differences between high /i:, u:/ versus low /a:/, and front /i:/ versus back /u:/ vowels?

6.5.4.1.3.3 Emphatic versus plain stops

a) Emphatic versus plain stops: Are there differences between the mean F0 of vowels in words with an initial emphatic stop /tˤ/ and plain alveolar stop /t/?
b) Vowel context: Does the vowel context in words affect the mean F0 of the front high vowel /i:/ versus the back high vowel /u:/ in plain and emphatic stops in the same way?

6.5.4.1.4 Sentences

a) Sentence type: Does sentence type (reading a passage versus reading a section of the Quran) affect the mean F0?

6.5.5 Hypotheses

The results from Alghamdi (1998) suggest that there are no differences between dialects of Arabic in vowels within words. Likewise when comparing the results from Jordanian Arabic (Natour & Wingate, 2009; Natour et al., 2011) to those of Saudi Arabic (Malki et al., 2009), the results did not differ between the studies (see Table 6.5). The differences between the Gulf dialect in Abu-Al-Makarem & Petrosino (2007) and (Alshahwan, 2008) might be a result of using different methodologies. Given that Bahraini and Najdi Arabic are geographically close and from similar origins, the first hypothesis is that no differences in mean F0 will be found between Najdi and Bahraini Arabic in mean F0 for sustained phonation for the vowels /a,i,u/, the target words with voiced (/b, d/), voiceless (/t, k/), voiced/voiceless contrast (/t,d/) and plain/emphatic stops (/t, $t^{ʕ}$/), and sections of the Quran and the reading sentences.

Although, studies on sex differences are scarce in Arabic, the few studies that have been conducted have found sex differences where males showed significantly lower mean F0 values than females in sustained phonation and sentences (Natour et al., 2011; Natour & Wingate, 2009; Malki et al., 2009). In addition, due to anatomical differences found between males and females (Hollien, 1960, Kent, 1976 ; Hirano et al., 1981 ,Titze, 1989a, Fung, 1990; Williams & Eccles, 1990) the second hypothesis is, therefore, that males will have lower mean F0 vales than females for the different stimuli employed in this study.

The studies on Arabic language are suggestive of vowel differences depending on height; high vowels have a higher mean F0 than lower vowels, which was seen explicitly in Alghamdi's (1998) study, and was observed in the sustained phonation data for Jordanian Arabic (Natour & Wingate, 2009; Natour et al., 2011). In addition, as was confirmed from Whalen & Levitt's (1995) review of a number of languages from various studies, the higher vowels /i, u/ have a higher mean F0 than the lower vowels /a, æ/. The third hypothesis is therefore that the lower vowel /a/ will have a lower mean F0 than the higher vowels /i, u/ in this study.

Differences in mean F0 between sentence types in Arabic showed different results. On the one hand, Alshahwan (2008) found that reading had a higher mean F0 than spontaneous speech. On the other hand, Abu-Al-Makarem & Petrosino (2007) found no differences between spontaneous speech and reading. However, studies on English (Zraick et al., 2000; Murry et al., 1995) found differences between types of sentences; the fourth hypothesis is therefore that such differences will be found in the present study, where the reading passage sentences will have a higher mean F0 than the Quran sentences since it might be considered semi-automatic speech compared to reading a text.

The relationship between voicing and mean F0 has shown that vowels in words with an initial voiced stop often have a lower mean F0 than vowels with an initial voiceless stop (House & Fairbanks, 1953; Lehiste & Peterson, 1961; Mohr, 1971; Löfqvist, 1975; Umeda, 1981; Kingston & Diehl, 1994; Van Alphen & Smits, 2004). Therefore, the fifth hypothesis is that vowels in words with the initial alveolar voiced stop (/d/) will have a lower mean F0 than words with initial alveolar voiceless stop (/t/).

Van Alphen & Smits (2004) showed no differences between places of articulation for mean F0; the sixth hypothesis is therefore that there are no differences in the mean F0 of vowels in words with the voiced stops /b, d/ with different places of articulation. In addition, there are no differences in the mean F0 between words with the initial voiceless stops /t, k/.

From Shoul's study (2008), where he did not find any differences in mean F0 between emphatic and plain stops, the seventh hypothesis is that there are no differences in mean F0 between alveolar plain /t/ and emphatic /tˤ/ stops.

6.6 Methods

6.6.1 F0 Acoustic Analysis

The third aim in this study was to establish normative mean F0 values Hz in Arabic speakers in different stimuli type (see §6.6.2) for male and females Saudi Najdi and Bahraini Bahraini speakers and to explore if differences between the two Arabic dialects. An additional aim was to explore sex differences in F0. The stimuli will be explained in the following section (see §6.6.2).

6.6.2 Stimuli

6.6.2.1 Sustained phonation and words

The procedure for the sustained phonation of vowels /a,i,u/ was previously described in §3.3.3.2. In addition, the medial vowels in monosyllabic minimal pair words were presented in §3.3.3.3 in Table 3.3. The three long vowels /a:,i:,u/ were assessed in words with initial voiced stops, and the two high vowels /i:,u:/ were assessed in words with initial voiceless plain and emphatic stops.

6.6.2.2 Sentences

As described earlier in §3.3.3.4, participants were instructed to read two passages. The first is the Arabic version of 'The North Wind and the Sun', (International Phonetic Association, 2004, pp. 53–54). The second was the first Sura (chapter) from the Holy Quran, which is called Al-Fatihah ("opening" when translated to English). These were repeated twice for each participant. The fifth sentence from the Arabic version 'The North Wind and the Sun', (International Phonetic Association, 2004, pp. 53–54), which had 17 words, was included in the analysis for F0. For comparisons between the two types of sentences, the fourth and fifth sentences chosen from the Sura which had a total of seven words. The rationale for selecting these particular sentences was to avoid the impact of the effects from the initial sentences where they might be influenced from the onset where it leads to higher mean F0 and the offset as a results from fatigue from different samples (Zraick et al., 2006).

6.6.3 Preparation for Acoustic Analysis

6.6.3.1 Sustained phonation, words and sentences

Preparation for acoustic analysis for sustained phonation, words and sentences were previously described in §3.4.3.2, §3.4.3.3, §3.4.3.4 respectively.

6.6.4 Acoustic Analysis

Fundamental frequency (F0) measurements were performed following the recommendations of Boersma & Weenick (2013). The text grid based methodology included identifying and annotating the boundaries of voiced elements identified visually on the spectrograms and waveforms of all parts of each of the speech samples. To facilitate analysis, settings were selected for window length and pre-emphasis in viewing the spectrograms. The primary focus of this part of the study is to measure the mean fundamental frequency. The same principle was used for the different contexts (i.e., sustained vowel vs. words vs. sentences). However, different annotation methods (described later in §6.6.4.1) were utilised to capture the F0.

Following the labelling of the sound files previously described in §6.63, all analysis for F0 used Praat (Boersma and Weenink, 2012). A script (available in Appendix 9) written by Pauline Welby (2002) was modified by the researcher so it would load sound files in WAV format from the folder. It would then open the text grid corresponding to the participants' WAV files for the stimuli analysed; after the marking had been done, it would save the annotation and then open the next audio and text grid files.

For sustained phonation, each participant produced the three vowels (/a, i, u/), meaning the total number of sustained vowels would be 240 (3 × 80). All of the participants produced all vowels correctly.

For the word items, each of the 80 participants repeated each of the 12 words twice (12 × 2 × 80), meaning that 1920 words were produced. Only 1852 words were analysed due to distortion or background noise; therefore, 68 words or 3.54%, were excluded from analysis, leaving the remaining 1852 or 96.46% for analysis. All participants from both dialects (Bahraini and Saudi) and gender (male and female) were represented in the analysis.

For the sentence production, each participant from both dialects (Bahraini and Saudi) and genders (male and female) produced two repetitions from reading of the Arabic version of 'The North Wind and the Sun', (International Phonetic Association, 2004, pp. 53–54) and the recitations of the first chapter of the holy Quran. As described earlier (§6.6.2.2), only the fifth sentences from the reading passage and the fourth and fifth sentences from the Quran were selected for acoustic analysis. However, only one of the repetitions was selected for analysis, the rationale for this was a number of sentences were excluded due to mispronunciations due to speed, long pauses or prolongation of a word. Therefore, in order to maintain an equal number of sentences. Those that were subjectively judged to be better were selected from each of the readings. Therefore, 160 sentences were chosen for analysis (2 × 80), and the remaining 160 were excluded. All participants were represented in the analysis.

6.6.4.1 Annotation method

6.6.4.1.1 Sustained vowels

The annotation procedure for sustained phonation was to exclude the first two seconds to avoid the effect of onset, as mentioned by Zraick et al. (2006), and the first boundary was set at two seconds into the vowel. After five seconds, the second boundary for voicing was placed. For each of the vowels, an annotation of the vowel was produced for use for later analysis, as the script included the annotation. An example is presented in Figure 6.1.

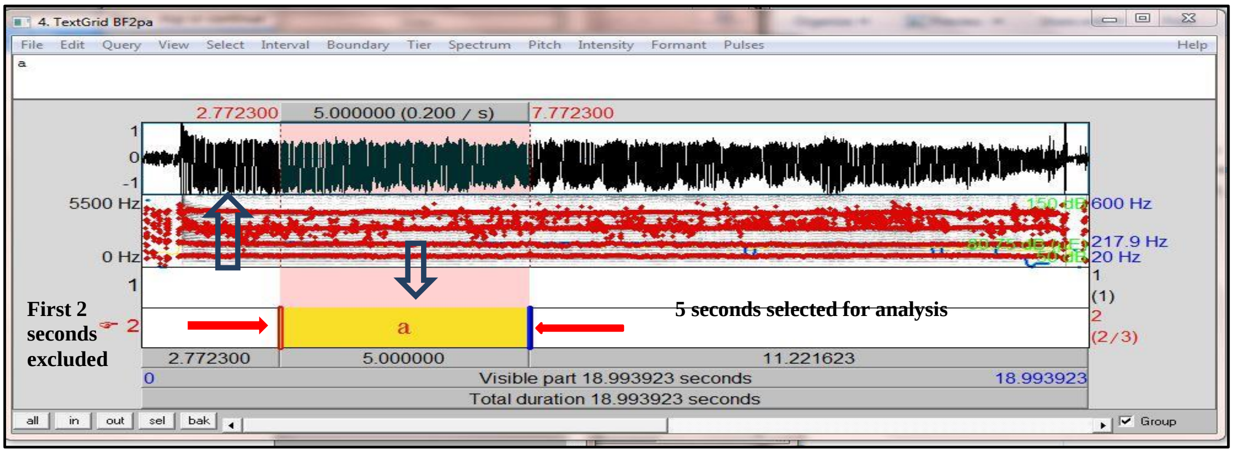


Figure 6.1 An example of annotation and marking boundaries for vowels, here in vowel /a/, where the first two seconds were excluded and the first boundary set and the second boundary is set after five seconds.

6.6.4.1.2 Words

For each word, the first boundary was selected at the beginning of the vowel and the periodic waveform, and another boundary was set at the end of the periodic waveform at the end of the vowel produced by the participant and annotated for use in analysis. Voicing is represented by a blue line, as shown in Figure 6.2. The analysis for mean F0 for vowels in words was performed from the second tier, labelled t2, representing relatively the full vowel production and not including consonants in the acoustic analysis.

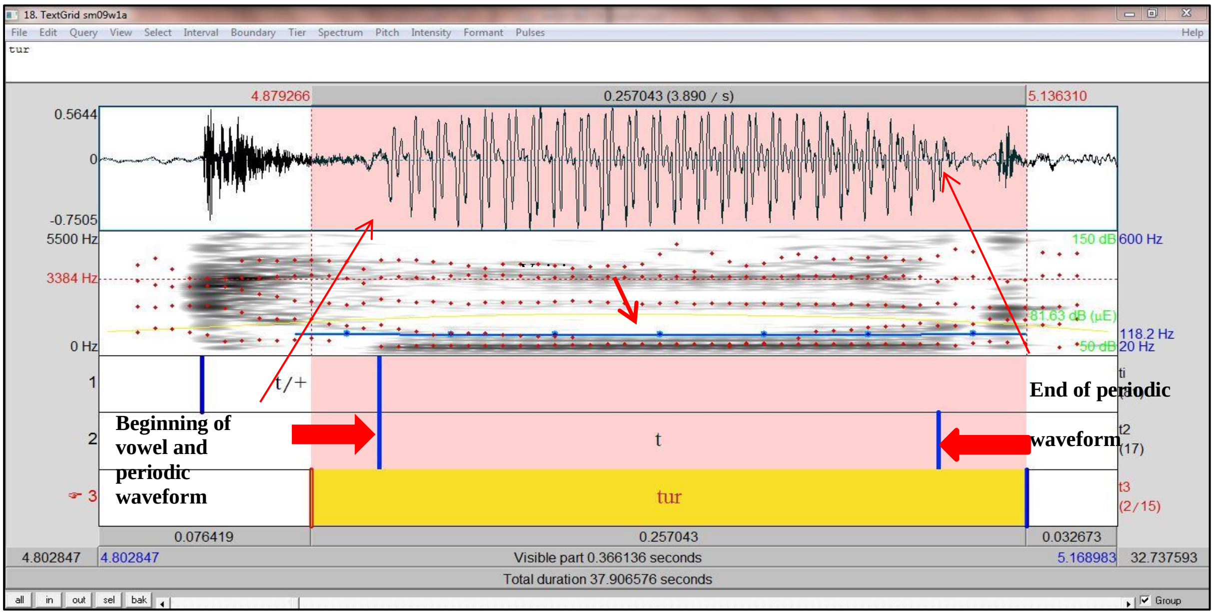


Figure 6.2. An example of annotating and marking the boundaries for the vowel /u:/ in the word /tu:r/, where the first boundary is at the beginning of the vowel and the periodic waveform and the second is at the end of the periodic waveform.

6.6.4.1.3 Sentences

For sentences, the first tier was used to set the boundaries of the sentence selected for analysis, where the first boundary is set at the beginning of the sentence and the second boundary is set at the end of the sentence. The first tier was not included in the analysis, as it was only used by the researcher as a reference for determining the boundaries for the selected sentences used in the analysis.

As each sentence contained many words, each word was marked by two boundaries: the first indicating the beginning of voicing and the second marking the end of voicing for the word; these were all annotated with a "1" (see the example in Figure 6.3). Although it was annotated differently, the marking of the boundaries was similar to the marking procedure used for words. The reason for annotating with a "1" for each word was that a different script (see §6.6.5) for analysis was used which will be elaborated on in the next section.

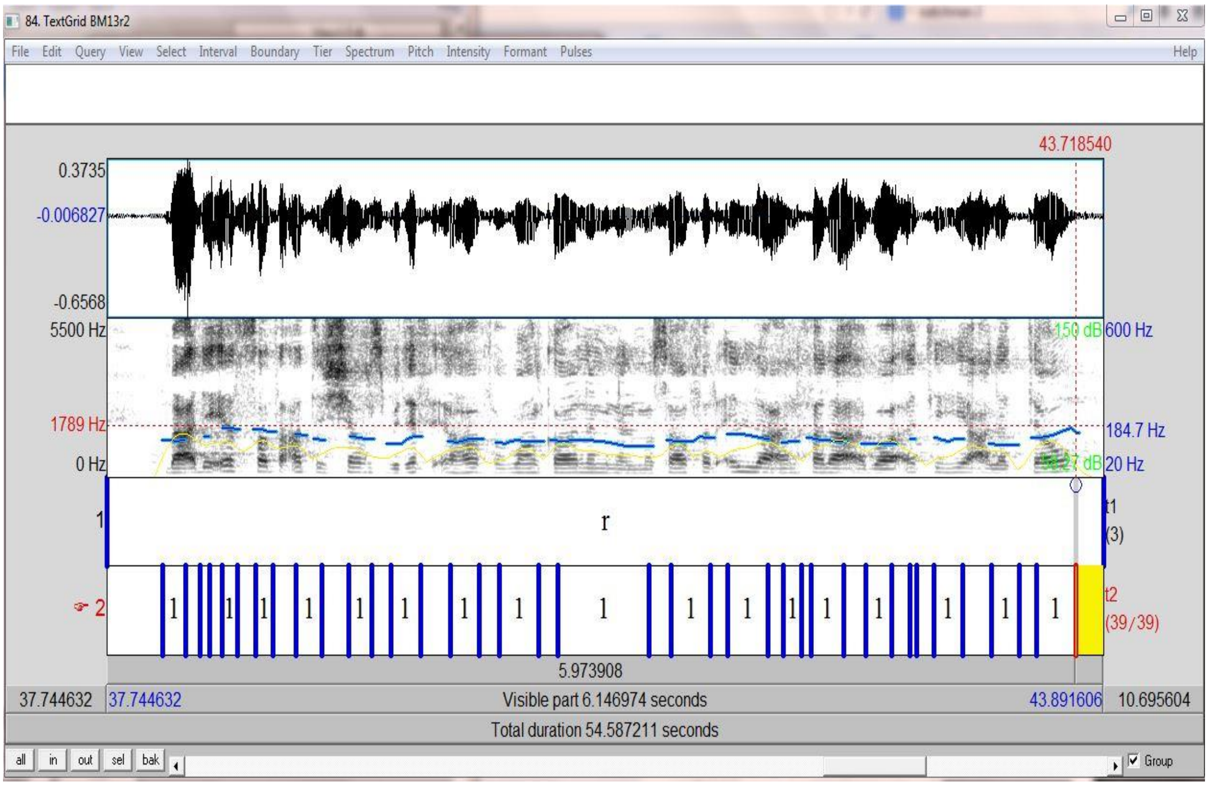


Figure 6.3. An example for the marking of the boundaries and the annotations used for sentences. The first tier is used for marking the boundaries of the whole sentences that are analysed. The second tier is where the marking of the words, where for the first boundary is at the beginning and the second boundary is at the end of the voicing for the selected word. Notice that the annotation for all words was with the number "1".

6.6.5 Analysis and Transfer

After marking the boundaries and annotation in the method described above, all of the sound files were stored. The audio files were stored as WAV sound files, while the annotated files were stored as Praat text grid files, in the same directory. Two different Praat (Boersma and Weenink, 2012) scripts were used for the analysis of F0. Both scripts used an autocorrelation method to extract pitch and were adjusted to the sex of the participants, where a higher maximum frequency was adjusted for males at 300 Hz, while for females the frequency was 600 Hz.

The first script (available in Appendix 6.1), which was written by Hirst (2012), was used for the sustained phonation data. Running the script would select the vowel in the sustained phonation file. The vowels selected in the words were annotated and the mean F0 was extracted across the 5 seconds selected as described in §6.6.4.1.1, together with the minimum and maximum F0 and the duration of the vowel; the focus for this study was the mean F0. The output of the script was then transferred to an Excel (2010) spreadsheet. The results for all of the participants were then compiled into one Excel spreadsheet, which was transferred to the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL) version 19 for statistical analysis.

The second script (available in Appendix 6.2) had been used previously (Alshahwan, 2008) and was modified by the researcher; it was also adapted by a phonetics researcher (Herrmann, 2008), which was adapted from a script published by Boersma and Weenink (2008). The script averages the voiced portions for all words for each sentence that were marked and annotated by the researcher. The outcome of running the script included a mean fundamental frequency (F0), F0 standard deviation, and a maximum and minimum F0 range; the focus for this study was mean F0. The output of the script was then transferred to an Excel (2010) spreadsheet. The results for all of the participants were subsequently compiled into one Excel spreadsheet, which was transferred to the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL) version 19 for statistical analysis.

6.6.6 Reliability

6.6.6.1 Inter-rater reliability:

As the task of annotating the voicing segment is a manual task that is undertaken by a single researcher, a degree of error can be made. Therefore, to ensure the reliability of the analysis, an independent speech and language pathologist, who was familiar with the acoustic process, repeated the acoustic analysis. The annotation of the text grids for these samples was then acoustically processed by Praat (Boersma and Weenink 2013).

For the sustained phonation data of the three vowels, 8 participants were randomly selected (2 Bahraini females, 2 Saudi females, 2 Saudi males and 2 Bahraini males). The number selected (3 × 8) meant 24 productions from the overall 240 productions for all participants were analysed by the independent rater, which is 10% of the total productions.

For the F0 analysis of words, 11 participants were randomly selected (5 Bahraini females, 2 Saudi females, 2 Saudi males and 2 Bahraini males). The number of words for these participants was 252, after excluding 12 from the total of 264 due to mispronunciations. The percentage of words selected for reanalysis by the independent rater from the total words analysed (1852) was 13.6%.

For the two sentences, 8 participants were randomly selected (2 Bahraini females, 2 Saudi females, 2 Saudi males and 2 Bahraini males). The number selected (2 × 8) meant 16 productions from the overall 160 productions for all participants were reanalysed by the independent rater. This was 10% of the total number of stimuli.

The overall percentage for stimuli across all data sets for relaibility was 13.85% from the data based on a total sample of 2108. The values for F0 (Hertz) were then transferred to test for inter-rater reliability, where the results from both raters were compared. The results for all participants were then compiled into one Excel spreadsheet, which was transferred to the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL) version 19 for statistical analysis.

6.6.6.2 Intra-rater reliability:

To assess intra-rater reliability, at least seven months later, the researcher conducted the F0 analysis for a second time using the same data sets described for the inter-rater reliability procedure described above

6.6.6.3 Results

The inter-rater and intra-rater reliability levels were estimated for 13.85% of the data measurements. The Pearson correlation coefficients were calculated, as shown in Table 6.8.

	Inter-rater Reliability	**Intra-rater Reliability**
Sustained phonation	$r = .999, n = 24, p < .001$	$r = 1.00, n = 24, p < .001$
Vowels in words	$r = .999, n = 253, p < .001$	$r = .999, n = 253, p < .001$
Sentences	$r = 1.00, n = 16, p < .001$	$r = .999, n = 16, p < .001$

Table 6.8 Inter- and intra-rater reliability Pearson correlation coefficients for F0 (Hz).

The inter-rater reliability levels were used to assess the reliability of F0 measurements in sustained phonation, and vowels embedded in words and sentences. There was a strong correlation between the measurements taken by a colleague for sustained phonation ($r = .999$, $n = 24$, $p < .001$), vowels in words ($r = .999$, $n = 253$, $p < .001$) and sentences ($r = 1.00$, $n = 16$, $p < .001$). In addition, the second measurements (intra-rater reliability) were taken at a later date for sustained phonation ($r = 1.00$, $n = 24$, $p < .001$), vowels embedded in words ($r = .999$, $n = 253$, $p < .001$) and sentences ($r = .999$, $n = 16$, $p < .001$). Overall, there was a strong positive correlation for all the measurements, revealing a high level of reliability for the acoustic analysis of F0 (Hz) in sustained phonation, and vowels in words and sentences.

6.6.7 Design and data analysis

This study's primary aim was to establish normative data for males and females from the two dialects of Arabic (Najdi and Bahraini) and to answer the two research questions. First, it sought to determine whether differences exist between the two dialects for mean F0. Secondly, whether differences exist for mean F0 between sexes (male and female) in both Arabic dialect speakers. In addition, the study was designed to examine mean F0 differences between production of three sustained vowels /a,i,u/. Also to examine vowels and place differences between monosyllabic minimal CV:C Arabic words with voiced /b, d/ in three vowel contexts /a:,i:,u:/. In addition, to voiceless stops /t, k/ in initial position with two vowel contexts /i:,u:/. Also, a comparison between plain /t/ stop with emphatic voiceless stop /tˤ/ in two vowel contexts /i:,u:/. In addition, differences between voiced and voiceless stop cognates /t,d/ in two vowel context /i:,u:/. Finally, F0 was explored for two types of sentences.

Results for F0 are presented in three sections, first for the sustained phonation of vowels followed by the results for the words, and finally the results for the sentences.

6.7 Results

6.7.1 Sustained phonation

Mean F0, Standard Deviation, Minimum and Maximum values in Hz for the three sustained vowels /a:,i:,u:/ are shown in Table 6.9 as a function of dialect and sex. A mixed model ANOVA was conducted for mean F0 for the sustained phonation of vowels /a:, i:, u:/, as the repeated measures (within subjects factor), and with gender (male–female) and dialect (Saudi–Bahraini) as the between-subjects factors. Mauchly's test of sphericity indicated that the assumption of sphericity had been violated, $\chi^2(2) = 95.5$, p = .001; therefore, Greenhouse-Geisser results were analysed.

		/a/	/i/	/u/
Sex	Dialect	Mean (S.D) Min-Max n	Mean (S.D) Min-Max	Mean (S.D) Min-Max
Male	S (20)	127.80 (16.42) 101.00-171.14	130.66 (17.42) 93.12-171.56	129.46 (17.23) 93.71-172.88
	B (20)	128.12 (20.76) 94.14-170.76	134.7 (19.89) 97.41-185.83	133.16 (20.12) 99.08-173.68
	Mean (40)	127.96 (18.48) 94.14-171.14	132.68 (18.57) 93.12-185.83	131.31 (18.58) 93.71-173.68
Female	S (20)	204.86 (18.61) 175.59-242.44	206.95 (27.32) 119.92-249.69	213.2 (19.88) 182.63-254.42
	B (20)	207.97 (27.09) 167.53-271.51	208.07 (35.67) 118.84-273.46	215.43 (28.34) 168.23-275.97
	Mean (40)	206.42 (22.99) 167.53-271.51	207.51 (31.36) 118.84-273.46	214.32 (24.19) 168.23-275.97
Total	S (40)	166.33 (42.69) 101.00-242.44	168.8 (44.76) 93.12-249.69	171.33 (46.21) 93.71-254.42
	B (40)	168.04 (46.93) 94.14-271.51	171.38 (46.83) 97.41-273.46	174.3 (48.21) 99.08-275.97
	All (80)	167.19 (44.58) 94.14-271.51	170.09 (45.53) 93.12-273.46	172.81 (46.94) 93.71-275.97

Table 6.9 Mean F0, Standard Deviation (S.D), Minmum (Min) and Maximum (Max) in Hz for vowels /a,i,u/ for male and female speakers from both dialects (Saudi = S and Bahraini = B).

6.7.1.1 *Dialect and sex*

For vowels, results for between-subjects factors showed that there was no dialect effect ($F(1,76) = .275$, $p = 0.601$). In addition, there was no significant interaction between sex and dialect ($F(1,76)=.003$, $p=.954$). However, sex had a main significant effect ($F(1,76),= 292.07$, $p <.001$) where males had lower F0 values (130.66 Hz) than females (209.41 Hz).

6.7.1.2 *Vowels*

For the within-subjects factor, vowels showed a significant main effect ($F(1.16, 88.45) = 3.89$, $p < .05$). Post hoc tests using the Bonferroni correction revealed significant differences ($p <.001$) between the open vowel /a/ which had a lower F0 (167.19 Hz) than the back front vowel /u/ (172.81 Hz); however, no significant differences in F0 were found between the open vowel /a/ and the front high vowel /i/, or between the high vowels /i,u/, ($p >.05$), see Figure 6.4.

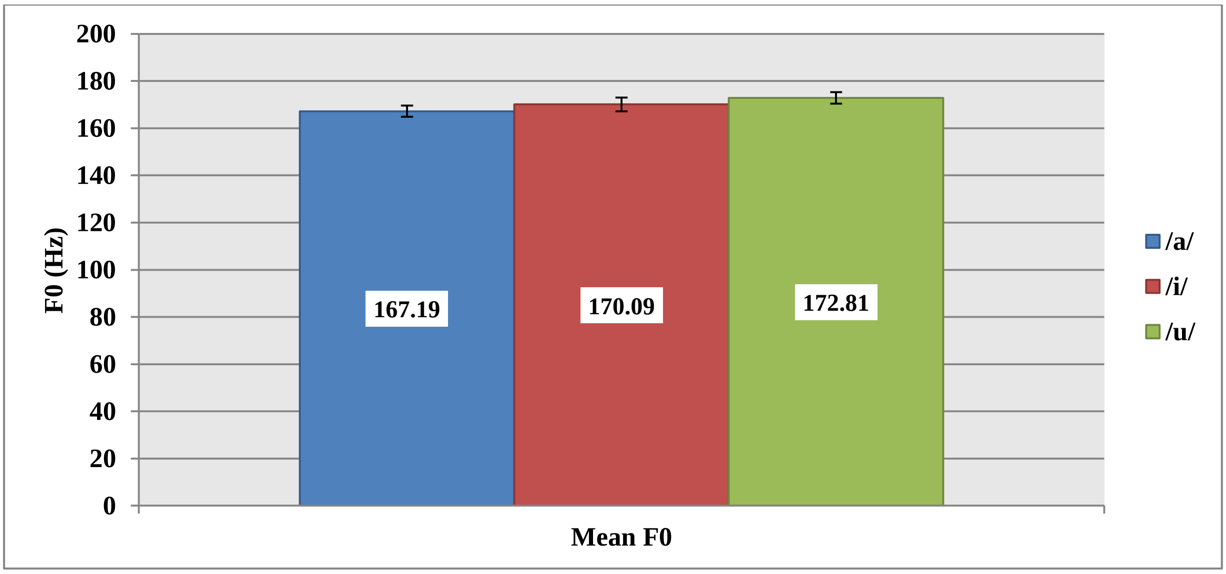


Figure 6.4 Mean ± S.E for F0 (Hz) for vowels (a,i,u) where significant difference were found between central open vowel /a/ and back high vowel /u/; however, differences were not found between front and back high vowels /i,u/ or between central vowel /a/ and front high vowel /i/.

Moreover, there was no significant interaction between vowel context by sex ($F(1.16, 88.45) = 2.06$, $p = .153$), vowel context by dialect ($F(1.16, 88.45) = .05$, $p = .858$) or vowel context by sex by dialect ($F(1.16, 88.45) = .27$, $p = .640$).

6.7.2 Words

6.7.2.1 Voiced stops /b,d/

Mean F0, Standard Deviation, Minimum and Maximum values in Hz for vowels /a:,i:,u:/ in words with initial voiced bilabial /b/ stops (/ba:r/, /bi:r/, /bu:r/) and words with initial alveolar /d/ stop (/da:r/, /di:r/,/du:r/) are shown in Table 6.10 as a function of dialect and sex. A mixed model ANOVA was conducted for mean F0 (Hz) for vowels /a:,i:,u:/ embedded in words with voiced stops /b/ and /d/ in initial position in three different vowel contexts, with gender (male–female) and dialect (Saudi–Bahraini) as the between-subjects factors. Place of articulation and vowel context were the repeated measures/within-subjects factors. Results showed Mauchly's test non-significant ($p > .05$) for place of articulation and vowel context; therefore, sphericity has been assumed. However, interaction between place of articulation and vowel context showed that assumption of sphericity was violated (significance $\chi^2(2) = 10.948$, $p = .001$); therefore, Greenhouse-Geisser results were analysed.

		/a:/		/i:/		/u:/	
Sex	Dialect	Mean (S.D) Min-Max		Mean (S.D) Min-Max		Mean (S.D) Min-Max	
		/b/	/d/	/b/	/d/	/b/	/d/
Male	S (20)	130.21 (17.38) 93.04-171.41	128.81 (16.14) 90.64-164.23	134.98 (18.66) 92.16-175.06	133.86 (21.94) 86.17-188.43	133.39 (18.42) 86.89-173.10	132.82 (20.21) 88.20-181.47
	B (20)	137.04 (23.19) 101.65-184.02	135.44 (21.36) 104.88-176.48	139.69 (20.61) 108.75-171.14	145.07 (26.08) 104.22-190.56	142.33 (15.42) 114.54-166.88	145.28 (22.55) 109.36-184.93
	Mean (40)	133.62 (20.52) 93.04-184.02	132.12 (18.99) 90.64-176.48	137.33 (19.55) 92.16-175.06	139.47 (24.46) 86.17-190.56	137.86 (17.37) 86.89-173.10	139.05 (22.06) 88.20-184.93
Female	S (20)	209.07 (17.87) 178.32-237.64	201.67 (17.77) 169.99-229.95	210.68 (21.52) 164.20-252.41	213.42 (13.48) 191.17-247.58	209.92 (21.18) 173.78-240.40	212.66 (20.08) 177.54-248.08
	B (20)	210.89 (18.47) 176.21-243.08	211.18 (16.16) 174.30-233.88	215.58 (21.67) 175.89-261.08	223.86 (20.31) 168.04-258.27	218.63 (21.03) 173.46-254.60	223.19 (21.15) 175.15-250.41
	Mean (40)	209.98 (17.96) 176.21-243.08	206.42 (17.44) 169.99-233.88	213.13 (21.46) 164.20-261.08	218.64 (17.82) 168.04-258.27	214.27 (21.30) 173.46-254.60	217.93 (21.04) 175.15-250.41
Total	S (40)	169.64 (43.56) 93.04-237.64	165.24 (40.52) 90.64-229.95	172.83 (43.18) 92.16-252.41	173.64 (44.11) 86.17-247.58	171.66 (43.42) 86.89-240.40	172.74 (45.05) 88.20-248.08
	B (40)	173.97 (42.74) 101.65-243.08	173.31 (42.67) 104.88-233.88	177.63 (43.73) 108.75-261.08	184.47 (46.09) 104.22-258.27	180.48 (42.71) 114.54-254.60	184.24 (44.97) 109.36-250.41
	All (80)	171.80 (42.93) 93.04-243.08	169.27 (41.54) 90.64-233.88	175.23 (43.25) 92.16-261.08	179.05 (45.15) 86.17-258.27	176.07 (43.02) 86.89-254.60	178.49 (45.10) 88.20-250.41

Table 6.10 Mean F0, Standard Deviation (S.D), Minmum (Min) and Maximum (Max) in Hz for stops b/d in three vowel contexts /a:,i:,u:/ for male and female speakers from both dialects (Saudi =S and Bahraini = B).

6.7.2.1.1 Dialects and sex

For voiced stops b/d in three vowel context /a:,i:,u:/, results for between-subjects fators showed that dialect had a significant effect ($F(1,76) = 4.132$, $p < .05$) where Saudis had a lower mean F0 (170.96 Hz) than Bahraini speakers (179.02 Hz) .

Furthermore, sex had a main significant effect ($F(1,76) = 375.54$, $p<.001$) where males had lower F0 values (135.58 Hz) than females (213.40 Hz). However, there was no significant interaction between dialect and sex ($F(1,76) = .010$, $p=.919$).

6.7.2.1.2 Place of articulation of stops b/d (bilabial /alveolar)

For place of articulation, results showed there was no significant effect ($F(1, 76) = 2.74$, $p =.102$). Furthermore, no significant interaction between place of articulation and sex ($F(1,76) = .711$, $p =.402$) and no significant interaction between place of articulation and sex and dialect ($F (1,76) = .339$, $p =.562$).

However, there was a significant interaction between place of articulation and dialect ($F (1,76) = 7.69$, $p < .05$). Subsequently, the data for the three vowel context (/a:,i:,u:/) were pooled analysed using a mixed model ANOVA, place of articulation (/b,d/) served as the repeated measures and dialect was the between subjects measure. The results showed that dialect had a significant effect on F0 for /d/ between Saudis and Bahrainis ($F(1,76),= 5.913$, $p < .05$), where the mean F0 values for Saudis (170.54 Hz) were lower than those of the Bahraini speakers (180.76 Hz). However, no significant differences was seen between Saudis and Bahrainis for voiced /b/ ($F(1,76) = 2.358$, $p = .129$). However, Saudis tended to produce lower F0 (171.38 Hz) than Bahraini speakers (177.36 Hz), (see Figure 6.5).

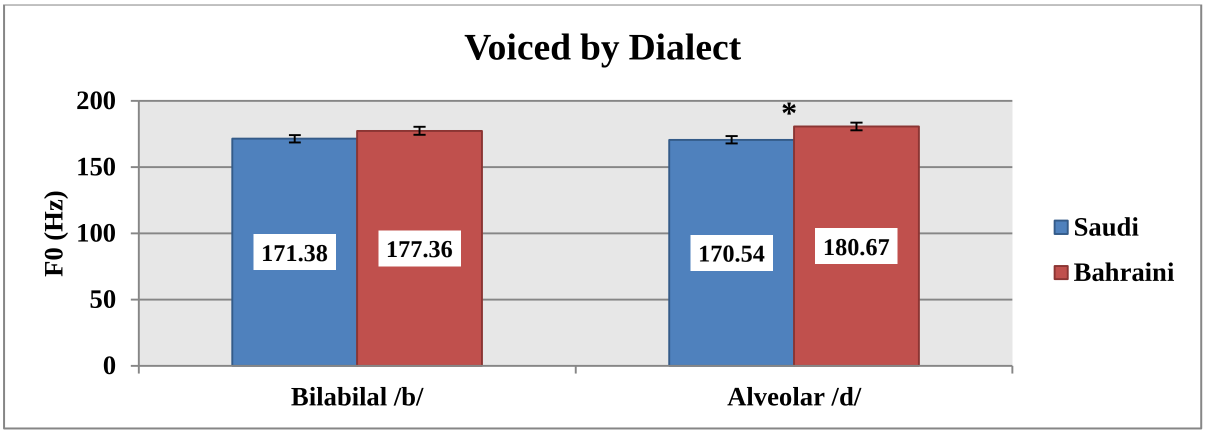


Figure 6.5 Mean ± S.E (Hz) for F0 for place of stops (b/d) interaction with dialects (Bahraini and Saudi) where Saudi showed significantly lower F0 for the alveolar stop /d/ while for biliabial /b/, Saudis tended to show lower F0 than Bahraini speakers.

6.7.2.1.3 Vowel context

For vowel context, results showed a significant effect ($F(2.152) = 19.17$, $p < .001$). A series of post hoc paired *t*-tests revealed significant differences between pooled data for vowel /a:/ and pooled data for vowel /i:/ from both /b/ and /d/ context (($t(79) = -5.284$, $p < .001$)): a lower mean F0 for central vowel /a:/ (170.54 Hz) than the front high vowel /i:/ (177.14 Hz). In addition, a significant difference was found between vowels /a:/ and /u:/ ($t(79) = -6.204$, $p < .001$) with vowel /a:/ having a lower F0 (177.14 Hz) than vowel /u:/ (177.28 Hz). However, pooled vowel data for high vowels /i:/ and /u:/ did not show significant differences ($t(79) = -102$, $p = .919$), (see Figure 6.6).

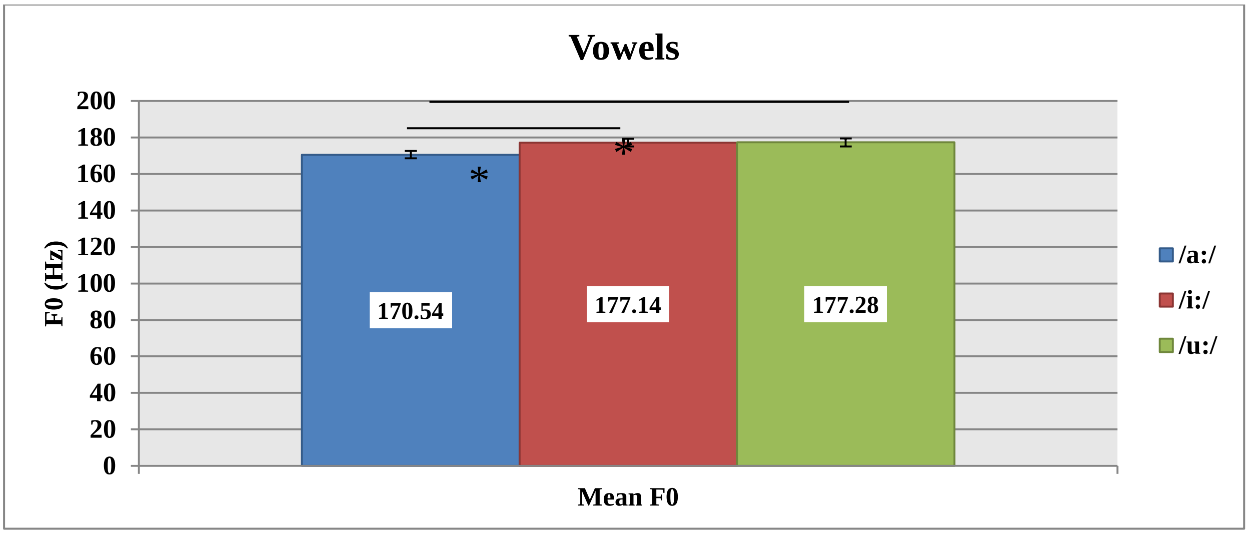


Figure 6.6 Mean ± S.E fundamental frequency (F0) Hz for vowels (a:,i:,u:) where central vowel /a:/ had significantly lower F0 than high vowels /i:,u:/ while no differences were shown between high vowels /i:/ and /u:/.

However, there was no significant interaction between vowel context and sex (F (2,152) = .539, p=.584), vowel context by dialect (F (2,152) = 1.28, p= .280) or vowel context by sex and dialect (F (2,152) = .959, p=.984).

There was a significant interaction between place of articulation of stops and vowel context (F(1.76, 133.82) = 5.16, p<.05). A series of post hoc paired *t*-tests within adjusted alpha level of (p < 0.00833) for multiple comparisons (see Table 6.11) (F0 values in Table 6.10 and Figure 6.7).

Paired	DF	t	p
/ba:r/ –/ bi:r/	79	-1.883	.063
/bi:r/ – /bu:r/	79	-.463	.645
/ba:r/ - /bu:r/	79	-2.521	.014
/da:r/ – /di:r/	79	-6.325	*.000
/di:r/ -/ du:r/	79	.335	.739
/da:r /– /du:r/	79	-9.824	*.000

Table 6.11 Results for paired t-tests for place of articulation of stops /b,d/ and vowels /a:,i:,u:/. * denotes significant results based on a significance level (0.00833) adjusted for multiple comparisons.

The results showed no significant differences for all vowel comparison for bilabial /b/,(see Table 6.11). For alveolar /d/, the results showed significant differences between the vowel /a:/ and the high vowels /i:/ and /u:/ (p <.001); whereas no differences were found between the high vowels /i:/ and /u:/ (p = .739).

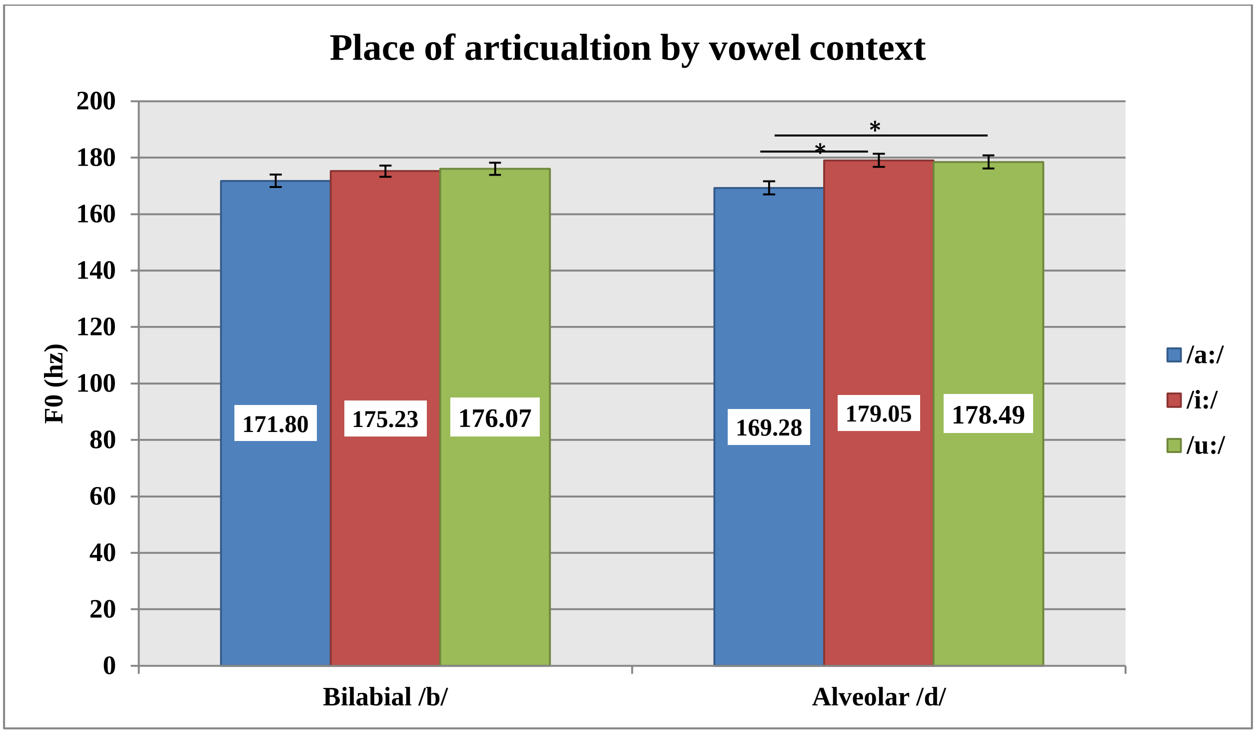


Figure 6.7 Mean ± S.E fundamental frequency (F0) Hz for significant interaction between place of articulation of stops /b,d/ and vowels /a:,i:,u/, * denotes significant differences.

There was no significant interaction between place of articulation and vowel context and sex (F(1.76,133.82) = 2.804, p= .368), place of articulation and vowel context and dialect (F(1.76,133.82) = 4.461, p= .685) or place of articulation and vowel context and sex and dialect (F(1.76,133.82) = 1.930,p = .427).

6.7.2.2 Voiceless stops t/k

Mean F0, Standard Deviation, Minimum and Maximum values in Hz for the vowels /i:, u:/ in words with initial voiceless alveolar /t/ stops (/ti:r/, /tu:r/) and words with an initial velar /k/ stop (/ki:r/, /ku:r/) are shown in Table 6.12 according to dialect and sex.

Sex	Dialect	/i:/		/u:/	
		/t/	/k/	/t/	/k/
		Mean (S.D) Min-Max	Mean (S.D) Min-Max	Mean (S.D) Min-Max	Mean (S.D) Min-Max
Male	S (20)	138.20 (23.29) 92.01-194.53	135.09 (18.48) 92.76-179.94	133.76 (17.14) 95.82-175.22	133.74 (16.83) 92.13-178.35
	B (20)	144.78 (21.40) 107.97-180.01	147.53 (30.97) 107.08-242.56	142.09 (21.83) 106.07-186.66	144.00 (22.23) 110.43-184.33
	Mean (40)	141.49 (22.33) 92.01-194.53	141.31 (25.95) 92.76-242.56	137.93 (19.83) 95.82-186.66	138.87 (20.14) 92.13-184.33
Female	S (20)	217.01 (20.08) 169.66-261.33	209.86 (24.77) 127.01-237.35	215.65 (20.95) 171.20-241.63	224.56 (24.98) 185.92-278.93
	B (20)	224.38 (22.63) 169.83-273.24	221.22 (17.35) 177.97-242.83	221.42 (21.95) 173.80-258.08	232.35 (26.19) 180.38-278.77
	Mean (40)	220.69 (21.44) 169.66-273.24	215.54 (21.88) 127.01-242.83	218.54 (21.38) 171.20-258.08	228.45 (25.57) 180.38-278.93
Total	S (40)	177.60 (45.31) 92.01-261.33	172.48 (43.58) 92.76-237.35	174.71 (45.57) 95.82-241.63	179.15 (50.57) 92.13-278.93
	B (40)	184.58 (45.79) 107.97-273.24	184.37 (44.79) 107.08-242.83	181.76 (45.61) 106.07-258.08	188.18 (50.76) 110.43-278.77
	All (80)	181.09 (45.40) 92.01-273.24	178.42 (44.31) 92.76-242.83	178.23 (45.44) 95.82-258.08	183.66 (50.55) 92.13-278.93

Table 6.12 Mean F0, Standard Deviation (S.D), Minmum (Min) and Maximum (Max) in Hz for stops t/k in two vowel contexts /i:,u:/ for male and female speakers from both dialects (Saudi = S and Bahraini = B).

A mixed-model ANOVA was conducted on the mean F0 (Hz) values of the vowels /i:, u:/ embedded in words with the voiceless stops /t/ and /k/ in initial position in two different vowel contexts, with gender (male–female) and dialect (Saudi–Bahraini) as the between-subjects factors. Place of articulation and vowel context were the repeated measures/within-subjects factors. The results showed non-significance ($p > .05$) in Mauchly's test for place of articulation and vowel context, and interaction between place of articulation and vowel context; therefore, sphericity was assumed.

6.7.2.2.1 Dialect and sex

For dialect, the results showed a significant effect ($F(1,76) = 5.03$, $p < .05$), where Saudis had a lower F0 (175.98 Hz) than Bahraini speakers (184.72 Hz). In addition, there was a main significant effect for sex ($F(1,76) = 431.85$, $p < .001$), where males had a lower mean F0 (139.90 Hz) than female speakers (220.81 Hz). However, there was no significant interaction between dialect and sex ($F(1,76) = .029$, $p = .913$).

6.7.2.2.2 Place of articulation

For place of articulation, there was no significant effect ($F(1,76) =1.10$, $p = .298$) and no significant interaction between place of articulation and sex ($F(1,76) = .580$, $p = .449$) and place of articulation and dialect ($F(1,76) = 1.717$, $p =.194$) or place of articulation and sex and dialect ($F(1,76) = .028$, $p = .867$).

6.7.2.2.3 Vowel context

There was no significant effect for vowel context ($F (1,76) = .275$, $p = .601$), and no significant interaction between vowel context and dialect ($F(1,76) = .095$,$p = .759$) ,or vowel context and sex and dialect ($F(1,76) = .068$,$p =.794$).

The interaction between vowel context and sex approached significance ($F(1,76) = 3.425$, $p = .068$). Post hoc paired *t-tests* for pooled vowel data for /i:/ and /u:/ for both stops /t,k/ split by sex group showed there were no significant differences between vowel /i:/ and vowel /u:/ for both males ($t(39) = -1.11$, $p =.274$) and females ($t(39) = -1.509$, $p =.139$). However, males tended to show higher F0 for vowels /i:/ (141.40 Hz) than /u:/ (138.40 Hz) whereas females tended to show lower F0 for vowel /i:/ (218.12 Hz) than vowel /u:/ (223.50 Hz), (see Figure 6.8).

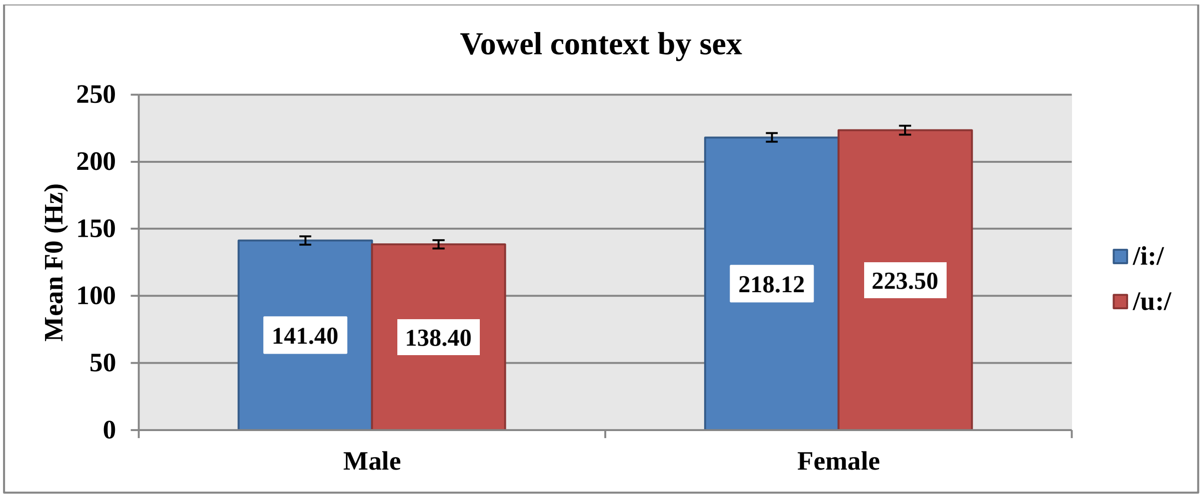


Figure 6.8 Mean ± S.E (Hz) for vowels by sex interaction.

Furthermore, there was a significant interaction between place of articulation with vowel context ($F(1,76) = 6.083$, $p < .05$). Post hoc paired t-tests showed no differences between vowels /i:/ and /u:/ for /t/ ($t(79) = 1.479$, $p = .143$) and no difference between vowels /i:/ and vowels /u:/ for /k/ ($t(79) = -1.505$, $p = .136$). However, F0 values for /t/, vowel /i:/ tended to show higher (181.09 Hz) than /u:/ (178.23 HZ) whereas for /k/, vowel /i:/ tended to show lower F0 (178.42 Hz) than vowel /u:/ (183.66 Hz), see Figure 6.9.

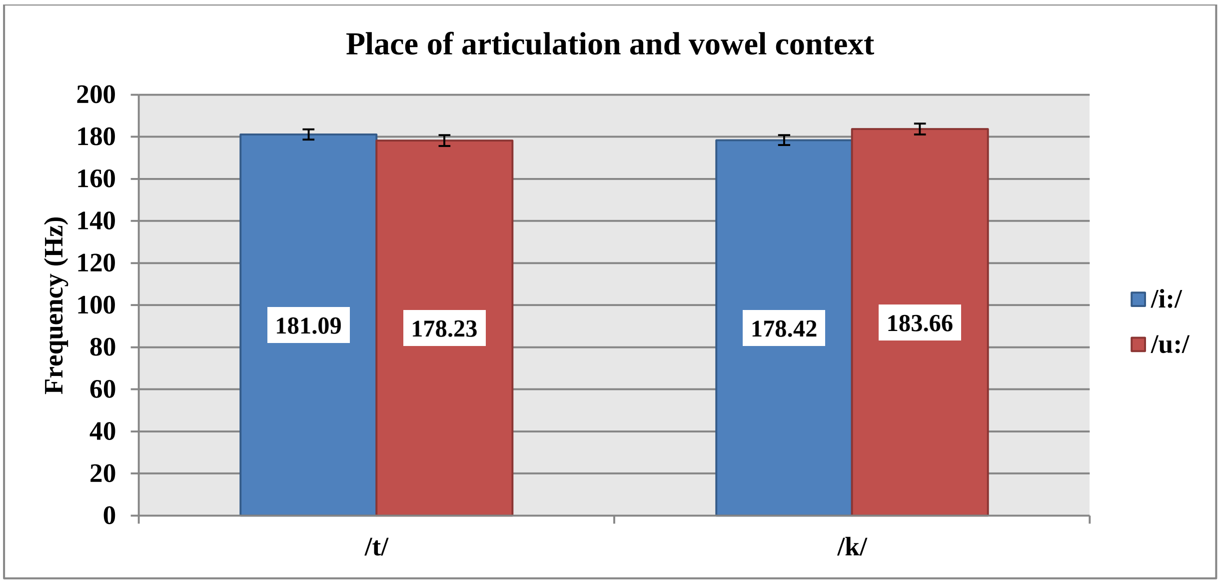


Figure 6.9 Mean ± S.E (Hz) for place of articulation and vowel context

In addition, there was a significant interaction between the place of articulation of stops and vowel context and sex ($F(1,76) = 4.508$, $p < .05$). A series of paired t-tests were conducted on data for the stops /t, k/ and the vowels /i:/ and /u:/ with sex split with an adjusted alpha level ($p < 0.00625$) for multiple comparisons. The results are seen in Table 6.13 where for males no differences were found ($p > 0.00625$), (see Table 6.13). For females, no differences were found for all contexts except between /tu:r/ and /ku:r/ ($p < .00625$), where /tu:r/ had a lower F0 (218.54 Hz) than /ku:r/ (228.46 Hz), (see Figure 6.10 and Tables 6.12 and 6.13).

Furthermore, there was no significant interaction between place of articulation and vowel context and dialect ($F(1,76) = .200$, $p = .656$), or between place of articulation and vowel context, dialect and sex ($F(1,76) =. 023$, $p = .881$).

	Paired	DF	t	p
Male	/ti:r/ - /tu:r/	39	1.733	0.091
	/ki:r/ – /ku:r/	39	0.591	0.558
	/ti:r/ -/ ki:r/	39	0.051	0.959
	/tu:r/ – /ku:r/	39	-1.07	0.286
Female	/ti:r/ - /tu:r/	39	0.653	0.517
	/ki:r/ – /ku:r/	39	-2.399	0.021
	/ti:r/ -/ ki:r/	39	1.441	0.157
	/tu:r/ – /ku:r/	39	-3.420	*0.001

Table 6.13 Results for a series of paired t-tests for place of stops t/k and vowels /i:,u:/ for males and females, * denotes significant differences based on a significance level (0.00625) adjusted for multiple comparisons. .

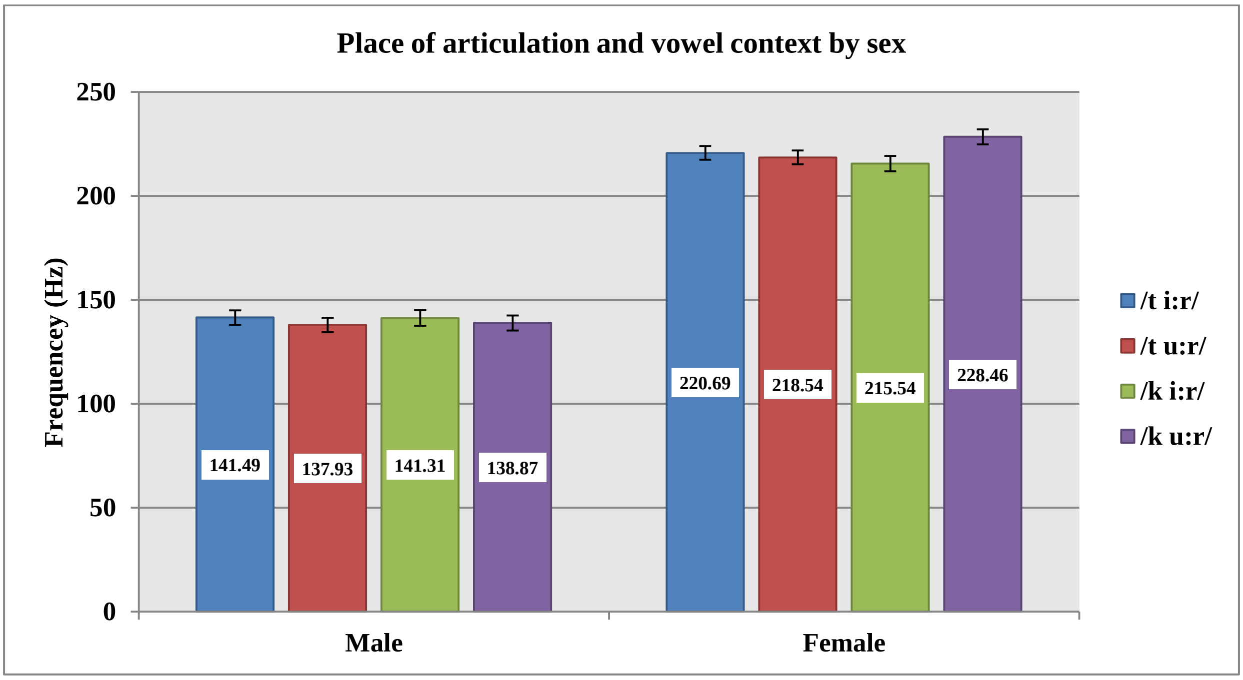


Figure 6.10 Mean F0 (Hz) ± S.E for place of stops t/k in vowel contexts /i:,u:/ for males and females.

6.7.2.3 Voiced voiceless stops t/d

Mean F0, Standard Deviation, Minimum and Maximum values in Hz for vowels /i:,u:/ in words with initial voiceless alveolar /t/ stops (/ti:r/,/tu:r/) and words with initial voiced alveolar /d/ stop (/di:r/,/du:r/) are shown in Table 6.14 as a function of dialect and sex. A mixed model ANOVA was conducted for mean F0 (Hz) for vowels /i:,u:/ embedded in words with alveolar voiceless stops /t/ and voiced /d/ in initial position in two different vowel contexts, with gender (male–female) and dialect (Saudi–Bahraini) as the between-subjects factors. Voicing and vowel context were the repeated measures/within-subjects factors. Results showed Mauchly's test to be non-significant (p>.05) for voicing and vowel context and the interaction between voicing and vowel context; therefore, sphericity was assumed.

Sex	Dialect	/i:/		/u:/	
		/t/	/d/	/t/	/d/
		Mean (S.D) Min-Max	Mean (S.D) Min-Max	Mean (S.D) Min-Max	Mean (S.D) Min-Max
Male	S (20)	138.20 (23.29) 92.01-194.53	133.86 (21.94) 86.17-188.43	133.76 (17.14) 95.82-175.22	132.82 (20.21) 88.20-181.47
	B (20)	144.78 (21.40) 107.97-180.01	145.07 (26.08) 104.22-190.56	142.09 (21.83) 106.07-186.66	145.28 (22.55) 109.36-184.93
	Mean (40)	141.49 (22.33) 92.01-194.53	139.47 (24.46) 86.17-190.56	137.93 (19.83) 95.82-186.66	139.05 (22.06) 88.20-184.93
Female	S (20)	217.01 (20.08) 169.66-261.33	213.42 (13.48) 191.17-247.58	215.65 (20.95) 171.20-241.63	212.66 (20.08) 177.54-248.08
	B (20)	224.38 (22.63) 169.83-273.24	223.86 (20.31) 168.04-258.27	221.42 (21.95) 173.80-258.08	223.19 (21.15) 175.15-250.41
	Mean (40)	220.69 (21.44) 169.66-273.24	218.64 (17.82) 168.04-258.27	218.54 (21.38) 171.20-258.08	217.93 (21.04) 175.15-250.41
Total	S (40)	177.60 (45.31) 92.01-261.33	173.64 (44.11) 86.17-247.58	174.71 (45.57) 95.82-241.63	172.74 (45.05) 88.20-248.08
	B (40)	184.58 (45.79) 107.97-273.24	184.47 (46.09) 104.22-258.27	181.76 (45.61) 106.07-258.08	184.24 (44.97) 109.36-250.41
	All (80)	181.09 (45.40) 92.01-273.24	179.05 (45.15) 86.17-258.27	178.23 (45.44) 95.82-258.08	178.49 (45.10) 88.20-250.41

Table 6.14 Mean F0, Standard Deviation (S.D), Minmum (Min) and Maximum (Max) in Hz for alveolar voiceless stop /t/ and voiced /d/ in two vowel contexts /i:,u:/ for male and female speakers from both dialects (Saudi = S and Bahraini = B).

6.7.2.3.1 Dialect and sex

Dialect showed a significant effect ($F(1,76) = 4.655$, $p<.05$), where Saudis had lower F0 values (174.67 Hz) than Bahraini speakers (183.76 Hz). In addition, there was a main significant effect of sex ($F(1,76) = 355.933$, $p<.001$) where male participants had lower F0 values (139.48 Hz) than females (218.95 Hz). However, there was no significant interaction between dialect and sex ($F(1,76) = 0.018$, $p = 0.894$).

6.7.2.3.2 Voicing

Voicing did not show a significant effect ($F(1,76) = 0.699$, $p = 0.406$). In addition, there was no significant interaction between voicing and sex ($F(1,76) = 0.172$, $p = 0.68$) or between voicing and sex and dialect ($F(1,76) = 0.012$, $p = 0.914$). However, the interaction between voicing and dialect approached significance ($F(1,76) = 3.794$, $p = .055$).

6.7.2.3.3 Vowel context

For vowel context, no significant effect was found ($F1,76) =1.508$, $p = 0.223$). In addition, no significant interaction was found between vowel context and sex ($F(1,76) = 0.04$,$p = 0.843$), vowel context and dialect ($F(1,76) = 0.018$, $p = 0.894$) or vowel context and sex and dialect ($F(1,76) =0.163$, $p=0.687$). Furthermore, there was no significant interaction between: voicing and vowel context ($F(1,76) = 0.904$, $p = 0.345$); voicing and vowel context and sex ($F(1,76) = 0.125$, $p = 0.725$); voicing and vowel context and dialect ($F(1,76)=0.015$,$p=0.902$) or voicing and vowel context and sex and dialect ($F(1,76) = 0.052$, $p = 0.82$).

6.7.2.4 Plain/emphatic stops

Mean F0, Standard Deviation, Minimum and Maximum values in Hz for vowels /i:,u:/ in words with initial voiceless alveolar plain /t/ stops (/ti:r/,/tu:r/) and words with initial voiceless alveolar emphatic /$t^{ʕ}$/ stop (/$t^{ʕ}$i:r/,/$t^{ʕ}$u:r/) are shown in Table 6.15 as a function of dialect and sex.

Sex	Dialect	/i:/		/u:/	
		/t/	/$t^{ʕ}$/	/t/	/$t^{ʕ}$/
		Mean (S.D) Min-Max	Mean (S.D) Min-Max	Mean (S.D) Min-Max	Mean (S.D) Min-Max
Male	S (20)	138.20 (23.29) 92.01-194.53	133.55 (20.12) 94.96-191.15	133.76 (17.14) 95.82-175.22	135.65 (20.64) 89.43-186.18
	B (20)	144.78 (21.40) 107.97-180.01	143.94 (24.59) 102.92-196.26	142.09 (21.83) 106.07-186.66	145.44 (23.33) 109.13-188.14
	Mean (40)	141.49 (22.33) 92.01-194.53	138.74 (22.79) 94.96-196.26	137.93 (19.83) 95.82-186.66	140.55 (22.30) 89.43-188.14
Female	S (20)	217.01 (20.08) 169.66-261.33	212.51 (17.91) 174.87-248.39	215.65 (20.95) 171.20-241.63	220.67 (21.97) 178.34-260.42
	B (20)	224.38 (22.63) 169.83-273.24	219.99 (21.82) 172.31-261.48	221.42 (21.95) 173.80-258.08	227.63 (23.50) 175.47-270.34
	Mean (40)	220.69 (21.44) 169.66-273.24	216.25 (20.06) 172.31-261.48	218.54 (21.38) 171.20-258.08	224.15 (22.73) 175.47-270.34
Total	S (40)	177.60 (45.31) 92.01-261.33	173.03 (44.18) 94.96-248.39	174.71 (45.57) 95.82-241.63	178.16 (47.92) 89.43-260.42
	B (40)	184.58 (45.79) 107.97-273.24	181.96 (44.83) 102.92-261.48	181.76 (45.61) 106.07-258.08	186.53 (47.60) 109.13-270.34
	All (80)	181.09 (45.40) 92.01-273.24	177.5 (44.45) 94.96-261.48	178.23 (45.44) 95.82-258.08	182.35 (47.64) 89.43-270.34

Table 6.15 Mean F0, Standard Deviation (S.D), Minmum (Min) and Maximum (Max) in for the plain alveolar voiceless stop /t/ and the alveolar emphatic alveolar stop /$t^{ʕ}$/ in two vowel contexts /i:,u:/ for male and female speakers from both dialects (Saudi = S and Bahraini= B).

A mixed model ANOVA was conducted with mean F0 (Hz) for vowels /i:,u:/ embedded in words with alveolar voiceless plain stops /t/ and emphatic /$t^{ʕ}$/ in initial position in two different vowel contexts, with gender (male–female) and dialect (Saudi–Bahraini) as the between-subjects factors. Emphasis and vowel context were the repeated measures/within-subjects factors. Results showed Mauchly's test non-significant results ($p>.05$) for place of articulation and vowel context, and interaction between manner of articulation and vowel context; therefore, sphericity was assumed.

6.7.2.4.1 Dialect and sex

The effect from dialect approached significance ($F(1,77) = 3.242$, $p = 0.076$) where Saudi speakers tended to have lower F0 values (175.88 Hz) than Bahraini speakers (183.71 Hz). However, sex had a significant effect ($F(1,76) = 340.123$, $p<.001$) where males had a significantly lower F0 (139.68 Hz) than female speakers (219.91 Hz). There was no significant interaction between dialect and sex ($F(1,78) = 0.047$, $p=0.83$).

6.7.2.4.2 Emphasis

Emphasis did not show a significant effect ($F(1,76) = 0.0640$, $p = .802$), and there was no significant interaction between emphasis and sex ($F(1,76) = 0.098$,$p = 0.755$), emphasis and dialect ($F(1,76) = 0.628$, $p = 0.431$) or emphasis and sex and dialect ($F(1,76) = 0.228$, $p = 0.635$).

6.7.2.4.3 Vowel context

Vowel context did not show a significant effect ($F(1,76) = 0..456$, $p=.501$). There was no significant interaction between vowel context and sex ($F(1,76) =1.626$,$p = 0.206$), vowel context and dialect ($F(1,76) = 0.007$,$p = 0.934$) or vowel context and sex and dialect ($F(1,76) = 0.078$,$p = 0.781$).

However, there was a significant interaction between emphasis and vowels ($F(1,76) = 14.581, p<.001$). A series of post hoc paired t-test with an adjusted alpha level of ($p < 0.0125$) for multiple comparisons. Results' showed that for plain /t/, no significant differences were found between the two vowels /i:,u:/ ($t(79) = 1.476$, $p=.143$). Whereas, for emphatic /tˤ/, results showed there was a significant difference between vowels ($t(79)=-3.054$), $p < 0.0125$), where the front high vowel /i:/ had a lower F0 (177.50 Hz) than the high back vowel /u:/ (182.35 Hz), (see Figure 6.12). Furthermore, there was a significant differences where /tur/ (178.23 Hz) had lower F0 than /tˤur/ (182.35 Hz), ($t(79) = -2.269$, $p < 0.0125$), (see Figure 6.12). While, no differences were found between /tir/ (181.09 Hz) and /tˤir/ (177.50 Hz), ($t(79) = 2.475$, $p= .015$).

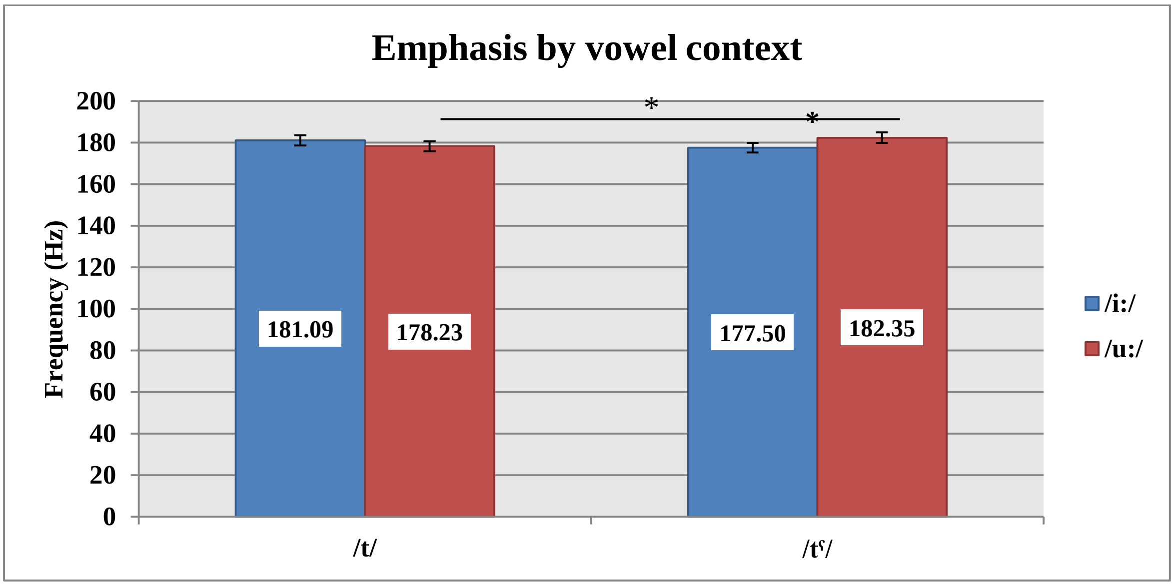


Figure 6.11 Mean F0 (Hz) ± S.E for plain and emphatic stops t/tˤ in the vowel contexts /i:,u:/.

In contrast, there was no significant interaction between emphasis and vowel context and sex ($F(1,76)= 1.345, p=.250$), emphasis and vowel context and dialect ($F(1,76)= .025, p=.876$) or emphasis and vowel conext and sex and dialect ($F(1,76)= .181, p=.250$).

6.7.3 Sentences

Two sentences were selected: from the Quran, the fourth and fifth sentences were combined, while the fifth sentence was selected from the Arabic version of “the North Wind and the Sun” (Thelwall & Sa’Adeddin, 1990). Mean F0, Standard Deviation, Minimum and Maximum values in Hz for the two sentences are shown in Table 6.16 as a function of dialect and gender.

Sex	Dialect	Quran	Reading
		Mean (S.D) Min-Max	Mean (S.D) Min-Max
Male	Saudi (20)	123.06 (16.65) 82.61-159.43	128.92 (17.79) 89.27-167.84
	Bahraini (20)	125.13 (20.96) 89.53-169.87	135.46 (21.45) 104.97-183.42
	Total (40)	124.09 (18.71) 82.61-169.87	132.19 (19.73) 89.27-183.42
Female	Saudi (20)	193.79 (18.85) 160.54-222.92	209.85 (21.41) 159.27-239.05
	Bahraini (20)	195.52 (17.08) 158.59-221.90	208.92 (15.96) 165.49-235.94
	Total (40)	194.66 (17.78) 158.59-222.92	209.38 (18.64) 159.27-239.05
Total	Saudi (40)	158.43 (39.89) 82.61-222.92	169.39 (45.35) 89.27-239.05
	Bahraini (40)	160.32 (40.33) 89.53-221.90	172.19 (41.61) 104.97-235.94
	Total (80)	159.38 (39.87) 82.61-222.92	170.79 (43.27) 89.27-239.05

Table 6.16 Mean F0, Standard Deviation (S.D), Minmum (Min) and Maximum (Max) in) for two sentence types, from the Quran and from the Arabic version of “the North Wind and the Sun” (Thelwall & Sa’Adeddin, 1990) for male and female speakers from both dialects (Saudi = S and Bahraini = B).

A mixed model ANOVA was conducted for mean F0 (Hz) with gender (male–female) and dialect (Saudi–Bahraini) as the between-subjects factors. Sentence type was the repeated measure/within-subjects factor. Results showed Mauchly's test non-significant ($p>.05$) for sentence type; therefore, sphericity was assumed.

6.7.3.1 Dialect and sex

Dialect did not show a significant effect ($F(1,76) = .693, p = 0.326$), and there was no significant interaction between dialect and sex ($F(1,76) = 0.225, p = 0.636$). However, sex showed a main significant effect ($F(1,76) = 322.475$, $p < .001$) where males had a lower F0 (128.14 Hz) than females (202.02 Hz).

6.7.3.2 Sentence type

Sentence type showed a main significant effect ($F(1,76) = 143.983$, $p < .001$) where Quran sentences showed a lower F0 value (159.38 Hz) than the sentence (170.79 Hz) from "the North Wind and the Sun" (Thelwall & Sa'Adeddin, 1990).

In addition, there was a significant interaction between sentence type and sex ($F(1,76) = 12.158$, $p <.05$). A series of post-hoc paired *t-test* split by sex group with an adjusted alpha level of ($p < 0.025$) for multiple comparisons. Results showed that males had a significantly lower F0 (124.10 Hz) for the Quran sentences than the reading passage sentence (132.19 Hz), ($t(39)= - 6.086 = p < .025$). In addition, the females had a significantly lower F0 for Quran (194.66 Hz) than reading passage sentence ($t(39)= - 10.605$, $p < .025$), (see Figure 6.13).

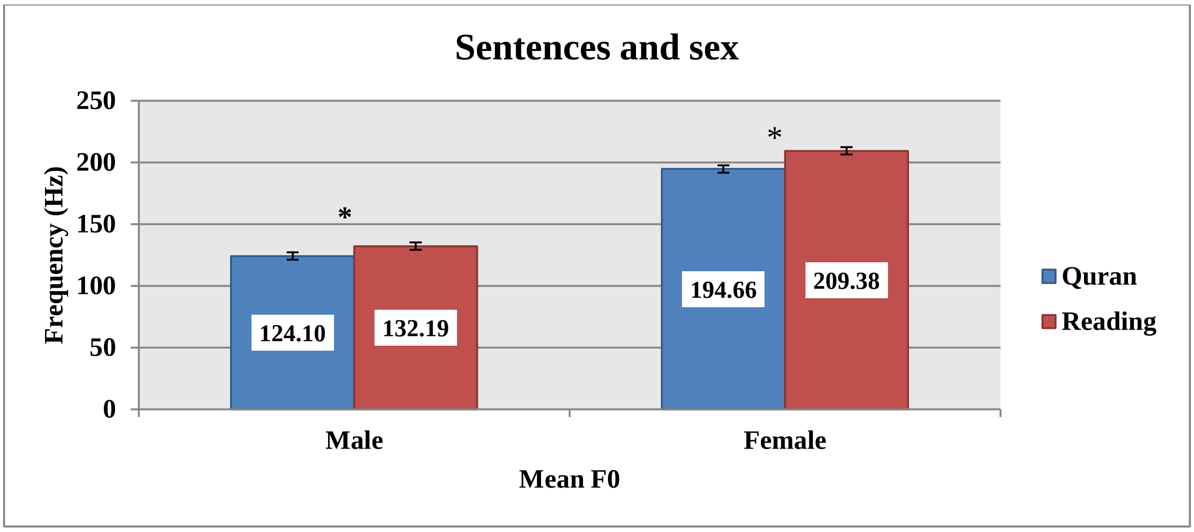


Figure 6.12 Mean ± S.E fundamental frequency (F0) Hz for sentences where type of sentence and sex showed a main significant interaction where for both males and females, and Quran sentence showed significantly lower F0 than reading sentence selected "the North Wind and the Sun" (Thelwall & Sa'Adeddin, 1990).

In addition, the interaction between type of sentence and dialect and sex approached significance (F(1,76) = 3.50, p= .065) which showed that males had lower mean F0 values than females while Quran sentences had lower mean F0 values than the reading sentences for both sexes. However, sentence type and dialect did not show a significant effect (F(1,76) = .225, p= .637).

	Vowels	Words				Sentences
		Voiced (/b/,/d/)	**Voiceless (/t/,/k/)**	**Voiced/voiceless (/d/,/t/)**	**Plain/Emphatic (/t/,/tˤ/)**	
Dialect	n.s	S<B ($p<.05$)	S<B ($p<.05$)	S<B ($p<.05$)	Approached significance S<B ($p=.076$)	n.s
Sex	M<F ($p<.001$)	M<F ($p<.001$)	M<F ($p<.001$)	M<F ($p<.001$)	M<F ($p<.001$)	M<F ($p<.001$)
Vowel	/a/</i,u/ ($p<.05$)	/a/</i/and u/ ($p<.001$) Place interaction /b/ (a:<u:) ($p<.001$) /d/(a:<i: ,u:) ($p<.001$)	Approached significance with sex ($p=.068$) M(i:<u)n.s F(u:<i:)n.s Place interaction ($p<.05$) /t/(i:<u) n.s /k/(u:<i:)n.s	n.s	Interaction with emphasis /t/(i:>u:)n.s /tˤ/(u:<i:) ($p<.05$)	NA
Place*	NA	Interaction with dialect ($p<.05$) /d/(S<B) ($p<.05$) /t/ n.s	n.s	Approached significance with dialect ($p=.055$) S(/t/>/d/) ($p<.05$) B(/t/</d/)n.s	n.s	Q<R ($p<.001$) With sex ($p<.05$) M & F (Q<R) Approached significance with dialect ($p=.065$) (M&F) for (S&B) (Q<R)

Table 6.17 Significant results and interactions for sustained vowels (a,i,u) and vowels /a:,i:,u:/ in words with voiced /b, d/; voiceless /t, k/; voiced/voiceless /t, d/; and plain/emphatic /t, tˤ/ for dialect, gender, place of articulation, and vowel contexts. (S and B denote Saudi and Bahraini speakers while M and F denote male and female,* Q and R denotes Q for Quran and R for reading)

		Dialect		Sex		Vowels		Voicing /Place/ Emphasis		sentences type	
		Hypothesis	**Results**	**Hypothesis**	**Results**	**Hypothesis**	**Results**	**Hypothesis**	**Results**	**Hypothesis**	**Results**
Sustained phonation		Differences will not be found between dialects	S=B	Males will have lower Mean F0 than females	M<F	High vowels will have higher mean F0 than low vowels	/i/,/u/</a/	NA		NA	
Words	**Voiced (b,d)**	Differences will not be found between dialects.	S<B	Males will have lower Mean F0 than females	M<F	High vowels will have higher mean F0 than low vowels	/i/,/u/</a/	Place will have no effect	/b/=/d/	NA	
Words	**Voiceless (t,k)**	Differences will not be found between dialects.	S<B	Males will have lower Mean F0 than females	M<F	No prediction	/i:/=/u:/	Place will have no effect	/t/=/k/	NA	
Words	**Voiced/voiceless (d,t)**	Differences will not be found between dialects.	S<B	Males will have lower Mean F0 than females	M<F	No prediction	/i:/=/u:/	Voiced will have lower mean F0 than voiceless	Saudis /t/>/d/	NA	
Words	**Plain /emphatic (t,tˤ)**	Differences will not be found between dialects.	S=B statistically	Males will have lower Mean F0 than females	M<F	No prediction	/i:/=/u:/	Differences will not be found between plain/t/ and emphatic /tˤ/	/t/=/tˤ/	NA	
Sentences		Differences will not be found between dialects.	S=B	Males will have lower Mean F0 than females	M<F	NA		NA		Differences will be found between Quran and reading	Q<R

Table 6.18 Comparison of hypotheses predicted for the study of mean F0 for sustained phonation and words with initial voiced (b,d), voiceless (t,k), voiced/voiceless (d,t) and plain/emphatic stops (t,tˤ) and sentences (Quran and Reading) and the outcomes of the statistical analysis. (S and B denote Saudi and Bahraini speakers while M and F denote male and female and NA reflects not applicable.

6.8 Discussion

The first aim of this study was to establish normative Mean F0, Standard Deviation, Minimum and Maximum values for different stimuli for male and female Saudi Najdi and Bahraini Bahraini speakers which have been achieved and results are displayed in Tables 6.9 ~ 6.15. The second aim was to determine the effects of dialect (Saudi and Bahraini) and sex (male and female) on mean F0 for sustained phonation for vowels (a,i,u) the words with initial plain stops /b, d, t, k/ amongst Arabic speakers. This chapter also examined the effects of voicing, place of articulation, vowel context and emphasis. This section begins with a discussion of dialect and gender differences identified in the study and the hypotheses that have been proposed, followed by a discussion of the within-subject measures of voicing, place of articulation, emphasis, and vowel context as well as the hypotheses proposed for them (see Tables 6.16 and 6.17). Finally, a summary of the findings is provided.

6.8.1 Dialect

The results showed no statistical differences between Saudi and Bahraini speakers for sustained vowels, words with initial emphatic and plain stops /t,tˤ/ and sentences. However, some significant differences were found and showed that Saudi speakers had lower mean F0 than Bahraini speakers for words with initial voiced /b,d/,voiceless/t,k/ and voiced/voiceless contrast /d,t/. The section is divided to three sections based on stimuli used followed by a general section for dialect.

6.8.1.1 Sustained phonation

Results did not show significant differences between the two Arabic dialects (Saudi Najdi and Bahraini) for the sustained phonation of the vowels /a,i,u/. This might come as a reasonable outcome since Baken & Orlikoff (2000) described the task of sustained phonation as monotonous in contrast with speech. Furthermore, Natour & Wingate (2009) went on further to explain that vocal modifications for sustained phonation are limited from the effects of culture and linguistics in comparison to the use of speech as stimuli. Altenberg & Ferrand (2006) shared the same view that sustained phonation reduces the complexity of speech production, which might be the reason for the lack of differences between the dialects of Arabic in this study for sustained phonation. Furthermore, when comparing the results of this study for both dialects (Saudi Najdi and Bahraini) to Jordanian Arabic (Natour et al., 2011), (see Table 6.18), which is the only study that provided mean F0 for sustained phonation for all three vowels, the results were similar in terms of mean F0. Moreover, a comparison with studies that provided mean F0 for sustained vowels for /a/ were studies by Malik et al. (2009) and Natour & Wingate (2009).

Study	Dialect	Sex	Stimuli type		
			/a/	/i/	/u/
Natour et al. (2011)	Jordanian Arabic	M	127	132	134
		F	225	236	233
Natour & Wingate (2009)	Jordanian Arabic	M	131		
		F	231		
Malki et al. (2009)	General Saudi	M	126		
		F	211		
Current Study	Saudi	M	128	131	129
		F	205	207	213
	Bahraini	M	128	135	133
		F	208	208	215

Table 6.19 Mean F0 (Hz) for Arabic studies (Natour et al., 2011; Natour & Wingate, 2009; Malki et al., 2009) in comparison with the results from this study for sustained phonation of vowels (/a/,/i/,/u/),(results were to the nearest decimal point for all studies).

However, as stimuli and methodologies were different between the Arabic studies, the comparison between studies remains limited.

6.8.1.2 Words

Saudi speakers showed lower mean F0 than Bahraini speakers in words with initial voiced /b,d/, voiceless /t,k/, voiced /d,t/ and showed near significant for emphatic/plain /t,tˤ/ stops. A possible reason for this is that the Saudis in this study had a lower mean F0 than the Bahraini speakers, which highlights the dialectal differences in Arabic speakers in their productions at word level.

The results are not in line with Alghamdi's study (1998) where no differences were found between Saudi, Sudanese and Egyptian speakers for vowels embedded in words. Different outcomes might be possible because of the dialects that were investigated in this study were specifically Bahraini and Najdi Saudi speakers. This is in contrast to Alghamdi's (1998) study where the dialects were classed into general Saudi, Sudanese and Egyptian, which might have masked the differences between dialects. Another possible reason for different outcomes between the studies was stimuli design. Where the monosyllables used in Alghamdi's (1998) study had initial and final fricative /s/, whereas in this study, the use of different stops in initial position might have invoked the dialect differences. In addition, a comparison between the results from Alghamdi's study (1998) and this study is not possible as stimuli and methodologies were different. Therefore comparisons between the studies are limited.

6.8.1.3 Sentences

Results did not show any dialect differences between Saudi and Bahraini speakers for the Quran and reading sentences (see Table 6.16). The reason that no significant differences were found in sentences between Saudi and Bahraini speakers might be due to the nature of the sentences chosen for analysis. The Quran chapter was of religious origin and might have played into restricting dialectical differences as it is used a minimum of 5 times per day (each prayer for participating Muslims). As the Quran chapter is much repeated and has religious value, Muslims would thereby adopt similar vocal registers when reciting the Quran. In addition, the reading of the passage might have been influenced by the use of MSA as an alternative to dialect use, which may explain the lack of differences between dialects in the reading data. The reading passage was an Arabic version of 'The North Wind and the Sun' (Thelwall & Sa'Adeddin, 1990) that was translated into MSA Arabic and had not been designed to invoke any dialectal differences. This might explain the lack of differences between dialects in the reading of the passage (for further discussion, see §6.8.4).

6.8.1.4 General

The results for sustained phonation and sentences did not show dialect differences between Saudi and Bahraini speakers, which agrees with the first hypothesis that no dialect differences would be found between them. However, results showed that mean F0 was lower for Saudis than Bahraini speakers for words with initial voiced /b,d/, voiceless /t,k/ and voiced/voiceless stops /d,t/. The results from this study show that dialectal differences might appear depending on stimulus type as exhibited in this study. Therefore, it is recommended that for future studies investigating dialects in Arabic and different languages that different speech samples should be presented to participants, in order to fully comprehend dialect differences as a function of stimulus type.

6.8.2 Sex

The results for sex differences showed that for all stimuli (sustained phonation, words and sentences); males had lower mean F0 than females. Results agreed with the results for sustained phonation for vowel and words and sentences for Arabic studies (Natour et al., 2011; Natour & Wingate, 2009; Malki et al., 2009). Furthermore, it agreed with general sex differences found in different languages where males had lower mean F0 than females (Hudson & Holbrook, 1982, 1982; Sapienza, 1997; Zhang et al., 1999; Andrianopoulos et al., 2001; Guimarães & Abberton, 2005; Chen, 2007; Andreeva et al., 2014). The results are in line with previous studies that explained that males have a larger membranous vocal fold length and laryngeal size, which would result in a lower F0 in males than females (Hollien, 1960; Kent, 1976; Hirano et al., 1981; Titze, 1989a; Fung, 1990; Williams & Eccles, 1990; Izadi et al., 2012). Moreover, males have lower tension in their vocal folds than females, thus resulting in a lower mean F0 than females (Hirano et al., 1981; Titze, 1989; Fung, 1990). The results support the second hypothesis that males would have lower mean F0 than females for sustained phonation of vowels, words and sentences.

6.8.3 Vowel context

Results for the sustained phonation of vowels showed that lower vowel /a/ had lower mean F0 than higher vowels /i,u/. This was similar to Natour et al.'s (2011), although that study did not investigat the effects of vowel context. Furthermore, it is in agreement with the results of Whalen & Levitt's review study (1995) and Andrianopoulos et al's (2001) and Guimarães & Abberton's (2005), although, the latter two studies did not investigate vowel context in their studies. Furthermore, for vowel context, the stimuli with voiced stops (/b,d/) were the only context that all vowels were represented (/a:/,/i:/,/u:/), and results showed similarities with sustained phonation where higher vowels (/i:/,/u:/) had significantly higher mean F0 than low vowel /a:/. This is in agreement with the results of Alghamdi (1998) and also agrees with a few studies on different languages (Whalen & Levitt, 1995). According to Ohala & Eukel (1987) the degree of tongue pull on the larynx causes the differences between mean F0 for high vowels and low vowels. The result from tongue pull is an increase in mean F0 for the high vowels, while for the lower vowels there is less tongue pull resulting in a lower mean F0. Whalen et al. (1999) further explain the involvement of the cricothyroid (CT) muscle, which widens the angle between the cricoid and thyroid cartilages, decreasing the tension in the vocal folds in lower vowels; therefore, with all else being equal, F0 decreases in lower vowels.This, however, remains a tentative explanation of the results from this study and future studies are warranted. Furthermore, it does not explain the results which showed higher mean F0 for vowel /a:/ in the context of /d/ as observed in Table 6.11, than remaining vowels /i:,u:/. This might suggest that /da:r/ is a high frequency item compared to remaining words in the context of /d/. However, this cannot be confirmed and future studies are warranted employing words with similar frequency rates.

The remaining initial voiceless stops /t,k/, voiced/voiceless /d,t/ and emphatic/plain /t,tˤ/ words had only two high vowels, the front high vowel /i:/ and back high vowel /u:/, the results for high vowels showed no significant differences similar to the results from the review study prepared by Whalen & Levitt (1995).

The results for the mean F0 according to vowel context support the third hypothesis that higher vowels would have a higher mean F0 than lower vowels.

6.8.4 Sentences type

Results showed that the fourth and fifth sentences from the Quran chapter had lower mean F0 than the reading of the fifth sentences from of Arabic version of the “the North Wind and the Sun” (Thelwall & Sa’Adeddin, 1990). Results were in agreement with studies in Arabic (Alshahwan, 2008; Abu-Al-Makarem & Petrosino, 2007) where reading had a higher mean F0 than other types of sentences. Furthermore, results showed similarity to other studies in

English (Zraick et al., 2000; Murry et al., 1995) where reading had the highest mean F0 amongst different tasks.

Quran sentences from the first chapter “Al-Fatihah” showed that it had lower mean F0 than the reading sentences. Possible reasons for the lower mean F0 for the Quran sentence are that it becomes semi-automatic speech as this chapter is one of the first of the Quran that Muslims learn to memorize as a child, as it is required for praying. Furthermore, Muslims pray at least 5 times a day and it is performed at least twice in each prayer. Reference to the study by Zraick et al. (2000), shows that automatic speech (counting from 1-3) had the lowest mean F0 amongst speech tasks. Reciting this Quran chapter might be considered a semi-automatic task; therefore, it might be expected to have a lower mean F0 than reading. Furthermore, Zraick et al's study (2006) showed that speaking to a superior had significantly lowered mean F0 than speaking to public and peers and subordinates. Religiously, for Muslims, in the task of reading the Quran - regardless of chapter – Muslims should show modesty and reciting the Quran might show similarities to speaking to a superior. Consequently, the Quran might have shown a lower mean F0 for that reason. Furthermore, Fatihi (2001) explained that recitation styles “/qira.at/” for the Quran are different, involving raising and lowering of pitch, punctuation and durational patterns. The Bahrainis and Saudis in this study share a similar recitation style /ħafsˤ ʕan ʕasˤim/, which might be a reason why dialect differences were not found. Further studies exploring different recitation styles of the Quran may aid in enabling an understanding to be reached of the differences in dialects of Arabic as well as the possible effects resulting from different recitation styles.

The results have confirmed the fourth hypothesis where mean F0 showed differences between the types of sentences where the reading of the fifth sentences from of Arabic version of the

"the North Wind and the Sun" (Thelwall & Sa'Adeddin, 1990) had higher mean F0 that the fourth and fifth sentences from the Quran chapter.

6.8.5 Voicing

Results showed that Saudi speakers had a lower mean F0 for words with initial voiced stop /d/ compared to those with initial voiceless /t/. This is in agreement with a number of studies (House & Fairbanks, 1953; Lehiste & Peterson, 1961; Mohr, 1971; Löfqvist, 1975; Umeda, 1981; Kingston & Diehl, 1994; Van Alphen & Smits, 2004). However, for Bahraini speakers, there were no differences in mean F0 for words with initial voiced /d/ and voiceless /t/ stops. This might be due to dialect. For example, Fox et al. (2013) investigated three American dialects and did not find any F0 differences between words with voiced and voiceless stops. Therefore, the fifth hypothesis was partially supported by the Saudi participants' data, but not supported by the Bahraini participants' data, indicating that dialect might play a role in mean F0 differences between voiced and voiceless stops.

6.8.6 Place of articulation

The results from this study showed no differences between place of articulation for words with initial voiced bilabial /b/ and alveolar/ d/ and voiceless alveolar /t/ and velar /k/. Only one study (Van Alphen & Smits, 2004) had compared mean F0 between place of articulation where it showed similarity to the results of this study, where it showed no differences between place of articulation between words with initial voiced bilabial /b/ and alveolar/ d/ and between voiceless bilabial/p/ and alveolar /t/. Therefore, the results confirmed the sixth hypothesis that there would be no differences in mean F0 between places of articulation for words with voiceless alveolar /t/ and velar /k/ and voiced bilabial /b/ and alveolar /d/ initial stops.

6.8.7 Emphasis

Results showed that statistically, there were no differences in mean F0 between words with initial plain /t/ and emphatic /tˤ/ alveolar stops. The results are similar to those reported by Shoul (2008) where no differences were found in mean F0 between plain and emphatic stops. However, although the results were not statistically significant, the results showed similarity to the results for words where Saudis tended to show lower mean F0 than Bahraini speakers. The results support the seventh hypothesis that there are no differences in mean F0 between words with initial plain /t/ and emphatic /tˤ/ stops.

6.8.8 Clinical use of normative mean F0 (Hz) for Saudi and Bahraini Arabic speakers established from this study

In clinical settings, speech and language pathologists frequently employ minimum and maximum, in addition to mean F0 rates to ascertain if vocal pathologies are present for a number of stimuli as mentioned in §6.2.2.3. Therefore, this study provides normative F0 (means, standard deviation, minimum and maximum) in Hz for Saudi and Bahraini male and female young adult speakers for a number of stimuli as seen in §6.7.1 ~ 6.7.3. When assessing patients from other Arabic dialects, it is recommended to use sustained phonation as it showed no effect from the dialects in this study. Although, dialect showed no effect on sentences from both the Quran and reading from the Arabic version of "the North Wind and the Sun" (Thelwall & Sa'Adeddin, 1990). These should be used with some caution as further analysis is required to control suprasegmental features of speech. However, when assessing dialects of Arabic, word alone analysis is suggested to be avoided. A limitation from F0 analysis in this study is restriction of analysis of mean F0 between the dialects and sexes. Further examination of standard deviation and ranges of F0 for all stimuli in this study is warranted. Further points will be provided in §8.3 ~8.5.

6.9 Summary

Results from this chapter revealed that sex played a major role in the F0 of the sustained phonation of the vowels /a, i, u/ and in vowels in words with initial voiced /b, d/, voiceless /t, k/, voiced/voiceless /d, t/ and plain/emphatic /t, tˤ/, and in the reading speech data from the fourth and fifth sentences from the Quran chapter and the fifth sentence from the Arabic version of the 'the North Wind and the Sun' (Thelwall & Sa'Adeddin, 1990). Therefore, differences between males and females in the mean F0 vlaues in Arabic, where females have a higher mean F0 than males, can be reliably attributed to physiological and anatomical differences (Hollien, 1960; Kent, 1976; Hirano et al., 1981; Titze, 1989a; Fung, 1990; Williams & Eccles, 1990; Izadi et al., 2012).

Dialect appeared to play a role in F0 values in vowels /a:,i:,u:/ in words with initial voiced /b,d/, voiceless /t,k/, and voiced/voiceless /d,t/ where it was found that Saudis had a lower mean F0 than Bahraini speakers for these stimuli. However, dialects did not play a role in the sustained phonation of the vowels /a, i, u/ and in the sentence data. Possible reason for lack of differences between dialects for sustained phonation might be due to lack of vocal and linguistic differences in their production as described earlier. Furthermore, the sentences selected for analysis from the Quran and the Arabic version of the "the North Wind and the Sun" (Thelwall & Sa'Adeddin, 1990) showed no differences between the Arabic dialects in this study and possible reasons for this outcome were discussed above. It is recommended when comparing dialects from different languages including Arabic, to increase the range of stimuli in order to make informed comparisons.

Finally, the study showed differences between sentences where the reading sentence had a higher mean F0 than the Quran sentences. In addition, results showed support for dialect differences where only Saudis had a lower mean F0 for words with initial voiced /d/ than words with initial voiceless /t/ stops, whereas no differences were found for Bahraini speakers between words with initial voiced and voiceless stops. For place of articulation and emphasis, no differences were found in mean F0 between place of articulation for voiced bilabial /b/ and alveolar /d/, as well as voiceless alveolar /t/ and velar /k/ stops. In addition, no differences in mean F0 were found between words with initial plain /t/ and emphatic /tˤ/.

Chapter 7. Formant Frequency

7.1 Introduction

In Chapter 6, fundamental frequency (F0) was examined, revealing differences between dialects only in words with initial voiced /b, d/, voiceless /t, k/, and voiced/voiceless /d, t/ where Saudis had a lower mean F0 than Bahraini speakers. Furthermore, sex-related differences showed that females had a higher mean F0 than males for the sustained phonation of the vowels, for vowels in words and sentences.

Formants are the resonant frequencies of the vocal tract (Fant, 1960). Formants result from the filtering effects of the supralaryngeal vocal tract and are measured in Hertz (Hz) with the lowest resonant frequency being F1 and increasing in frequencies such as F2 and F3 and so on.

In this chapter, formant frequencies will be examined to determine the dialect and sex-related differences in Arabic speakers from two dialects (Najdi and Bahraini).

Formant frequencies play a role in the assessment of voice by phoneticians and speech and language therapists and clinicians. Studies have established normative data for English and have shown differences between sexes where males have been shown to have lower formant frequencies than females (Peterson & Barney, 1952; Hillenbrand et al., 1995; Lee et al., 1999). Studies on Arabic are scarce (Alghamdi, 1998; Kotby et al., 2010; Natour et al., 2011; Amir et al., 2014), and studies on sex-related speaker differences in Arabic are even more scarce (Kotby et al., 2010; Natour et al., 2011; Amir et al., 2014). However, research on the effect of emphasis on formant frequencies has received more attention (Kahn, 1975; Card, 1983; Royal, 1985; Wahba, 1993; Al-Masri & Jongman, 2004; Bin-Muqbil, 2006; Khattab et al., 2006; Almbark, 2009; Al-Masri, 2009; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011). Although, F3 values were attempted to controlled by tracking errors and outliers (see §7.4.5), it is imperative to acknowledge that recordings were made in WMA format which might have an effect on F3 values (Schilling, 2013).

The structure of the chapter is as follows: first, a general section will present some key studies on formant frequencies, followed by studies on dialect differences in English and other languages. Studies on formant frequencies in Arabic will then be reviewed, followed by a presentation of the research questions and hypotheses. Finally, the methodology, results and discussion will be presented.

7.2 General information

As noted earlier, formant frequencies are dependent on the shape of the vocal tract. The most important formant frequencies are F1 and F2, in addition to F3 (Peterson & Barney, 1952; Baken & Orlikoff, 2000; Kent et al., 2002; Raphael et al., 2007; Ladefoged & Johnson, 2014).

There is general agreement from the above authors that F1 is related inversely to tongue height, whereas F2 is related conversely to tongue advancement and F3 is affected by lip rounding (Raphael et al., 2007) and the point of constriction within the pharynx (Klatt & Stevens, 1969). Lip rounding has a lowering effect on all formant frequencies depending on the level of rounding; F3 is relatively affected more by lip rounding. Furthermore, rhotacization entails an effect on the point of constriction posteriorly and therefore lowers F3 values (Raphael et al., 2007). This can be demonstrated by taking the example of the vowel /u/ which would typically show relatively low F1 of around 300 Hz, high F2 of around 870 Hz and low F3 around 2240 Hz; this indicates that the tongue dorsum is raised, pulling the bulk of the tongue out of the pharyngeal cavity which would enlarge the cavity, therefore making it resonate at a lower F1 frequency. In addition, the posterior constriction made by the tongue would allow it to resonate at a relatively lower F2 frequency compared to the vowel /i/ where the constriction is more anterior, which would result in a higher F2 frequency nearly around 2500 Hz while approximately an F1 value of 300 Hz. In addition, the protrusion of the lips (rounding) would elongate the length of the vocal tract for /u/ and thus lower all formant frequencies and particularly F3 as described earlier, while F3 for /i/ would have around 3000 Hz (Raphael et al., 2007). For the low vowel /a/, there is a small pharyngeal cavity which would resonate at a high F1 of around 730 Hz while the large oral cavity would generate a low F2 of nearly around 1090 Hz and would show an F3 value of nearly 2440 Hz. The values above are reflective of an adult male production of vowels (/a/,/i/,/u/) from Peterson & Barney (1952) as described by Raphael et al. (2007). Most often, the first two formants are represented in an F2/F1 plot for each vowel produced by a speaker, showing differences in the F1 and F2 coordinates. An example of such a plot is presented in Figure 7.1, the vertical and the horizontal axes represents this account of vowel quality based on Raphael et al. (2007) description and adapted to Arabic from a number of studies later described in §7.3.1.

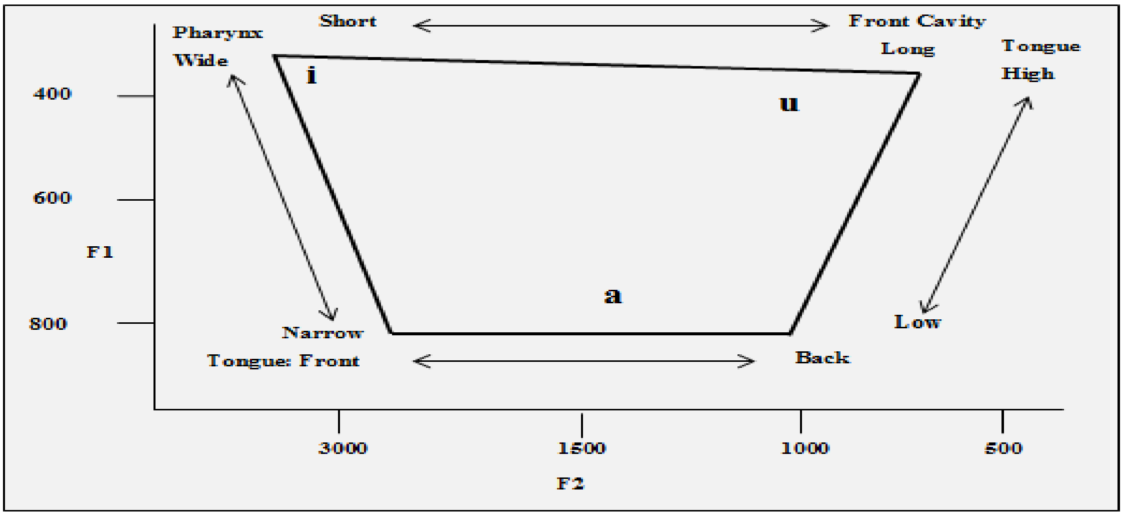


Figure 7.1: An example of an F2/F1 plot (Hz) representing the relationship among tongue position, cavity size and their relationship with formant frequencies in the Arabic vowels (/a, i, u/). Figure adapted to Arabic from Raphael et al. (2007, p. 106).

Peterson & Barney (1952) studied formant frequencies in General American English (GAE) in a sample of 33 males, 28 females and 15 children. Ten vowels were examined in the (hVd) syllable. The results showed that males had lower mean F1-F3 values than females and children due to anatomical differences: males have a longer vocal tract than females and children which lowers their formant frequency values. Each of the ten vowels in the study had different F1 and F2 values depending on the vowel, while there were also individual differences in the production between in the formant values of each vowel.

More recently, Hillenbrand et al. (1995) replicated Peterson & Barney's study (1952) in an attempt to control the dialect differences found in the original study. The results showed consistency in terms of the formant frequency differences related to anatomical differences between males, females and children. However, the study found differences in the low and mid-vowel formant frequencies compared to those in Peterson & Barney (1952). Hagiwara (1997), in a later study on speakers from southern California, found similarities in the vowel spaces studied to that found in Peterson & Barney (1952), therefore implying that similar dialects were focused on in both studies, while Hillenbrand et al.'s (1995) study was specific to data collected from northern Midwest American speakers.

Frequently /hVd/ is used in studies of formant frequencies while altering the vowel in order to control coarticulatory effects (e.g. Peterson & Barney, 1952; Hillenbrand et al., 1995; Hagiwara, 1997). However, a few studies have investigated coarticulatory effects in the presence of different consonants in initial position. Hillenbrand et al. (1997) examined American English in a sample of 12 participants (six males and six females aged 25-64 years old), focusing on consonants in different contexts in initial position (/h, b, d, g, p, t, k/), (although the consonant /h/ was not used in final position) and the eight medial vowels (/i, ɪ, ɛ, æ, ɑ, ʌ, ʊ, u/) in the analysis. In terms of voicing, vowels adjacent to initial voiced consonants showed a slight increase in F1 values. The results according to the place of articulation showed effects similar to those presented by Stevens and House (1963), where an initial labial consonant resulted in a slight decrease in the F1 values of the front vowels. Furthermore, in initial alveolar environments, back vowels showed an increase in F2 values, while in the environment of low vowels there was a slight increase in F2 values. Finally, back vowels in the environment of velar consonants showed a slight increase in F2 values. However, one of the limitations of this study is that a number of the participants were from different areas (e.g. Nebraska, Northern Ohio and upstate New York), therefore preventing generalizability of the results to some extent.

In another study, Strange et al. (2007) compared the effect of different phonetic contexts in Parisian French (PF), Northern German (NG) and American English (AE) vowels. The results varied between languages; however, the F1 and F2 values were shown to shift more in alveolar than in labial environments. In PF, the F2 values of the back and front vowels increased while the F1 values of the low and mid-low vowels slightly increased in alveolar environments. This was not as evident in NG where the F1 and F2 values increased slightly in alveolar environments. In AE, in alveolar environments, mid and high vowels had high F2 values but this was less observed in the case of mid-low and long vowels. Strange et al. (2007) commented that the coarticulatory effect on vowels is not a universal phonetic effect but a learned effect, which is exemplified in the results of their study. In the researcher's opinion, this shows that there is for need to further knowledge on different consonantal environments in speech stimuli utilising true words rather than the /hVd/ environment.

7.2.1 Dialect studies of formant frequencies in English, Spanish, Portuguese and Dutch

In this section, a review of some of the studies that have been conducted on dialect differences in vowel production in English (Purnell et al., 1999; Hagiwara, 2006) will be presented. Followed by dialect studies in other languages such as Spanish (Morrison & Escudero, 2007), Portuguese (Escudero et al., 2009) and Dutch (Adank et al., 2004).

In a study by Purnell et al. (1999) on three American varieties: African American Vernacular English (AAE), Chicano Hispanic English (CHE) and Standard American English (SAE). Phonetic experiment involved formant frequency measures which included F1 and F2 frequencies at the midpoint of vowel /ɛ/ in "hello". Amongst the tests, only the F2 values showed significant differences between the varieties of English, where AAE and CHE had different F2 values to SAE with a more fronted quality (higher F2). However, the post hoc analysis displayed no differences between the two varieties (AAE and CHE).

Hagiwara (2006) performed a preliminary study on the Winnipeg dialect in Canada on ten participants (five males and five females) aged between 18 and 35 years old. The study focused on 15 monophthongs and diphthongs embedded in /hVd/ and /hVt/ syllables in a carrier phrase. The results from this study were compared to his 1997 study on Southern Californian speakers and to those of Peterson & Barney (1952) using a customized normalisation technique used by Hagiwara (2006). Before discussing the results of Hagiwara (2006), normalisation techniques (Watt et al., 2011) are a number of different algorithms and methods that have been established by different researchers in order a) to eliminate anatomical and physiological differences between sexes b) to preserve vowel quality between sociolinguistic/dialectal/cross-linguistic differences c) preservation of phonological distinction between vowels and d) to perceptually identify normalized vowel by different speakers, for a review, see Watt et al. (2011). Returning to Hagiwara's study (2006), in a comparison of the speech of the GAE and Canadian speakers, the study revealed a merger of the low back vowels /ɔ/ and /ɑ/ in Canadian speech. Furthermore, there seemed to be relative fronting (high F2) for the following Canadian vowels (/u, ʊ, ʌ/) as well as a more open quality (high F1) for /æ/. However, these differences were similar to the findings in Hagiwara

(1997). In addition, raw data showed male speakers to have lower F1-F2 values than females on all vowels for all English dialects, although no statistical test were provided. Hagiwara (2006) concluded that the sample size in his study is too small to be able to generalise his results.

Morrison & Escudero (2007) conducted a study comparing Peninsular and Peruvian Spanish in a sample of 20 participants from each dialect (ten males and ten females) aged between 18 and 25 years old. The vowels assessed were /i,e,a,o,u/ produced in sentence-final position and were measured at different time points during the vowel. The results after normalisation showed that the only differences between the dialects were in F2 for vowel /o/ where Peninsular Spanish speakers produced higher values than Peruvian Spanish speakers while no interaction between gender and dialect emerged.

In a study on Portuguese, Escudero et al. (2009) compared European and Brazilian Portuguese, using a sample of 20 speakers of each dialect (10 males and females) who were reported to be young adults. The first vowel was analysed in a CVCV word embedded in a sentence, and the vowels compared in both dialects were /i,e,ɛ,a,ɔ,o,u/. As expected, males had lower formant frequencies than females for F1 and F2. The results showed that the only difference in formant frequencies between the dialects was in F1, where European Portuguese had higher F1 values for /ɛ/ than Brazilian Portuguese. However, the study used the median value in their comparison of formant frequencies between the Portuguese dialects compared to means commonly used in formant frequency studies. The use of median F1-F2 values is normal practice, however, providing mean F1-F2 would enable future comparisons with others studies in Portuguese.

In a study on Dutch, Adank et al. (2004) compared Northern and Southern Standard Dutch, using a sample of 40 participants (20 males and 20 females), with ten speakers being sampled from each variety. Fifteen vowels were analysed: 12 monophthongs (3 long vowels) and 3 diphthongs that were in a /sVs/ word embedded in a sentence. The results showed no differences in F1-F3 between the varieties of Dutch in the nine monophthong vowels; however, long vowels had higher F1 and F2 values in Northern Dutch than in Southern Standard Dutch. In addition, an interaction between sex and the Dutch varieties showed that only in the female sample did diphthongs have a higher F1 in Northern Dutch than in Southern Standard Dutch, whereas no differences were found between the varieties for the male Dutch speakers.

7.3 Studies on formant frequencies in Arabic

7.3.1 General Arabic studies

A few studies have been conducted that provide preliminary acoustic data on the formant frequencies of Arabic (Abou Haidar, 1994; Newman & Verhoeven, 2002; Alotaibi & Husain, 2009; Tsukada, 2009; Muhammad et al., 2011; Seddiq & Alotaibi, 2012). However, the majority of these studies have some limitations in their methodologies (see Table 7.1). For example, Abou Haidar (1994) in one of the earlier studies conducted on Arabic separated his participants in terms of their country of origin. However, there are extreme differences between each of the general Arabic dialects, as is demonstrated in the case of the Saudi dialect, described earlier (§2.3). Newman and Verhoeven (2002) analysed Quranic recitation from Egypt; as explained in Chapter 2, reciters adopt a different style which might have limited the generalizability of the results to extend to normal speakers. Alotaibi and Husain (2009) analysed Saudi dialects as well as Egyptian dialects and included a child in their participant sample. Tsukada (2009) analysed multiple dialects of Arabic with relatively low numbers of speakers. Muhammad et al. (2011) did not specify the dialects of their Arabic speakers and included a wide age range in their sample. Similar to Newman and Verhoeven (2002), Seddiq and Alotaibi (2012) employed Quranic recitation and did not specify the linguistic context. Furthermore, some of the studies (Alotaibi & Husain, 2009; Seddiq & Alotaibi, 2012) were directed towards speech perception and recognition with different algorithms being adopted; this might prevent the generalizability of the data. A number of Arabic studies with fewer limitations will now be reviewed in this section (Alghamdi, 1998; Kotby et al., 2010; Natour et al., 2011; Amir et al., 2014).

Study	Dialect	Number of Participants	Reason for exclusion
Abou Haidar (1994)	Qatar, Lebanon ,Saudi, Tunisian ,Syrian, Sudanese, Emiratese, and Jordanian	8	Multiple dialects
Newman & Verhoeven (2002)	Egyptian (Cairene)	1	Quranic recitations
Alotaibi & Husain (2009)	Saudi and Egyptian	10	Multiple Saudi dialects, inclusion of Egyptian and inclusion of one child
Tsukada (2009)	Lebanese, Egyptian and Saudi	(1, 1, 3) respectively, total of 5	Multiple dialects
Muhammad et al. (2011)	Multiple Arabic dialects	40	Multiple Arabic dialects (not specified), wide age range (18-50 years old) and the data did not specify sex, although it assumes males
Seddiq & Alotaibi (2012)	Egyptian, Saudi	3	Quranic recitations

Table 7.1: Limitations of formant frequency Arabic studies on (Abou Haidar, 1994; Newman & Verhoeven, 2002; Tsukada, 2009; Alotaibi & Husain, 2009; Seddiq & Alotaibi, 2012; AlMalki, et al., 2011).

Alghamdi (1998) compared Arabic dialects more systematically as well as focusing on Saudi Arabic participants. In his study, he compared vowels in C<u>V</u>C syllables in the speech of five Saudis, five Sudanese and five Egyptian males between the ages of 29-48 years old. The syllables contained the consonant /s/ in initial and final position, and the long vowels /a:, i:, u:/ in meaningful words, while syllables with the short vowels /a, i, u/ were in nonsense words. The F1-F3 results for the long vowels in all dialects can be seen in Table 7.2; the study found no differences between dialects for F3. There were significant differences in F1 and F2 between all of the dialects in the study and described as follows. Saudis produced a higher F1 for /u, u:, i:/ than Sudanese and Egyptian speakers. Furthermore, Egyptians produced a higher F1 for /i/ than Saudi and Sudanese speakers, while there were differences for /a/ between all of the dialects. For F2, only the production of /i/ by Sudanese speakers resulted in a higher F2 value than in the remaining dialects. A comment was made by the author that short vowels were more centralized than long vowels; however, significant differences between Arabic dialects were more apparent for short vowels than long vowels.

Furthermore, formant frequencies were dependent on vowel quality where F1 was highest in /a, a:/, while F2 was highest in /i, i:/ and lowest for /u, u:/ in all Arabic dialects. Similar to limitations realted to study of F0 (see§6.4.1), the participant sample had a wide age range while the Saudi informants were from two regions: the Najdi and the Southern region. Furthermore, the Sudanese and Egyptian participants had been living between 1-5 years in Saudi Arabia which might have affected their dialects. Furthermore, only male participants were included in the study and the sample size might be considered small.

Kotby et al. (2010) studied the Cairene Arabic dialect in 60 participants consisting of 30 males (22 -52 old) and 30 females (21- 42years old) and examined the short and their long vowel counterparts (/i, e, ɛ, ɑ, ɔ, u/) and the short vowel /ʊ/ embedded in words that were read out loud by the speakers. The F1 and F2 results for only the long vowels are presented in Table 7.2 and show that males had significantly lower F1 and F2 values than females for the short and long vowels /i, e/; however, only F2 was significantly different in the production of male and female speakers for the short and long vowel /ɛ/. In addition, the F1 and F2 values of the vowel /ʊ/ were significantly different in the speech of male and female speakers, while the values for the remaining short and long vowels (/ɑ, u ,ɔ/) showed no significant differences between male and female speakers.

The formant frequencies were dependent on vowel quality; however, this was examined for only short vowels. For males, there were significant differences in the F1 values between all vowels except between /e/ and /ɔ, u, ʊ/ and between /u/ and /ʊ/. In addition, significant differences in the F2 values were found between all vowels except between /i/ and /e/. Similarly, for the females in the sample, the F1 differences were due to vowel quality for all vowels except for the F1 value between /i, e/ and /ɔ, u/ as well as between /ɔ/ and /u/ and between /u/ and /ʊ/. There were differences in the F2 values between all vowels except between /i/ and /e/. From observing long vowels in Table 7.2, F1 and F2 values were depend on vowel quality where /a:/ had higher F1 values then remaining vowels while /i/ had the highest F2 values amongst the vowels. The authors did not offer an explanation for the differences that were not found between the male and female data.

Natour et al. (2011) performed a study on Jordanian Arabic, focusing on a sample of 200 participants (100 males, 100 females) aged between 18-24 years old. F1-F3 was investigated for sustained phonation in vowels (/ɑ:, i:, u:, a:, e:, o:/). The F1-F3 results for females and males are reported in Table 7.2 where males had statistically significant lower formant frequencies than females. The study did not offer statistical tests to differentiate F1-F3 values depending on vowel quality. However, when observing formant values in Table 7.2, it can be viewed that for both sexes that the low vowel /a:/ had the highest F1 value among the vowels while the higher front vowel /i:/ had the highest F2 in comparison with high back vowel /u:/ which had the lowest F2 values. One of the limitations as described by the authors was its use of sustained phonation of vowels in comparison with vowels produced in words alone or in sentences.

In a recent study conducted on dialects in Arabic, Amir et al. (2014) studied two Arabic dialects, using a sample of 40 participants for each dialect (20 males and 20 females). The first dialect is from the Galilei area (GD) and the second dialect is from the Muthallath (triangle) area (MD) in Israel. The age of the participants was restricted to young adults with a mean age of 24.63 years who were educated in both Arabic and Hebrew; however, the researchers restricted the study to Muslims only in order to avoid differences that may exist between different faiths, as described by Blanc (1964) in relation to Iraqi Arabic. The stimuli used in the study were 24 monosyllabic words and six disyllabic words with short and long vowels (/i, i:, e, e:, a, a:, o, o:, u, u:/) in carrier sentences. In addition, emphatic consonants in any word position were excluded from the study. The results for the F1- F2 formant frequencies of the long vowels are shown in Table 7.2 for both dialects. The results for the long vowels did not show significant differences between the GD and MD data for males and females. The results showed that there was a similar pattern in both dialects, with the two mid vowels (/e:, o:/) having lower F1 values than the low vowel /a:/. The MD data showed no statistical differences in vowel height between the two high vowels (/i:, u:/); however, /i:/ in the GD data had significantly lower F1 values than /u:/.

Furthermore, in terms of the front/back tongue position for long vowels, /i:/ was the most fronted while /u:/ was the most backed; of the remaining vowels, /e:/ was mid-front, while /a:, o:/ were mid-back vowels. For the short vowels, the MD data exhibited an overlap between /i/ and /e/ in both the male and female data; however, the GD data showed distinct /i/ and /e/ vowels. As described by the authors, formant centralisation is evident in the F1-F2 plane for both dialects; the MD data showed a shift in the vowel space than the GD data as a result of the overlap between the two vowels /i/ and /u/. This distinctive pattern was seen in the MD data for males and females, while the vowel space pattern for the male and female GD speakers was more symmetrical. Males had statistically significant lower formant frequencies for short and long vowels than females; however, as described by the researchers, the vowel space patterns were maintained in each dialect by both sexes. One of the limitations of the study was that some vowels were not matched in terms of the surrounding context; where words were used, different stimuli were used in the dialects for both monosyllabic and disyllabic forms (e.g. /f**eː**n/ “where” vs. /w**eː**n/ “where” and /ridʒel/ “leg” vs. /ʔidʒer/ “leg” (Amir et al., 2014, p. 1906)).

	Vowels		/aː/			/iː/			/uː/			/eː/			/ɔː/			/ɛː/			/oː/		
Study	Formants	Sex	F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3	F1	F2	F3
Alghamdi (1998)	Saudi	M	573	1537	2260	402	1841	2646	451	1302	2427												
		F	-	-	-	-	-	-	-	-	-												
	Sudanese	M	525	1564	2624	331	2066	2674	354	1308	2505	NA											
		F	-	-	-	-	-	-	-	-	-												
	General Egyptian	M	468	1505	2537	357	1749	2565	270	1285	2483												
		F	-	-	-	-	-	-	-	-	-												
Natour et al. (2010)	Jordanian	M	616	1427	2644	329	2167	2869	369	953	2502	452	1873	2610							470	1007	2562
		F	888	1947	3089	382	1970	2760	487	1402	2586	544	1879	2835							568	1311	2598
Kotby et al. (2011)	Cairene Egypt	M	611	1043	-	287	2202	-	241	857	-	356	2124	-	389	796	-	504	1838				
		F	666	1130	-	356	2662	-	269	876	-	425	2567	-	382	796	-	540	2320				
Amir et al. (2014)	Muthalath Daielct (MD)	M	591	1296	-	375	1931	-	391	1023		456	1779	-							479	1024	
		F	770	1541	-	456	2345	-	382	965	-	579	2116	-							588	1192	
	Galiliean Dialect (GD)	M	597	1270	-	361	2013	-	382	965	-	477	1754	-							481	1043	
		F	728	1593	-	411	2416	-	444	1086	-	533	2209	-							558	1163	

Table 7.2 Formant frequencies in Hertz (Hz) in Arabic studies (Alghamdi, 1998, pp. 8,12,16; Natour et al., 2011, pp. 79–80; Kotby et al., 2010, p. 174; Amir et al., 2014, p. 1898), Note: Formant Frequencies were rounded up in all Arabic studies reported.

7.3.2 Studies on formant frequencies in the emphatic context in Arabic

Interest in formant frequencies in the emphatic context has attracted much attention due to the nature of the secondary articulation. To reiterate, it can be described as a retracted tongue dorsum, resulting in a narrowing of the upper portion of the pharynx; this retraction is accompanied by a small retraction of the lower part of the anterior wall of the pharynx and the epiglottis (Bin-Muqbil, 2006), which would generally result in a lowering of F2 (Kahn, 1975; Card, 1983; Wahba, 1993; Al-Masri & Jongman, 2004; Bin-Muqbil, 2006; Khattab et al., 2006; Almbark, 2009; Al-Masri, 2009; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011). Furthermore, some studies have reported an increase in F1 when the vowel is adjacent to an emphatic consonant as the secondary articulation might involve the tongue position being raised (Al-Masri, 2009; Al-Masri & Jongman, 2004; Bin-Muqbil, 2006; Khattab et al., 2006; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011). This section will review the effect of emphasis on formant frequencies in Arabic dialects.

In one of the earliest studies that compared emphatics in dialects of Arabic acoustically, Kahn (1975) conducted two experiments; in the first, she examined four Cairene participants (two males and two females). The results showed that males exhibited more pharyngealization (lower F2 values) than females with plain /t/ and the emphatic stop /tˤ/. The second experiment involved 21 speakers of different dialects (Palestinian, Lebanese, Kuwaiti and Saudi) who were asked to utter a randomized list of words containing plain and emphatic stops. A trend appeared, where females showed more variation in emphasis correlates than males. In addition, the study showed differences between Cairene Egyptian and the different dialects in the second experiment, where Saudi females exhibited more emphasis (lower F2 values) than was apparent in the other dialects. Kahn (1975) suggested that pharyngealization is more associated with the norms of classical Arabic, thereby considering Saudi as being closest to classical Arabic. This study is one of the pioneering studies in the study of sociolinguistic variation in emphasis. In a further study of Cairene Arabic, Royal (1985) compared two social classes of Egyptian Arabic spoken by females: high class westernized Heliopolis and lower class Gamaliya. The results showed that females from the latter exhibited more pharyngealization in their F2 values than the former.

Card (1983) examined four male Palestinian Arabic participants where two were from an urban area and the remaining two were from a rural area. The stimuli in the study were nonsense and real words. A main result from the study was the lowering of F2 values in vowels adjacent to emphatics in comparison to the plain context, while the F1 and F3 values showed no significant changes in the emphatic context compared to the plain context. Furthermore, short and long low /æ/ and back /u/ vowels were affected more by lowering F2 values when adjacent to emphatics. With regards to the varieties of Palestinian Arabic, no differences were found between the two. The results were informed by a visual comparison of the data without using statistical tests.

Wahba (1993) provided results for Alexandrian Egyptian Arabic on eight vowels in minimal and near minimal pair monosyllabic and disyllabic words. Formant frequencies (F1-F2) were measured at two points (onset and mid-point). The results showed no differences between emphatic and plain contexts for F1, similar to the finding of Card (1983). However, F2 values were significantly lower in the emphatic context in comparison with the plain context at the vowel onset and mid-point for all participants. With regards to vowels, the low and back vowels showed more lowering of F2 when adjacent to emphatics than was the case for the remaining vowels.

Another dialect that has received attention is the Jordanian Arabic dialect. Al-Masri & Jongman (2004) focused on the northern Jordanian dialect (using a sample consisting of five males and three females), examining monosyllablic, disyllablic and trisyllablic minimal pair words. The study’s main focus was on emphasis spread in different word structures with a particular interest in F2 values between plain and emphatic contexts. The results showed a lowering of F2 values adjacent to vowels when compared to the plain context. Emphasis spread was blocked when adjacent to the vowels /i/ and /u/ to the right for emphatic stops; however, they had significantly lower F2 values than the plain contexts. Furthermore, emphasis in females had statistically lower F2 values than males.

A further study on Jordanian Arabic was conducted by Khattab et al. (2006) on a sample of ten participants (five males and two females were from Irbid, while the remaining three females were from Amman, the capital city of Jordan). The study was restricted to the alveolar emphatic /tˤ/ and plain /t/ stops. The vowels examined in the study were the short and long vowels /i, i:/ and /a, a:/. The results showed a significant effect of emphasis where F1 was higher while F2 was lower in both sexes than the plain /t/. However, females showed a lower significance level than males for F2 which showed a different pattern than was present in Al-Masri & Jongman's paper (2004). The authors attributed this to a single female Ammani who showed less emphasis than the male participants, as was found in similar studies (Kahn, 1975; Royal, 1985). Furthermore, Khattab et al. (2006) commented that the inclusion of non-words in the minimal pairs in Al-Masri & Jongman’s study (2004) might have induced a formal style of speech.

In a study on MSA on Arabic speakers from Saudi Arabia, Bin-Muqbil (2006) investigated a sample of five male speakers of the Najdi dialect. The stimuli were monosyllable and disyllable words that had the structure of CV and VC words where the emphatic /tˤ, sˤ, dˤ,ðˤ/, plain consonants /t,s,d,ð/ and gutturals /q,χ,ʁ,ħ,ʕ,h,ʔ/ with long vowels /i:,a:,u:/ were in the initial or final position. The emphatic /ðˤ/ was examined in the final position. The results for the CV context for /d,t,k,tˤ,s,sˤ/ in initial position are displayed in Table 7.3, which show clearly that F1-F2 for vowels at midpoint had higher F1 and lower F2 values when adjacent to emphatics than when adjacent to plain consonants. Furthermore, the effect of place and manner of articulation was assessed which revealed for F1 no significant effect for vowels /a:/ and /u/. However, significant differences for the vowel /i:/ between the alveolar voiceless stop /t/ and the alveolar voiceless fricative /s/ were reported. For F2, no significant differences were found between places of articulation for the vowels /a:,i:,u:/ between / t / and / k /, / t / and /d /, and /d / and / k/.

	Vowels			/a:/		/i:/		/u:/	
Study	F1-F2	Consonant		F1	F2	F1	F2	F1	F2
Bin-Muqbil (2006)	MSA Saudi Najdi	Alv. Vd. stop	/d/	688	1679	331	2293	370	920
		Alv. Vl. stop	/t/	730	1594	382	2386	378	960
		Velar. Vl. stop	/k/	737	1934	332	2309	402	868
		Alv.Vl. fricative	/s/	727	1610	321	2327	403	962
		Alv. Vd. Emph. Stop	/dˤ/	704	1094	362	2200	405	848
		Alv.Vl. Emph stop	/tˤ/	757	1179	360	2310	426	812
		Alv. Vl. Emph fricative	/sˤ/	751	1186	365	2249	421	895

Table 7.3 Results from Bin-Muqbil (2006) for F1 – F2 in (Hz) for vowels /a:,i:,u:/ at midpoint for 5 Saudi male speakers in plain stops /d, t/ and fricative /s/ and emphatic /dˤ, tˤ ,sˤ/ as well as the velar voiceless stop /k/. (Note[1]: Alv: alveolar, Vd: voiced, Vl : voiceless and Emph: emphatic), (Note[2] : results are reported as in the study).

In a different method of analysis, Embarki et al. (2007) used locus equations of F2 values at onset and at midpoint of vowels in MSA words vs. dialectal words in four Arabic dialects (Yemeni , Kuwaiti , Jordanian and Moroccan), with four male participants representing each dialect in VCV words. Results showed that locus equations were able to distinguish between pharyngealized and non pharyngealized. Furthermore, they were able to distinguish between MSA and dialects. In addition, they were able to classify the varieties of Arabic into Eastern (Yemeni, Kuwaiti and Jordanian) and Western (Moroccan).

Al-Masri (2009) conducted a study on urban Jordanian Arabic using a sample of eight participants (four males and four females). The stimuli used in the study were monosyllabic and bisyllabic words where emphatic /tˤ, sˤ, dˤ, ðˤ/ and plain /t, s, d, ð/ stops and fricatives were in initial, medial and final positions. Measurements for formant frequency were taken at the onset, middle and offset of the vowel. Monosyllabic and bisyllabic words with emphatic consonants all had a rise in the F1 value. For monosyllables, this was seen in all positions; however, it increased when the vowel was in the same syllable for bisyllabic words and to a lesser degree when the emphatic consonant was not in the same syllable. Monosyllabic and bisyllabic words with emphatic consonants had significantly lower F2 values. In monosyllabic words, the low vowel /a:/ had a lower F2 value at the midpoint of vowels, while the back vowel /u:/ showed the least effect from emphasis. In terms of F3, monosyllabic and bisyllabic words showed higher values when adjacent to emphatics rather than plain consonants. With respect to gender, male speakers showed more emphasis in F1 (higher F1 values) than females while an opposite trend appeared for F2 where females showed more emphasis (lowering of F2 values) than males. The author described the results as being in agreement with Khattab et al's (2006) suggestion that F1 might be an added acoustic cue for emphasis in addition to the lowering of F2. The results showed similarity with the results from Card (1983) in terms of the lower F2 values for low vowels and Wahba (1994) in terms of high back vowels being the least affected by the presence of emphatic consonants.

In another study on Jordanian Arabic, Abudalbuh (2010) recruited 22 participants (12 males and ten females) aged 19-23 years from the northern part of Jordan, as mentioned in §5.6.2. The study's main objective was to ascertain the effect of gender on emphasis among Jordanian speakers. Formant frequency measurements were performed at the onset, midpoint and offset of vowels. The results showed a high F1 in emphatic context at the onset and midpoint of vowels while there was a decrease in F2 throughout the vowel. However, there was an increase in F3 at the onset and offset of the vowels. Similar to previous studies (Card, 1983; Wahba, 1993; Al-Masri & Jongman, 2004; Khattab et al., 2006; Al-Masri, 2009), the low vowels /a, a:/ showed more lowering of F2 than the remaining vowels, while the high back vowel /u/ showed the highest F3 values amongst the vowels. Abudalbuh (2010) did not offer any statistical analysis comparing male and female production of plain and emphatic consonants. However, as observed in vowel spaces (Abudalbuh, 2010, pp. 37–39) males produced lower formant frequencies for all vowels (F1-F2) for the combined emphatic /tˤ, sˤ, dˤ, ðˤ/ and plain /t, s, d, ð/ consonants than females. After normalisation, the results showed no significant differences between male and female speakers for the F1 and F2 values measured at the vowel onset, midpoint and offset. Moreover, there were no gender differences for the F3 value of the vowel offset; however, there was a main effect of gender for F3 at the onset and midpoint of the vowels, where males had lower F3 values than females. For the interaction of emphasis with gender, the results showed an interaction for F1 and F2 at both the onset and midpoint of the vowels, where more emphasis was found for males (shown by a raising of F1 and lowering of F2). However, there was no interaction for F1 and F2 at the offset of the vowels, as well as there being no interaction for F3 at all points of the vowel.

Jongman et al. (2011) completed a study on 12 participants (six males and six females) of urban Jordanian Arabic from the city of Irbid. The stimuli used in their study were monosyllabic words and nonsense words with emphatic /tˤ, sˤ, dˤ, ðˤ/ and plain /t, s, d, ð/ consonants in initial and final position. Formant frequencies were measured at the onset, midpoint and offset of vowels. The results showed higher F1 and F3 values and lower F2 values in vowels adjacent to emphatic consonants compared to plain consonants. The results showed consistent formant frequency values regardless of whether the measurements were taken in initial or final position. The low vowel /æ:/ showed more effects from the presence of emphatics compared to other vowels, as described in previous studies (Card, 1983; Wahba, 1993; Al-Masri & Jongman, 2004; Khattab et al., 2006; Al-Masri, 2009; Abudalbuh, 2010). Similar results for Asseri dialect (tribe in Southern Saudi Arabia) (Shar & Ingram, 2010) were obtained for F1-F2 as well as the interaction of vowel quality with emphasis, utilizing the same emphatic and plain consonants. However, the voiced pharyngealized and plain consonants showed significant differences while no differences were seen between the voiceless plain and pharyngealized sounds.

In the Syrian Arabic dialect, Almbark (2009) compared two Syrian dialects, the Aleppian dialect spoken in Aleppo (North of Syria) and the Damascene dialect spoken in Damascus (South of Syria). She recruited four speakers (two males and two females) from each dialect and compared initial emphatic stops (/tˤ, dˤ/) and fricatives (/sˤ, ðˤ/) to their non-emphatic cognates (/t, d, s, ð/). Formant frequencies were measured at the onset of vowels. The results showed a lowering of F2 values as the acoustic correlate of emphasis. Females showed significantly lower F2 values than males after emphatic stops in both dialects. No statistical differences were found between the two dialects in the F2 values. However, Aleppo speakers had a greater tendency to show lower F2 values after emphatic consonants than Damascus speakers.

To summarize, studies on vowel formant frequencies in Arabic are scarce compared to those on other languages. Furthermore, even fewer studies have compared different dialects of Arabic. On the one hand, Alghamdi (1998) found differences in F1 and F2 values between Arabic dialects that might be considered dissimilar, such as Egyptian and Sudanese, which can be extended to showing a difference between the western dialects of Arabia in comparison to Saudi dialects. On the other hand, other studies have shown no differences between Syrian Arabic dialects for emphatics (Almbark, 2009) and no differences between Palestinian Arabic dialects (Amir et al., 2014) for vowels. Furthermore, methodological differences add to the complexity of comparing formant frequencies across studies, as seen in Table 7.2. For example, the formant frequencies in the Egyptian dialect as reported in Alghamdi's study (1998) are lower than those reported by Kotby et al. (2010). This might result from differences between Egyptian dialects or possibly due to methodological differences such as word choice or the method of analysis. However, having an awareness of the interaction between dialect and sex for emphatics might provide an understanding of the differences between dialects, as has been researched by Kahn (1975), Royal (1985) and Khattab et al. (2006). This will be elaborated on further below.

Studies on sex differences in Arabic for vowels in contexts other than emphatics are scarce; however, studies on Jordanian (Natour et al., 2011) and Palestinian Arabic (Amir et al., 2014) clearly showed males to have lower formant frequencies than females. Furthermore, this was seen in a number of vowels in Egyptian Arabic (Kotby et al., 2010); however, three vowels showed no differences between sexes and the authors provide no explanation for this – the reason for this may be due to dialect. As described above, emphasis is an interesting feature in Arabic, particularly due to its interaction with speaker sex, although emphasis has been unanimously correlated with a lowering of F2 in vowels in many studies (Kahn, 1975; Card, 1983; Royal, 1985; Wahba, 1993; Al-Masri & Jongman, 2004; Bin-Muqbil, 2006; Khattab et al., 2006; Al-Masri, 2009; Almbark, 2009; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011). Furthermore, most of the studies reported an increase in F1 values when the vowel under study is adjacent to emphatics (Al-Masri, 2009; Al-Masri & Jongman, 2004; Bin-Muqbil, 2006; Khattab et al., 2006; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011).

However, some sex-related linguistic differences have been found in Arabic dialects. For example, Khattab et al. (2006) found more emphasis to be present in the speech of males than females (shown by an increase of F1 and a lowering of F2), although not all females conformed to the patterns seen in Al-Masri & Jongman's study (2004). In a later study, Al-Masri (2009) showed males to have more effects of emphasis on F1 in contrast to F2; the latter formant showed more effects of emphasis in females than males. Therefore, the role of emphasis in vowels might shed some light onto the differences between dialects. In addition, studies on sex differences in the dialects of the Arabian Gulf are scarce as the focus has been predominantly on males in plain (Alghamdi, 1998) and in emphatic contexts (Bin-Muqbil, 2006; Shar & Ingram, 2010).

In terms of the vowel quality of Arabic vowels in plain words, F1-F3 showed similar patterns, where the F1 value was higher in the vowel /a/ and F2 was higher in the vowel /i/ while /u/ had the lowest F2 value amongst the vowles (Alghamdi, 1998; Kotby et al., 2010; Natour et al., 2011; Amir et al., 2014). In addition, /u:/ had the lowest F3 value amongst the vowels due to lip rounding (and protrusion), as has been discussed in a number of studies (Alghamdi, 1998; Natour et al., 2011). The interaction between vowels when preceded by emphatics will be elaborated on below.

To reiterate, the impact of emphasis on formant frequencies has been consistently shown to lower F2 values (Kahn, 1975; Card, 1983; Royal, 1985; Wahba, 1993; Al-Masri & Jongman, 2004; Bin-Muqbil, 2006; Khattab et al., 2006; Al-Masri, 2009; Almbark, 2009; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011). While F1 has been shown to increase in vowels when adjacent to emphatics (Al-Masri & Jongman, 2004; Bin-Muqbil, 2006; Khattab et al., 2006; Al-Masri, 2009; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011), F3 has been shown to increase in the context of emphasis (Al-Masri, 2009; Abudalbuh, 2010; Jongman et al., 2011). The effect of emphasis on vowels has been shown to have the greatest effect on the vowel /a/ (resulting in the lowering of F2) in the presence of an emphatic (Card, 1983; Wahba, 1993; Al-Masri & Jongman, 2004b; Khattab et al., 2006; Bin-Muqbil, 2006; Al-Masri, 2009; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011). Furthermore, emphasis spread showed similarities for Jordanian Arabic (Al-Masri & Jongman, 2004b; Abudalbuh, 2010) where F2 was blocked in high vowels while in Saudi Arabic emphasis spread was blocked by the high front vowel /i/ for both F1 and F2 (Bin-Muqbil, 2006). Although this might suggest dialectal differences in the effects of emphatics on vowels, it is difficult to ascertain in the absence of a consistent methodology.

Therefore, one of the main objectives in this study is to establish normative formant frequencies (F1-F3) for two dialects of Gulf Arabic (Najdi and Bahraini) as well as to explore differences between the Najdi and Bahraini Arabic dialects. In addition, the second research question will assess differences between male and female Arabic speakers, analysing the speech of a large number of male and female speakers from two dialects. In addition, the place of articulation, vowel quality and emphasis will be studied using stimuli which include the sustained vowels /a, i, u/ and vowels in the context of the voiced stops /b, d/, the voiceless stops /t, k/ and the emphatic /tˤ/. In the next section, the research questions and hypotheses of this study will be presented.

7.3.3 Research aim, questions and hypotheses

7.3.3.1 Research aim

To establish mean F1-F3 nomative data in different stimuli for male and female Saudi and barhaini speakers.

7.3.3.2 Research questions

7.3.3.2.1 Main research questions

1) Are there differences in mean formant frequencies (F1-F3) between the Najdi and Bahraini Arabic dialects?
2) Are there differences in mean formant frequencies (F1-F3) between the sexes in both Arabic dialects?

7.3.3.3 Mean formant frequencies (F1-F3) – specific questions

7.3.3.3.1 Sustained phonation

a) Are there differences in mean formant frequencies (F1-F3) between vowels – high /i:, u:/ versus low /a:/, and front /i:/ versus back /u:/?

7.3.2.1.1 Words

7.3.2.1.1.1 Plain stop context

a) Place of articulation: do stops in initial position with different places of articulation have an effect on formant frequencies (F1-F3) in vowels (initial voiced stops – bilabial /b/ versus alveolar /d/ and initial voiceless stops – alveolar /t/ versus velar /k/)?
b) Vowel context: Are there differences in mean formant frequencies (F1-F3) between vowels – high /i:,u:/ versus low,/a:/ and front /i:/ versus back /u:/ vowel?

7.3.2.1.1.2 Emphatic versus plain stops

a) Emphatic versus plain stops: are there differences in the mean formant frequencies (F1-F3) of vowels in words with an initial emphatic stop /tˤ/ and an initial plain alveolar stop /t/?
b) Vowel context: Is there an effect of vowel context on mean formant frequencies (F1-F3) between vowels – the front high vowel /i:/ versus the back high vowel /u:/?

7.3.4 Hypotheses

The results from Alghamdi (1998) suggest that there are slight differences between dialects of Arabic in the long vowels within words as well as differences between western Arabic dialects (Egyptian and Sudanese) and Eastern Arabic dialect (Saudi); however, the results from Syrian Arabic dialects (Almbark, 2009) and Palestinian Arabic dialects (Amir et al., 2014) showed no differences between dialects within the same region. Furthermore, Alghamdi's (1998) results might have been in effect from regionally different Arabic dialects, with Egyptian and Sudanese being geographically distant from the Saudi dialect in the study.

Given this argument, in addition to Bahraini and Najd having the same Bedouin origin (Bellem, 2008), the **first hypothesis** is that there are no differences in the mean formant frequencies (F1-F3) between Bahraini and Najdi Arabic dialects in vowels (/i, a, u/) in sustained phonation and long vowels (/i:, a:, u:/) in target words with initial voiced (/b, d/), voiceless (/t, k/) and plain/emphatic stops (/t, tˤ/).

Arabic studies on formant frequencies in vowels have shown that males have lower mean F1-F3 values in vowels than females (Khattab et al., 2006; Al-Masri, 2009; Kotby et al., 2010; Jongman et al., 2011; Natour et al., 2011; Amir et al., 2014). Therefore, taking into consideration the anatomical differences between males and females in the configuration of the vocal tract (Fant, 1960) as well as results from different studies on different languages (e.g. Peterson & Barney, 1952; Hillenbrand et al., 1995; Hagiwara, 1997; Adank et al., 2004; Escudero et al., 2009; Chládková et al., 2011), the **second hypothesis** is that males will consequently have lower mean F1-F3 values than females in the stimuli described above.

Studies on Arabic (Alghamdi, 1998; Kotby et al., 2010; Natour et al., 2011; Amir et al., 2014), as seen in Table 7.2 , presented different formant frequencies depending on the vowel quality where, for example, /a/ had a more open quality indicating a high F1 value while the F2 value for /a/ was between the highest value of /i/ and the lowest value of /u/. In addition, the F3 values were the lowest for the vowel /u/ (Alghamdi, 1998; Natour et al., 2011). In addition, as described earlier in §7.2 in relation to the different positioning of the tongue subsequently resulting in different formant frequencies (Peterson & Barney, 1952; Baken & Orlikoff, 2000; Kent et al., 2002; Raphael et al., 2007; Ladefoged & Johnson, 2014), the **third hypothesis** is that for the vowels /i, a, u/ in sustained phonation and in words in a plain context, the F1 value will be the highest for the vowel /a/ while the F2 value will be higher for the vowel /i/ and lower for the vowel /u/. Furthermore, the vowel /u/ will have the lowest F3 value amongst the values in the stimuli described earlier.

In terms of the effect of the place and manner of articulation on formant frequencies in Arabic, to the knowledge of the researcher only Bin-Muqbil (2006) has compared the place and manner of articulation; this study revealed differences in the F1 value of the vowel /i:/ between the alveolar voiceless stop /t/ and the alveolar voiceless fricative /s/. Furthermore, Strange et al. (2007) commented that rather than being universal, coarticulation is learned as demonstrated in their study of NG, PF and AE. Therefore, the **fourth hypothesis** is that the place of articulation will not have an effect on the mean F1-F3 formant frequencies of the vowels /i:, a:, u:/ in words with initial voiced labial and alveolar stops (/b, d/) and voiceless alveolar and velar stops (/t, k/).

The Arabic studies unanimously showed a decrease in F2 when the vowels were adjacent to emphatics rather than plain consonants (Kahn, 1975; Card, 1983; Royal, 1985; Wahba, 1993; Al-Masri & Jongman, 2004; Bin-Muqbil, 2006; Khattab et al., 2006; Al-Masri, 2009; Almbark, 2009; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011). Furthermore, the majority of studies showed an increase in F1 when the vowels were adjacent to emphatics rather than plain consonants (Al-Masri & Jongman, 2004; Bin-Muqbil, 2006; Khattab et al., 2006; Al-Masri, 2009; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011). However, few studies included F3 in their analysis; those that did found an increase in F3 when the vowels were adjacent to emphatics rather than plain consonants (Al-Masri, 2009; Abudalbuh, 2010; Jongman et al., 2011), with the exception of Card (1983) who found no differences in F3 values in vowels between plain and emphatic consonants. Bin-Muqbil (2006) and Shar and Ingram (2010) were the only studies on Saudi dialects which found an increase in F1 and a decrease in F2 in the presence of a neighbouring emphatic. In addition, results from studies on F3 are from the Jordanian dialect, which is in close proximity to the Saudi dialect. Therefore, the **fifth hypothesis** is that when vowels are adjacent to the emphatic stop /tˤ/, there will be an increase in F1 and F3 and a lowering of F2 compared to when the vowels are adjacent to the plain stop /t/.

7.4 Methods

7.4.1 Formant Frequency Acoustic Analysis

The fourth aim of this study was to measure formant frequencies (F1–F3) in Hz in the vowels of Arabic speakers and to explore the differences between speech characteristics from two Arabic dialects: Saudi Najdi (spoken in the central region of Saudi Arabia) and Bahraini (primarily spoken by Bahraini Arabs in the islands of the Kingdom of Bahrain). An additional aim was to explore the sex differences in formant frequencies. The stimuli used in the formant frequency analysis were identical to those for the analysis of fundamental frequency (see §6.6.2.1) with the exception of sentences that were not present in this analysis.

7.4.2 Stimuli and Procedure

7.4.2.1 Sustained phonation and words

The procedure for eliciting sustained phonation of vowels /a,i,u/ was previously described in §3.3.3.2. In addition, medial vowels in monosyllabic minimal pair words were presented in §3.3.3.3 in Table 3.3. The three long vowels /a:,i:,u/ were assessed in words with initial voiced stops while the two high vowels /i:,u:/ were assessed in words with initial voiceless plain and emphatic stops.

7.4.3 Preparation for Acoustical Analysis

7.4.3.1 Sustained phonation and words

Preparation for acoustic analysis for sustained phonation stimuli and words were previously described in §3.4.3.2, §3.4.3.3, respectively.

7.4.4 Acoustic Analysis

Formant frequency measurements were performed following the recommendations of Boersma & Weenink (2013); the text grid based methodology included identifying and annotating the boundaries of the vowels formant frequency, which is identified visually on the spectrograms and waveforms of all parts of each of the speech samples. The formants were generated using the Burg algorithm in Praat. Bhore & Shah (2015) have showed that the burg algorithm believed that is more accurate than Cepstral and Liner Predication based cepstral (LPCC) techniques. Although this same principle was used in different contexts (i.e., sustained vowel vs. words), different annotation methods were utilised to capture formant frequencies, which will be explained in the following sections.

Following the labelling of the sound files, all analysis for formants used Praat (Boersma & Weenink, 2013). A script (available in Appendix 3.5) written by Pauline Welby (2002) was modified by the researcher so it would upload sound files in WAV format from the folder. It would then open the text grid corresponding to their WAV information for the word lists and close after the marking had been done. It would then open the next file for formant stimuli within the same folder for marking, and so on. The labelling and annotation were performed on the second tier labelled 2 for sustained vowels and t2 for vowels in words, as the scripts later described in (§7.4.4.1 and §7.4.4.2) would analyse this specific tier.

For sustained phonation, each participant produced the three vowels (a, i, u) meaning the total (3 × 80) number of sustained vowels would be 240. All of the participants produced all of the vowels correctly.

For words, each participant repeated the 12 words twice; there were 80 participants (12 × 2 × 80), meaning that 1920 words were produced. Because of distortion and background noise, only 1845 words were analysed; therefore, 75 words or 3.91% were excluded from analysis, the remaining 1845 analysed words represented 96.1% of the total words produced. All participants from both dialects (Bahraini and Saudi) and gender (male and female) were represented in the analysis.

7.4.4.1 Sustained vowels

The annotation procedure for sustained phonation was to exclude the first two seconds to avoid the effect of onset, as suggested by Zraick et al. (2006), and the first boundary was set at that point. The second boundary was placed after five seconds. For each of the vowels, an annotation of the vowel produced was made for use in later analysis, as the script would include the annotation with an example in Figure 7.2. In her analysis of vowel formants, Syrdal (1996) chose between five and seven seconds from the vowel; however, in this study only five seconds was used in the analysis.

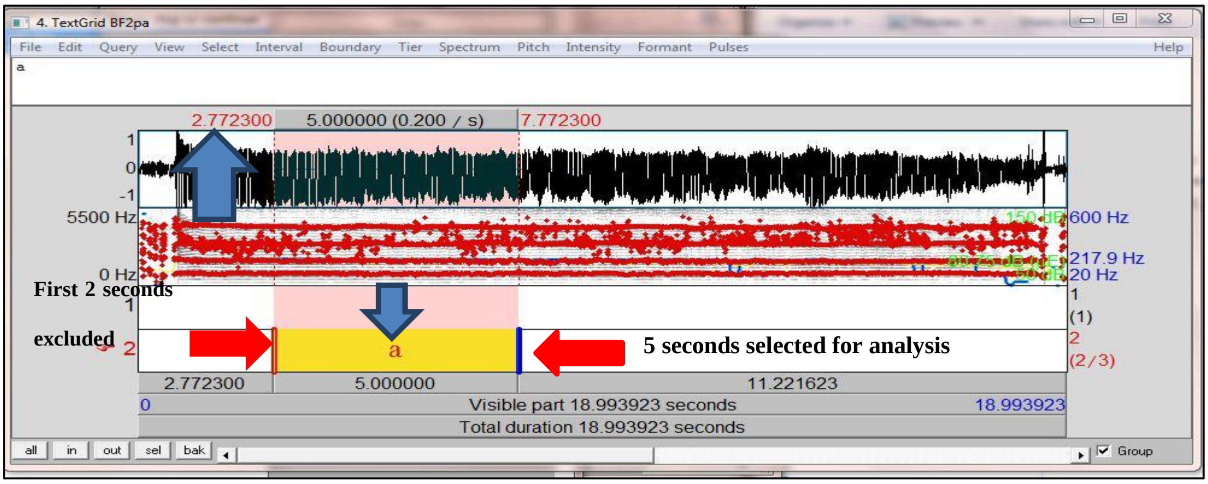


Figure 7.2 An example of annotation and marking boundaries in vowel /a/, where the first two seconds were excluded before setting the first boundary and the second boundary is set after five seconds.

7.4.4.2 Words

For each word, the placement of boundaries was done manually by identifying the beginning of the first trace of the first formants and the beginning of the periodic waveform for the vowel where the first boundary was set. The second boundary was set at the end of the analysis with an example in Figure 7.3.

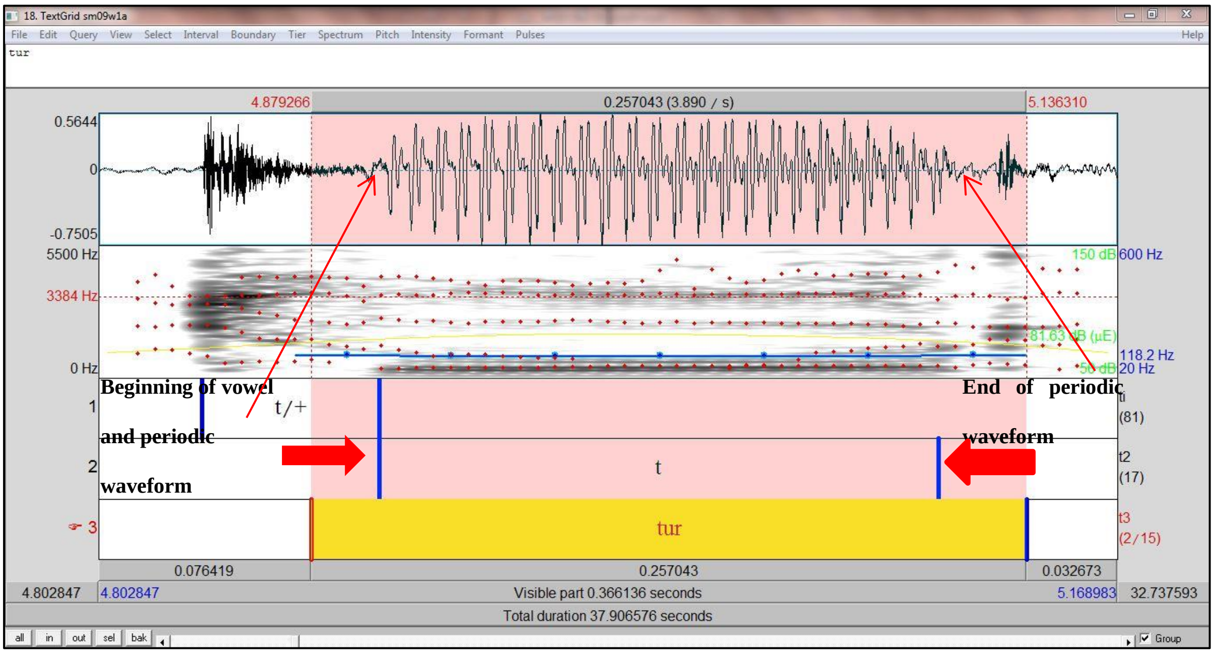


Figure 7.3 An example of annotation and marking the boundaries for the word /tur/, where the first boundary is at the beginning of voicing and the second at the end of the voicing.

7.4.5 Analysis and Transfer

After marking the boundaries and annotation using the methods described above, all of the sound files were stored. The audio files were stored as WAV sound files, while the annotated files were stored as Praat (Boersma and Weenink, 2012) files, in the same directory. The Praat script, used for analysis and extracting the formants (F1–F3) in Hertz, was written by Lennes (2003), (Appendix 7.1). It used the Burg algorithm; all tracks were generated using a 0.025 ms window length, 50 Hz pre-emphasis and were adjusted to the sex of the participants, where males were 5000 Hz while females were 5500 Hz.The output of the script was then transferred to an Excel (2010) spreadsheet. The results for all of the participants were then compiled into one Excel spreadsheet, which was then transferred to the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL) version 19 for statistical analysis.

Box plots were generated for F1-F3 values for vowels in all stimuli in order to detect outliers. If present, visual inspection of the spectrogram and manual detection of the formants were analysed. The corrected formant values would replace the outlier values. After visual and manual outlier check, statistical analysis would be performed.

7.4.6 Reliability

7.4.6.1 Inter-rater reliability:

Since the task of annotating vowel periodic waveform is a manual task that is undertaken by a single researcher, a degree of error can be made. Therefore, to ensure optimum reliability, an independent speech and language pathologist, who was familiar with the acoustic analysis process, repeated the text grid method analysis. The annotation of the text grids for these samples were then acoustically processed by Praat (Boersma and Weenink, 2013).

For sustained phonation of the three vowels, 8 participants were randomly selected (2 Bahraini females, 2 Saudi females, 2 Saudi males and 2 Bahraini males). The number selected (3 × 8) meant 24 productions from the total of 240 for all participants were analysed by the independent rater, which is 10% of the total number of productions.

For the formant frequency analysis representing words, 11 participants were randomly selected (5 Bahraini females, 2 Saudi females, 2 Saudi males and 2 Bahraini males). There were 251 words for these participants, excluding 13 from the total 264 words, meaning the percent of words selected from 1845 words selected is 13.60% from the total analysed words.

The outcomes in formants (Hertz) were then transferred to test for inter-rater reliability, where the results from both markers were compared. The results for all participants were then compiled into one Excel spreadsheet, which was transferred to the Statistical Package for the Social Sciences (SPSS, Inc., Chicago, IL) version 19 for statistical analysis.

7.4.6.2 Intra-rater reliability:

To further assess intra-rater reliability, at least seven months later, the researcher conducted a second marking of formants for the randomly selected sample as described above, thereby comparing the first set of ratings with those obtained during the second period.

7.4.6.3 Results

Pearson correlation coefficients were calculated as shown in the Table 7.4 for the inter – rater and intra – rater reliability measurements.

Formants	**Inter-rater Reliability**		**Intra-rater Reliability**	
	Sustained phonation	**Words**	**Sustained phonation**	**Words**
F1 (Hz)	r = 1.00, n = 24, p < .001	r = .997, n = 251, p < .001	r = 1.00, n = 24, p < .001	r = .1.00, n = 251, p < .001
F2 (Hz)	r = .998, n = 24, p < .001	r = .983, n = 251, p < .001	r = .1.00, n = 24, p < .001	r = .989, n = 251, p < .001
F3 (Hz)	r = 1.00, n = 24, p < .001	r = .978, n =251, p < .001	r = .999, n = 24, p < .001	r = .996, n = 251, p < .001

Table 7.4 Pearson correlation coefficient for formant frequencies (F1-F3) in Hz for inter-and intra-rater reliability in sustained phonation and in words for 11 participants.

The inter-rater reliability level was used to assess the reliability of the F1-F3 measurements in sustained phonation, and for vowels embedded in words. There was a strong correlation between the measurements taken by a colleague in the sustained phonation data for F1 ($r = 1.00$, $n = 24$, $p < .001$), F2 ($r = .998$, $n = 24$, $p < .001$) and F3 ($r = 1.00$, $n = 24$, $p < .001$), and in the data containing vowels in words for F1 ($r = .997$, $n = 251$, $p < .001$), F2 ($r = .983$, $n = 251$, $p < .001$) and F3 ($r = .978$, $n = 251$, $p < .001$). In addition, the second measurements (intra-rater reliability) were taken at a later date in the sustained phonation data for F1 ($r = 1.00$, $n = 24$, $p < .001$), F2 ($r = 1.00$, $n = 24$, $p < .001$) and F3 ($r = .999$, $n = 24$, $p < .001$) and in vowels embedded in words for F1 ($r = 1.00$, $n = 251$, $p < .001$), F2 ($r = .989$, $n = 251$, $p < .001$) and F3 ($r = .996$, $n = 251$, $p < .001$). Overall, there was a strong positive correlation between the measurements, revealing a high level of reliability for the acoustic analysis of F1-F3 (Hz) in the sustained phonation data, and in the data containing vowels in words.

7.4.7 Design and data analysis

This study's primary aim was to establish normative mean F1-F3 data for Saudi and Bahraini male and female speakers. In addition, to answer two main research questions. First, to determine whether differences exist between the two dialects of Arabic—Najdi and Bahraini—and, second, whether differences exist between sexes (male and female) in the speakers of these two dialects. In addition, the study was designed to examine formant frequency (F1-F3) in vowels /a,i,u/ in sustained phonation and vowels /a:,i:,u:/ in words with initial voiced bilabial/alveolar /b,d/ voiceless alveolar/velar (/t, k/) stops in CV:C Arabic words. Also, an emphatic voiceless stop /tˤ/ was added to examine the effect of emphasis on formant frequencies (F1-F3). Statistical analysis were performed in a series of analysis where dialect and sex were the between subject factors, while the within subject factors were the effects of place of articulation and vowel quality. The results section will be presented for sustained phonation of vowels /a,i,u/ and words with initial voiced /b,d/, voiceless /t,k/, and plain/emphatic stops /t,tˤ/.

7.5 Results

7.5.1 Sustained phonation of vowels /a,i,u/

Results for mean formant frequencies (F1-F3 in Hertz) for sustained phonation of vowels /a,i,u/ are presented in Table 7.5 as a function of dialect and gender.

A mixed-model ANOVA where vowels /a,i,u/ were the repeated measures was conducted with mean formant frequencies (F1-F3) as the measures of analysis in the model, while dialect and sex were the between subjects factors. Note that, in the following ANOVA and in other ANOVAs reported in the results section, in cases in which Mauchly's test of sphericity was violated, Greenhouse-Geisser estimates were used, since these are considered to be the most conservative.

			/a/			/i/			/u/		
			F1	F2	F3	F1	F2	F3	F1	F2	F3
Sex	Dialect	N	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)
Male	Saudi	20	611.69 (50.34)	1393.33 (92.84)	2635.13 (167.89)	342.10 (31.45)	2307.64 (176.07)	2788.80 (145.09)	392.28 (35.04)	875.90 (206.45)	2566.08 (188.42)
	Bahraini	20	630.02 (66.33)	1456.56 (87.86)	2681.76 (166.88)	343.83 (34.41)	2263.14 (106.73)	2760.17 (175.18)	412.70 (73.89)	984.43 (250.84)	2587.06 (258.92)
	Total	40	620.85 (58.86)	1424.94 (94.79)	2658.44 (166.90)	342.96 (32.55)	2285.39 (145.46)	2774.49 (159.43)	402.49 (58.01)	930.17 (233.32)	2576.57 (223.76)
Female	Saudi	20	789.05 (68.04)	1540.34 (178.06)	2920.16 (195.87)	424.21 (41.65)	2642.88 (249.00)	3159.40 (126.57)	460.55 (30.48)	1070.80 (161.50)	2768.70 (266.81)
	Bahraini	20	699.61 (74.82)	1629.16 (144.01)	3051.67 (179.82)	419.48 (59.50)	2414.96 (342.85)	3011.61 (188.27)	483.02 (55.02)	1485.34 (533.49)	2996.95 (313.45)
	Total	40	744.33 (83.86)	1584.75 (166.05)	2985.92 (197.18)	421.85 (50.75)	2528.92 (317.48)	3085.50 (175.14)	471.78 (45.35)	1278.07 (442.07)	2882.82 (309.69)
Total	Saudi	40	700.37 (107.50)	1466.84 (158.70)	2777.65 (230.77)	383.16 (55.28)	2475.26 (272.26)	2974.10 (230.82)	426.41 (47.39)	973.35 (207.87)	2667.39 (250.01)
	Bahraini	40	664.82 (78.18)	1542.86 (146.64)	2866.71 (253.78)	381.65 (61.39)	2339.05 (262.16)	2885.89 (220.07)	447.86 (73.50)	1234.89 (483.37)	2792.01 (351.57)
	Total	80	682.59 (95.09)	1504.85 (156.57)	2822.18 (245.14)	382.41 (58.05)	2407.15 (274.26)	2930.00 (228.43)	437.14 (62.39)	1104.12 (392.42)	2729.70 (309.53)

Table 7.5 Mean formant frequency values (F1-F3) in Hz and standard deviation values for the sustained phonation of vowels /a,i,u/ for male and female Saudi and Bahraini speakers.

7.5.1.1 Dialect and sex

Univariate tests for dialect showed no significant effects for all formant frequencies (F1-F3) ($p>.05$), as seen in Table 7.6.

Between subjects	Dialect			Sex			Dialect and sex		
Formant	*df*	F	p	*df*	F	p	*df*	F	p
F1	1,76	2.416	0.124	1,76	28.466	0.001*	1,76	0.019	0.89
F2	1,76	3.228	0.076	1,76	81.862	0.001*	1,76	3.911	0.052
F3	1,76	0.207	0.65	1,76	104.426	0.001*	1,76	3.633	0.06

Table 7.6 Results for univariate tests for formant frequencies (F1-F3) for between-subject factors (dialect, sex and interaction between sex and dialect); * denotes significance.

Univariate tests revealed a significant effect of sex for F1 ($p<.001$), F2 ($p<.001$) and F3 ($p<.001$), as shown in Table 7.6. Post hoc Bonferroni tests showed significant differences ($p<.001$) for all formant frequencies (F1-F3), such that males had lower values for F1 (459.71 Hz), F2 (1576.33 Hz) and F3 (2683.48 Hz) than females did for F1 (564.64 Hz), F2 (11816.66Hz) and F3 (3002.15 Hz), see

Figure 7.4.

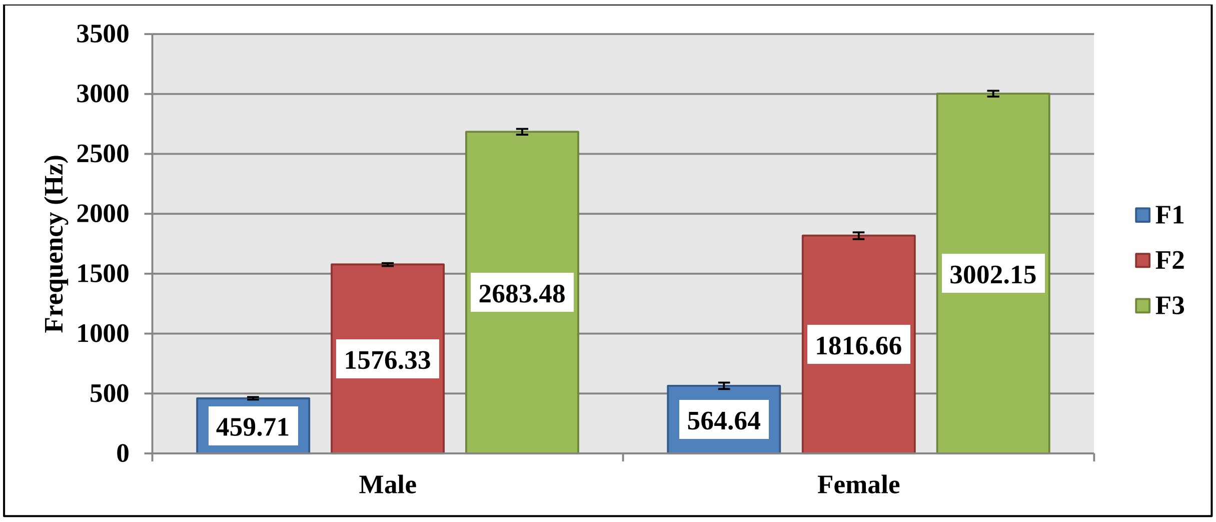


Figure 7.4 Mean ± S.E. formant frequencies (F1-F3) in Hz for male and female Arabic speakers.

However, for all formant frequencies, there was no significant interaction between sex and dialect ($p > .05$).

7.5.1.2 Effect of vowel context

Univariate results for each formant frequency (F1-F3) for within-subject vowel context and for the interaction between place and vowel are shown in Table 7.7.

With regard to vowels, a significant effect of vowels on F1 frequencies was observed ($p<.001$), (see Table 7.7). Post hoc Bonferroni tests showed no significant differences for F1 between /i/ (399.24 Hz) and /u/ (447.38 Hz) ($p= .77$). However, /i/ (399.24 Hz) and /u/ (447.38 Hz) had significantly lower F1 values than /a/ (689.90 Hz) ($p < .001$) (Figure 7.5 (a,b,c)).

In addition, vowels had a significant effect on F2 ($p < .05$) (see Table 7.7). Post hoc Bonferroni tests showed differences across all vowels, such that F2 was highest for /i/ (2405.20 Hz), and F2 values for /a/ (1518.98Hz) and /u/ (1165.30 Hz) were lower ($p<.001$), (see Figure 7.5 (a,b,c)).

Furthermore, vowels had a significant effect on F3 ($p<.001$) (see Table 7.7). Post hoc Bonferroni tests showed no significant differences in F3 values between /a/ (2833.05Hz) and /u/ (2742.12 Hz) ($p=.61$), both of which were significantly lower than the F3 value for /i:/ (2952.86 Hz) ($p<.001$) (See Figure 7.5 (a)).

In Figure 7.5 (c) , it is clear that /i/ had a more distinct vowel area than /a/ and /u/, and overlapping can be observed between the ellipses for /u/ and /a/. This overlap is observed in the individual productions of the vowels. In terms of dispersion, /u/ productions for all Arabic speakers showed more dispersion than productions of /i/ and /u/.

Within subjects	Vowels			Vowels and dialect			Vowels and sex			Vowels, sex and dialect		
Formants	*df*	F	p	*df*	F	p	*df*	F	p	*df*	F	p
F1	1.32,100.47[1]	129.38	0.001*	1.32,100.47[1]	1.363	0.254	1.32,100.47[1]	0.498	0.533	1.32,100.47[1]	2.987	0.075
F2	1.49,113.55[1]	345.39	0.001*	1.49,113.55[1]	6.534	0.005*	1.49,113.55[1]	2.351	0.114	1.49,113.55[1]	1.704	0.193
F3	1.84,140.47[1]	17.74	0.001*	1.84,140.47[1]	4.802	0.011*	1.84,140.47[1]	0.425	0.639	1.84,140.47[1]	1.637	0.2

Table 7.7 Results of univariate tests for formant frequencies (F1-F3) for vowel context for the sustained phonation /a,i,u/ as it interacts with sex, dialect and sex and dialect; * denotes significance, and [1] denotes the use of Greenhouse-Geisser estimates (due to a violation of sphericity).

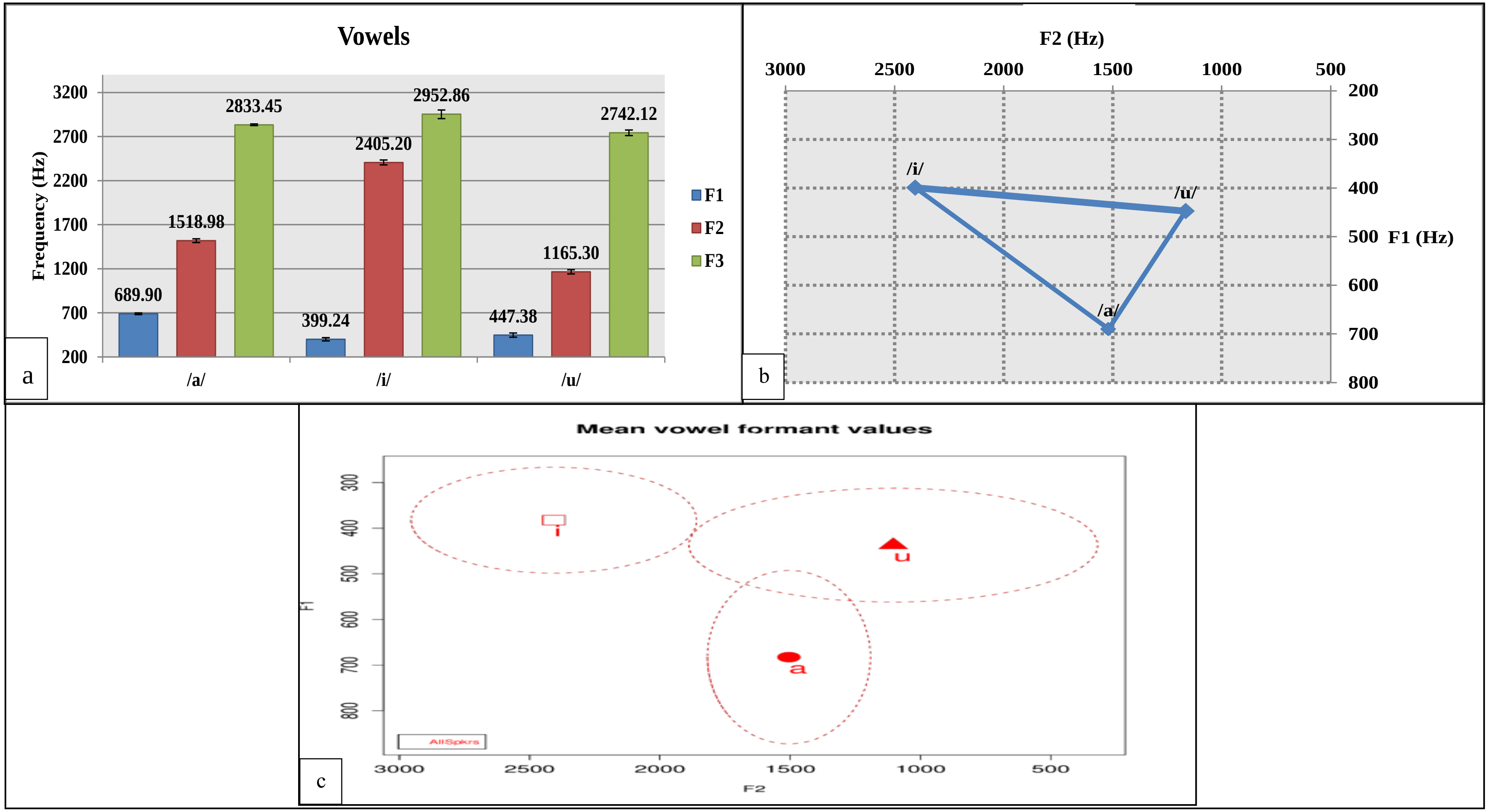


Figure 7.5 a) Mean ± S.E. for mean formants (F1-F3) in Hz for sustained vowels (/a,i,u/) for words with collapsed sex and dialect for Arabic speakers; b) Vowel spaces for Arabic speakers; c) Vowel centroids for vowels (/a,i,u/) for Arabic speakers, with ellipses representing two standard deviations from the group mean.

The results showed no significant interaction between vowels and dialect for F1 ($p = 0.254$) (see Table 7.7). For F2, there was a significant interaction between vowels and dialect ($p<.001$) (see Table 7.7). As can be seen in Figure 7.4, Saudis exhibited lower F2 values for /a/ (1479.56 Hz) and /u/ (1048.77 Hz) than Bahrainis (1558.40 Hz and 1281.53 Hz for /a/ and /u/, respectively). Meanwhile, Saudis showed higher F2 values in Hz for /i/ (2463.96 Hz) than Bahrainis (2346.44 Hz), (see Figure 7.6 (a,b,c)).

For F3, there was significant interaction between vowels and dialect ($p < .05$) (see Table 7.3). As can be seen in Figure 7.4, Saudis exhibited lower F3 values for /a/ (2796.4 Hz) and /u/ (2677.18 Hz) than Bahrainis (2870.43 Hz and 2807.06 Hz for /a/ and /u/, respectively). Meanwhile, Saudis showed higher F3 values for /i/ (2993.98 Hz) than Bahrainis (2911.74 Hz), (see Figure 7.6 (a)).

Figures Figure 7.6 (a,b,c) illustrate that /i/ had a more distinct vowel space than /a/ and /u/ for both Saudis and Bahrainis. For Bahrainis, /u/ overlapped with Saudi and Bahraini /i/ productions, suggesting greater dispersion. In contrast, Saudi production of /a/ showed more dispersion than Bahraini /a/ production. In addition, overlap between Saudi and Bahraini productions for all vowels.

From Table 7.7, it is clear that there is no significant interaction between vowels and sex for F1, F2 or F3 ($p>.05$). In addition, no significant interaction among vowels, dialect and sex for F1, F2 or F3 ($p>.05$).

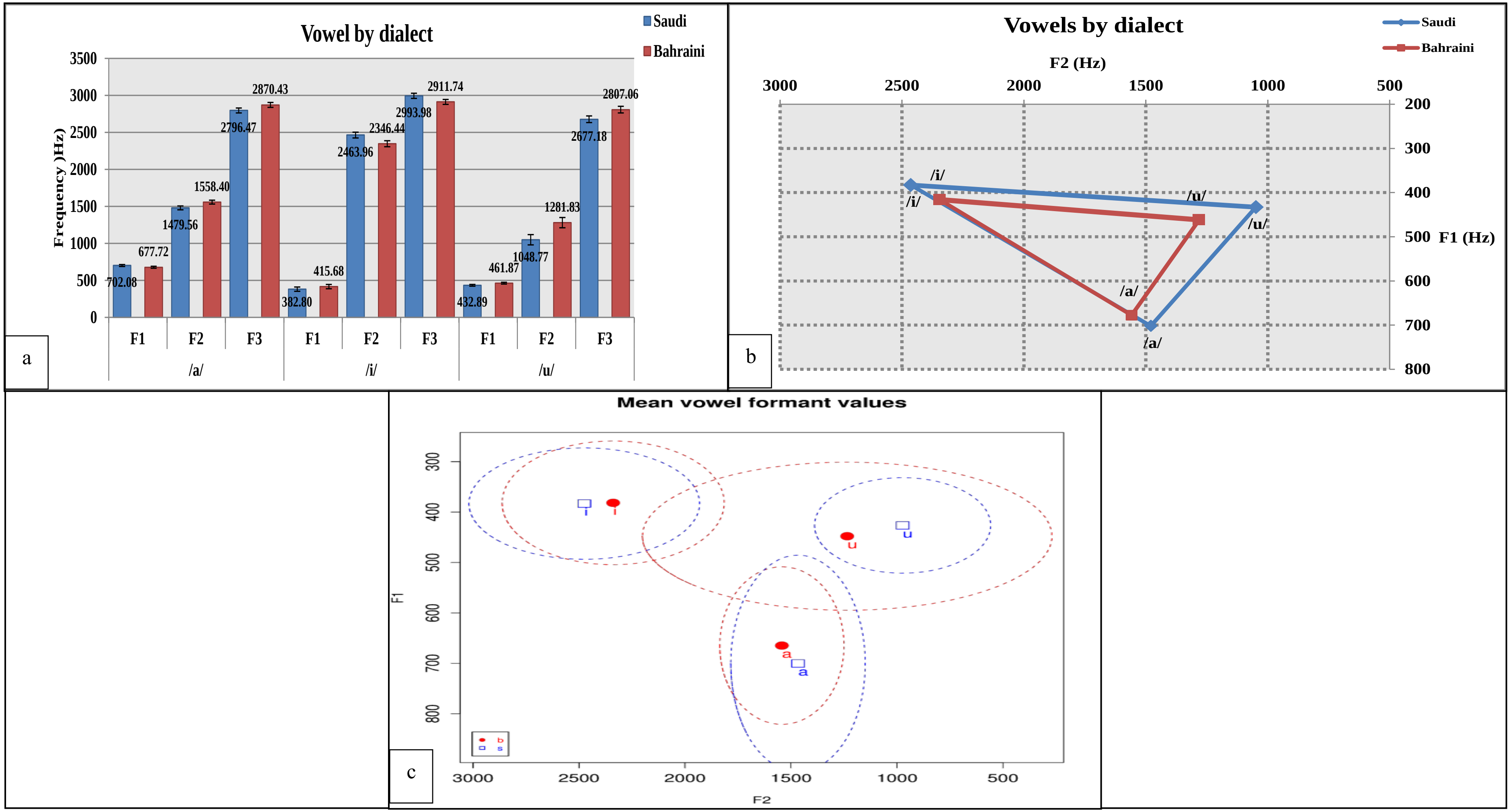


Figure 7.6 a) Mean ± S.E. for mean formants (F1-F3) in Hz for sustained vowels (a,i,u) between 40 Saudi and 40 Bahraini Arabic speakers (vowels split by dialect); b) Vowel spaces for 40 Saudi and 40 Bahraini Arabic speakers; c) Vowel centroids for vowels /a,i,u/ for 40 Saudi and 40 Bahraini Arabic speakers, with ellipses representing two standard deviations from the group mean.

7.5.2 Voiced stops /b,d/

The results for the mean formant frequencies (F1-F3 in Hertz) for three vowel contexts /a:,i:,u:/ for words with initial voiced stops (bilabial /b/ vs. alveolar /d/) are presented in table 7.4 as a function of dialect and gender. Word contexts were as follows: (/ba:r/, /bi:r/, /bu:r/) × (/da:r/, /di:r/, /du:r/).

				/a:/			/i:/			/u:/		
				F1	F2	F3	F1	F2	F3	F1	F2	F3
	S	D	N	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)
/b/	Male	S	20	684.17 (30.40)	1199.21 (71.09)	2648.53 (145.62)	342.73 (27.52)	2238.99 (114.43)	2779.30 (137.06)	454.64 (42.39)	867.53 (238.37)	2699.10 (176.85)
		B	20	654.84 (62.61)	1135.66 (107.64)	2686.03 (198.16)	349.51 (28.96)	2171.29 (113.10)	2704.03 (154.21)	477.18 (80.47)	1170.97 (573.48)	2878.68 (215.06)
		T	40	669.50 (50.80)	1167.43 (95.61)	2667.28 (172.69)	346.12 (28.09)	2205.14 (117.42)	2741.67 (148.96)	465.91 (64.50)	1019.25 (459.91)	2788.89 (214.56)
	Female	S	20	818.56 (81.12)	1381.86 (126.34)	2882.12 (203.15)	415.40 (26.67)	2710.92 (101.05)	3166.50 (117.29)	474.49 (34.20)	1044.96 (230.63)	2977.33 (194.77)
		B	20	719.51 (62.36)	1260.41 (104.61)	2934.12 (134.83)	434.13 (60.01)	2550.49 (162.67)	3072.72 (208.86)	506.69 (57.93)	1137.03 (400.60)	2944.44 (230.96)
		T	40	769.03 (87.27)	1321.13 (129.96)	2908.12 (172.21)	424.77 (46.81)	2630.71 (156.42)	3119.61 (173.80)	490.59 (49.71)	1091.00 (325.99)	2960.88 (211.53)
	Total	S	40	751.36 (91.03)	1290.53 (137.08)	2765.33 (210.78)	379.07 (45.49)	2474.96 (261.65)	2972.90 (233.02)	464.57 (39.32)	956.24 (248.33)	2838.22 (231.45)
		B	40	687.17 (69.83)	1198.03 (122.33)	2810.08 (209.21)	391.82 (63.24)	2360.89 (236.63)	2888.38 (260.17)	491.94 (70.80)	1154.00 (488.57)	2911.56 (222.78)
		T	80	719.27 (86.84)	1244.28 (137.23)	2787.70 (209.87)	385.45 (55.11)	2417.92 (254.43)	2930.64 (249.06)	478.25 (58.55)	1055.12 (397.72)	2874.89 (228.71)
/d/	Male	S	20	673.86 (28.94)	1330.21 (72.51)	2631.77 (140.89)	375.78 (48.00)	2209.79 (134.43)	2759.24 (154.42)	499.91 (60.58)	1022.50 (103.74)	2636.99 (148.16)
		B	20	638.28 (44.56)	1227.62 (106.41)	2634.42 (145.03)	371.27 (54.02)	2179.94 (137.20)	2753.15 (125.07)	455.99 (49.50)	1100.34 (294.34)	2660.99 (204.98)
		T	40	656.07 (41.23)	1278.92 (103.81)	2633.09 (141.14)	373.52 (50.49)	2194.86 (134.92)	2756.20 (138.74)	477.95 (58.96)	1061.42 (221.37)	2648.99 (176.95)
	Female	S	20	817.02 (66.76)	1515.96 (118.10)	2884.21 (241.01)	440.99 (69.54)	2693.31 (167.83)	3195.31 (154.02)	502.74 (64.94)	1190.22 (224.17)	2878.69 (183.59)
		B	20	707.75 (62.25)	1539.38 (186.36)	2910.09 (163.73)	430.46 (53.68)	2523.92 (197.46)	3025.62 (135.41)	500.79 (70.87)	1394.99 (327.07)	2787.02 (143.23)
		T	40	762.38 (84.38)	1527.67 (154.45)	2897.15 (203.79)	435.73 (61.55)	2608.61 (200.19)	3110.47 (166.95)	501.77 (67.10)	1292.61 (295.55)	2832.86 (169.03)
	Total	S	40	745.44 (88.51)	1423.09 (134.92)	2757.99 (233.04)	408.38 (67.59)	2451.55 (287.18)	2977.28 (268.20)	501.32 (62.01)	1106.36 (192.19)	2757.84 (205.17)
		B	40	673.01 (63.97)	1383.50 (217.62)	2772.25 (206.87)	400.86 (61.02)	2351.93 (241.88)	2889.39 (188.65)	478.39 (64.46)	1247.66 (341.44)	2724.01 (185.84)
		T	80	709.23 (84.94)	1403.30 (181.00)	2765.12 (219.06)	404.62 (64.09)	2401.74 (268.53)	2933.33 (234.60)	489.86 (63.89)	1177.01 (284.33)	2740.92 (195.25)

Table 7.8 Mean formant frequency values F1 through F3 (Hz) and standard deviation values in parentheses for words with initial voiced stops (b/d) in three vowel contexts (/a:,i:,u:/) for male and female participants from two Arabic dialects (Saudi = S and Bahraini = B).

A mixed model ANOVA where place of articulation and vowels were the repeated measures was conducted with the mean formant frequencies (F1-F3) as the measures of analysis in the model, while dialect and sex were the between-subject factors.

7.5.2.1 Dialect and sex

Univariate tests for dialect showed a significant effect for F1 only ($p < .05$)[12], as seen in Table 7.9. A post hoc Bonferroni test showed that Saudis had higher F1 frequencies (541.69 Hz) than Bahraini speakers (520.53 Hz) ($p<.001$) (see Figure 7.7).

Between subjects	Dialect			Sex			Sex and dialect		
Formant	*df*	F	p	*df*	F	p	*df*	F	p
F1	1,76	10.66	0.002*	1,76	103.35	0.001*	1,76	1.219	0.27
F2	1,76	0.002	0.96	1,76	115.91	0.001*	1,76	0.751	0.39
F3	1,76	0.22	0.64	1,76	2.66	0.001*	1,76	2.258	0.14

Table 7.9 Results for univariate tests for formant frequencies (F1-F3) for between-subject factors (dialect, sex and the interaction between sex and dialect) for vowels /a:,i:,u:/ in the context of voiced stops /b,d/; * denotes significance.

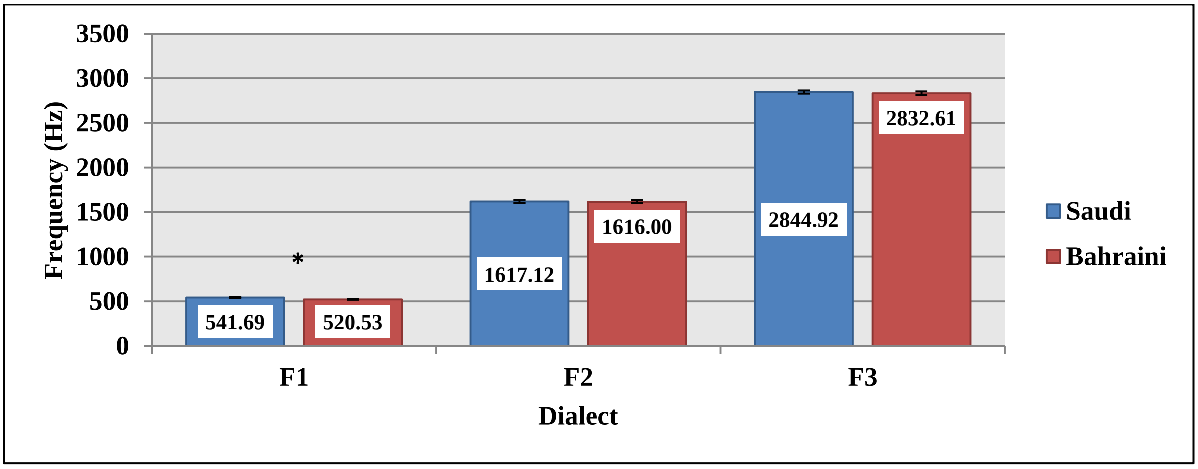


Figure 7.7 Mean ± S.E. formant frequencies (F1-F3) in Hz for Saudi and Bahraini Arabic speakers.

[12] Note that the results within text reflect the significance threshold, while the actual results are shown in the table specified within text. This will be maintained in this section and throughout the remaining result sections.

Furthermore, sex showed a significant effect (F(3,74) = 66.40, p < .001), and univariate tests for sex revealed significant effects for F1 (p < .001), F2 (p < .001) and F3 (p < .001), as shown in Table 7.9. Post hoc Bonferroni tests showed significant differences (p < .001) for all formant frequencies (F1-F3), such that males had lower F1 (498.18 Hz), F2 (1487.84 Hz) and F3 (2706.02 Hz) values than females' F1 (560.05 Hz), F2 (1745.29 Hz) and F3 (2971.51 Hz) values (see Figure 7.8).

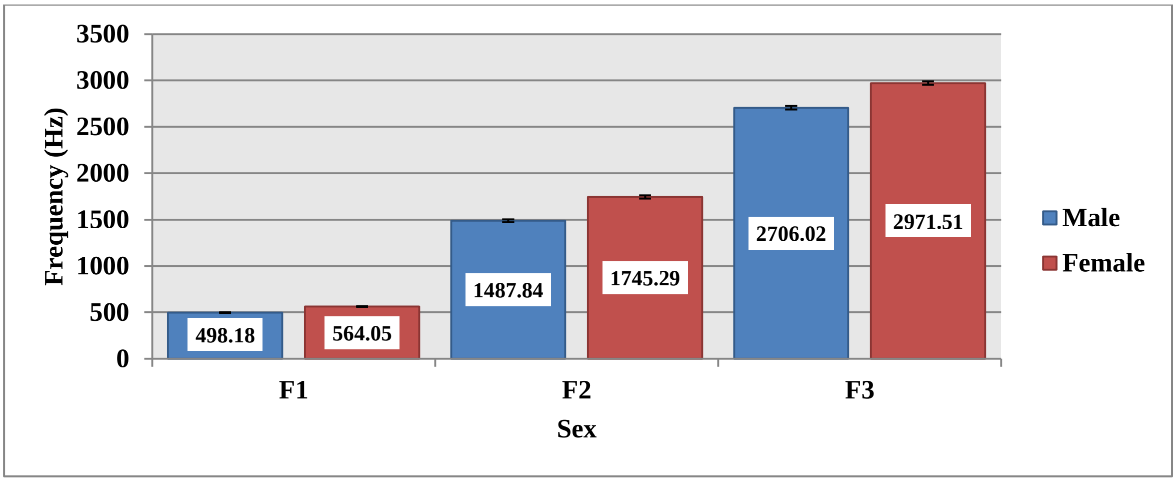


Figure 7.8 Mean ± S.E. formant frequencies (F1-F3) in Hz for male and female Arabic speakers.

However, there was no significant interaction between sex and dialect for F1, F2, or F3 (p>.05), as can be seen in Table 7.9.

7.5.2.2 Place of voiced stops

Univariate tests for place showed a significant effect for F2 (p<.001), as well as for F3 (p<.001), as can be seen in Table 7.10 and Figure 7.9.

	Place			Place and dialect			Place and sex			Place, sex and dialect		
Formants	*df*	F	p	*df*	F	p	*df*	F	p	*df*	F	p
F1	1,76	2.78	0.1	1,76	10.03	0.002*	1,76	0.18	0.67	1,76	0.04	0.84
F2	1,76	30.75	0.001*	1,76	0.01	0.91	1,76	6.46	0.01*	1,76	6.2	0.02*
F3	1,76	20.62	0.001*	1,76	4.33	0.04*	1,76	0.03	0.87	1,76	0.09	0.77

Table 7.10 Results for univariate tests for formants (F1-F3) for place for voiced stops and for interactions with sex, dialect and place, sex and dialect; * denotes significance.

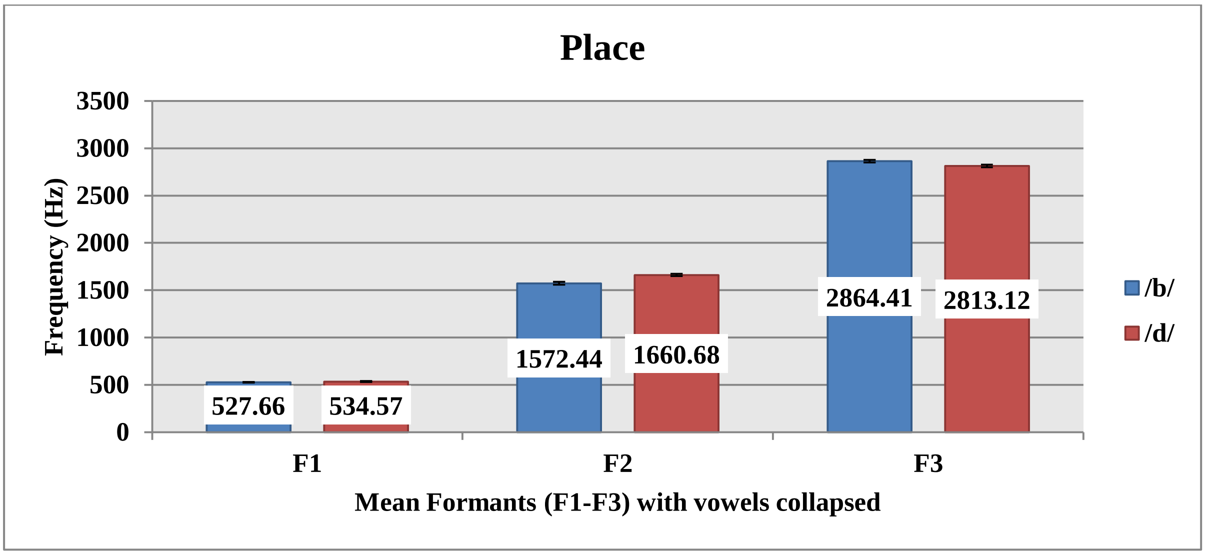


Figure 7.9 Mean formant frequencies (F1-F3) ± S.E in Hz for bilabial /b/ and alveolar /d/ from collapsed vowels

Post hoc Bonferroni tests showed significant results for F2 ($p < .001$) and F3 ($p < .001$), such that /b/ had a lower F2 (1572.44 Hz) than /d/ (1660.68 Hz). However, /b/ had a higher F3 (2864.41 Hz) than /d/ (2813.12 Hz) (see Figure 7.9).

Place and dialect showed significant interactions for F1 ($p < .001$) and F3 ($p < .05$), as can be viewed in Table 7.10. The results showed that Saudis had higher F1 frequencies for /b/ (531.67 Hz) than Bahrainis did (523.64 Hz). In contrast, Bahrainis showed lower frequencies for /d/ (517.42 Hz) than Saudis (551.72 Hz) (see Figure 7.10).

Furthermore, results for F3 showed that Saudis had lower F3 frequencies for /b/ (2858.81 Hz) than Bahrainis /b/ (2870.00 Hz), while Saudis had higher F3 frequencies for /d/ (2831.03 Hz) than Bahrainis (2795.22 Hz) (see Figure 7.10).

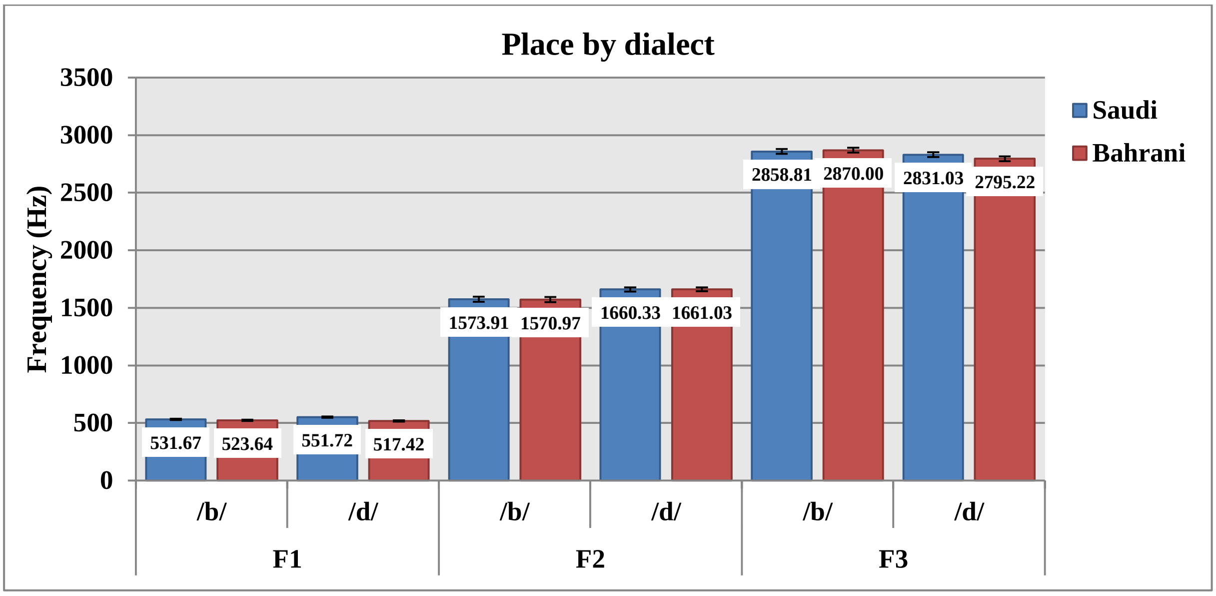


Figure 7.10 Mean formant frequencies (F1-F3) ± S.E in Hz for bilabial /b/ and alveolar /d/ from collapsed vowels and interactions with dialects.

Place and sex showed a significant interactions for F2 ($p<.05$), as can be viewed in Table 7.10, such that males had F2 values lower for /b/ (1463.94 Hz) than /d/ (1511.73 Hz). Although the trend was similar for females, the difference between /b/ (1680.95 Hz) and /d/ (1809.63 Hz) is larger than that for males as can be seen in Figure 7.11.

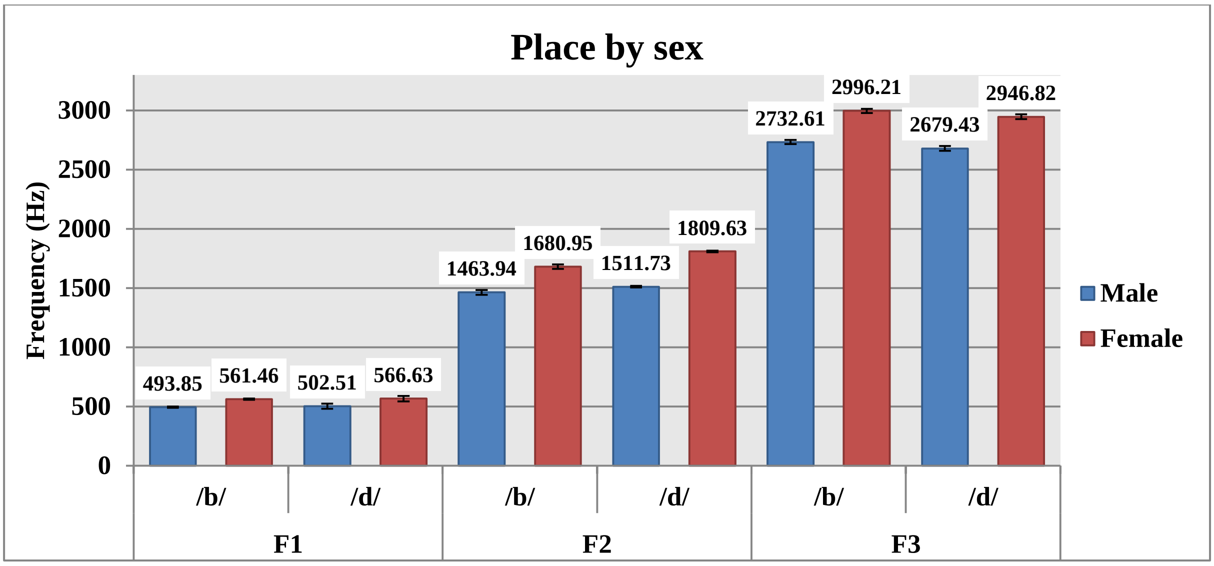


Figure 7.11 Mean formant frequencies (F1-F3) ± S.E in Hz for bilabial /b/ and alveolar /d/ from collapsed vowels and interactions with sexes.

Place, sex and dialect only showed significant interactions for F2 ($p<.05$) (see Table 7.10). The results showed that Saudi males had lower mean F2 frequencies for /b/ (1435.24 Hz) than Bahraini males (1492.64 Hz). Meanwhile, Bahraini males had lower mean formant frequencies for /d/ (1502.63 Hz) than Saudi males (1520.83 Hz). The trend was opposite for females; Saudi females had higher mean formant frequencies for /b/ (1712.85 Hz) than Bahraini females (1649.31 Hz), but Bahraini females had higher mean formant frequencies for /d/ (1819.43 Hz) than Saudi females (1799.83 Hz) (see Figure 7.12).

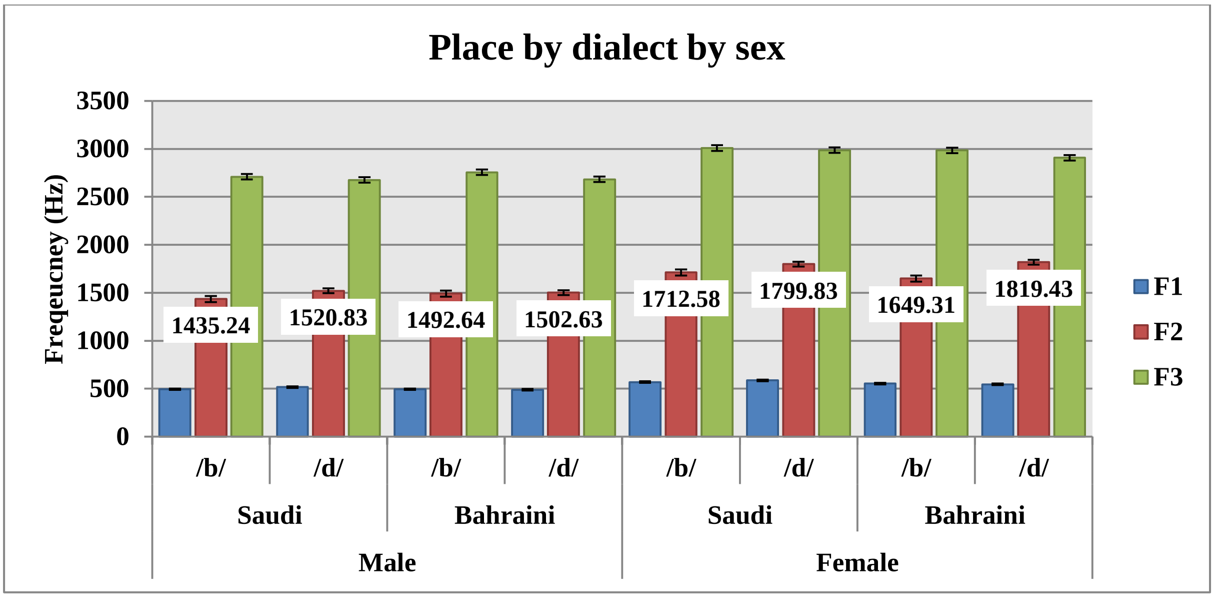


Figure 7.12 Mean ± S.E. for mean formants (F1-F3) in Hz for bilabial /b/ and alveolar /d/ from collapsed vowels between sexes and dialects.

7.5.2.3 Effect of vowel context and the interaction between place and vowel context

Univariate results for each formant frequency (F1-F3) for within-subject vowel context and for the interaction between place and vowel are shown in Table 7.11.

Within subjects	F1			F2			F3		
	df	F	p	*df*	F	p	*df*	F	p
Vowel	2,152	1108.90	0.001*	1.44,109.87[1]	1235.79	0.001*	2,152	41.77	0.001*
Vowel and dialect	2,152	17.035	0.001*	1.44,109.87[1]	14.244	0.001*	2,152	6.358	0.002*
Vowel and sex	2,152	15.966	0.001*	1.44,109.87[1]	13.025	0.001*	2,152	13.863	0.001*
Vowel, sex and dialect	2,152	6.65	0.002*	1.44,109.87[1]	0.902	0.38	2,152	3.273	0.041*
Place and vowel	1.66,126.39[1]	5.353	0.009*	1.24,94.61	11.685	0.001*	1.81,138.25[1]	14.57	0.001*
Place, vowel and dialect	1.66,126.39[1]	2.732	0.079	1.24,94.61[1]	1.055	0.323	1.81,138.25[1]	1.997	0.144
Place, vowel and sex	1.66,126.39[1]	0.815	0.425	1.24,94.61[1]	2.564	0.105	1.81,138.25[1]	0.412	0.644
Place, vowel, sex and dialect	1.66,126.39[1]	0.98	0.365	1.24,94.61[1]	3.219	0.067	1.81,138.25[1]	2.581	0.084

Table 7.11 Results for univariate tests for formant frequencies (F1-F3) for vowels in the context of voiced stops /b,d/ as it interacts with sex, dialect and sex and dialect; * denotes significance, and [1] denotes the use of Greenhouse-Geisser estimates (due to violations of sphericity).

In this section, vowels will be discussed in terms of their relations with each formant frequency, since the measures of analysis were formants (F1-F3).

Vowels were found to have a significant effect on F1 frequencies ($p < .001$) (see Table 7.11). Post hoc Bonferroni tests showed differences among all vowels, such that F1 was highest for vowel /a:/ (714.25 Hz), followed by the F1 values for /u:/ (484.06 Hz) and /i:/ (395.031 Hz) ($p < .001$), (see Figure 7.13 (a,b,c)).

In addition, vowels were shown to have a significant effect on F2 ($p < .001$) (see Table 7.11). Post hoc Bonferroni tests showed differences among all vowels, such that F2 was highest for /i:/ (2409.83 Hz) ($p < .001$), followed by the F2 values for /a:/ (1323.79 Hz) and /u:/ (1116.07 Hz) ($p < .001$), (see Figure 7.13 (a,b,c)).

Furthermore, vowels were found to have a significant effect on F3 ($p < .001$) (see Table 7.11). Post hoc Bonferroni tests showed significantly higher F3 values for /i:/ (2931.98 Hz) than both /u:/ (2807.91 Hz) and /a:/ (2776.41 Hz) ($p < .001$). However, no significant difference was found for F3 between /a:/ (2776.41 Hz) and /u:/ (2807.91 Hz) ($p=.242$) (see Figure 7.13 (a)).

In Figure 7.13 (a,b,c) , it is clear that /i:/ has a more distinct vowel space than /a:/ and /u:/. Moreover, overlap can be seen between the ellipses for vowels /u:/ and /a:/. In terms of dispersion, /u:/ exhibits greater dispersion than /i:/ and /a:/.

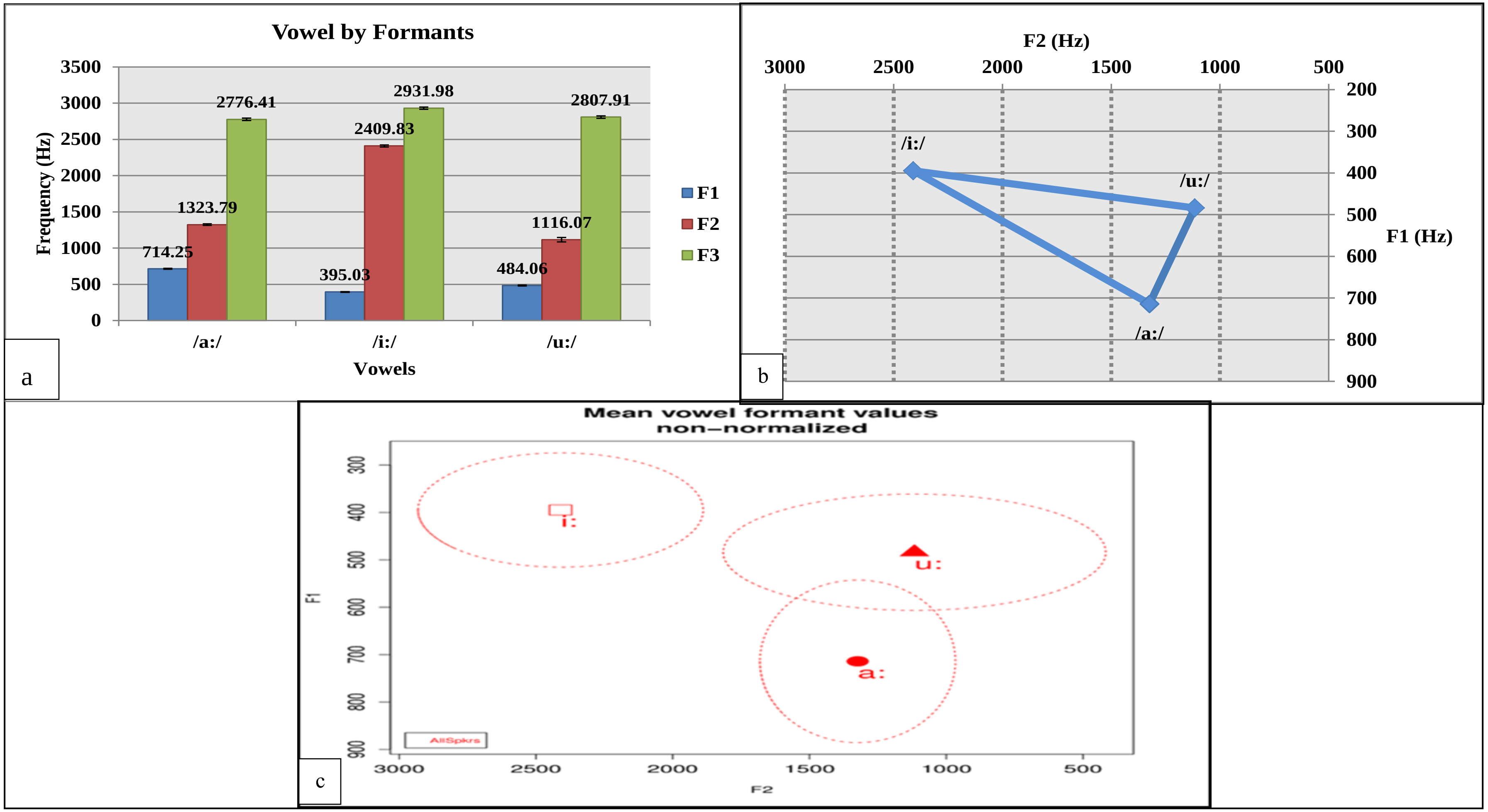


Figure 7.13 a) Mean ± S.E for mean formants (F1-F3) in Hz for vowels /a:,i:,u:/ for words with collapsed places of articulation for voiced stops /b,d/, sex and dialect for Arabic speakers; b) Vowel spaces for Arabic speakers; c) Vowel centroids for vowels /a:,i:,u:/ for Arabic speakers, with ellipses representing two standard deviations from the group mean.

The results showed a significant interaction between vowels and dialect for F1 ($p < .001$), (see Table 7.11). For /a:/, Saudis showed higher F1 values (748.40 Hz) than Bahrainis (680.09 Hz). In contrast, Bahraini speakers showed slightly higher F1 frequencies for vowels /i:/ and /u:/ (396.34 Hz and 485.16 Hz, respectively) than Saudi speakers (393.73 Hz and 482.16 Hz, respectively) (see Figure 7.14 (a,b,c)).

For F2, there was a significant interaction between vowels and dialect ($p < .001$) (see Table 7.7). For /a:/, Saudis showed higher F2 values (1356.81 Hz) than Bahrainis (1290.77 Hz). This was also seen with vowel /i:/, for which F2 values were higher for Saudis (2463.25 Hz) than for Bahrainis (2356.41 Hz). However, for /u:/, Bahrainis had higher F2 values (1200.83 Hz) than Saudi speakers (1031.30 Hz), (see Figure 7.14 (a,b,c)) .

For F3, there was a significant interaction between vowels and dialect ($p < .05$) (see Table 7.7). For /a:/, Saudis had lower F3 values (2761.33 Hz) than Bahrainis (2790.16 Hz). Similarly, Saudis exhibited lower F3 values for /u:/ (2798.03 Hz) than Bahrainis (2817.78 Hz). In contrast, Saudis had higher F3 values for /i:/ (2975.09 Hz) than Bahrainis (2888.88 Hz), (see Figure 7.14 (a)).

From Figure 7.14 (b,c), it is clear that Saudis exhibit more peripheral positions for /a:,i:,u:/ than Bahraini speakers. In terms of dispersion, Bahrainis showed more dispersed production for /u:/ than Saudis. For /i:/, a similar dispersion pattern can be seen, although Saudis showed slightly more dispersed productions.

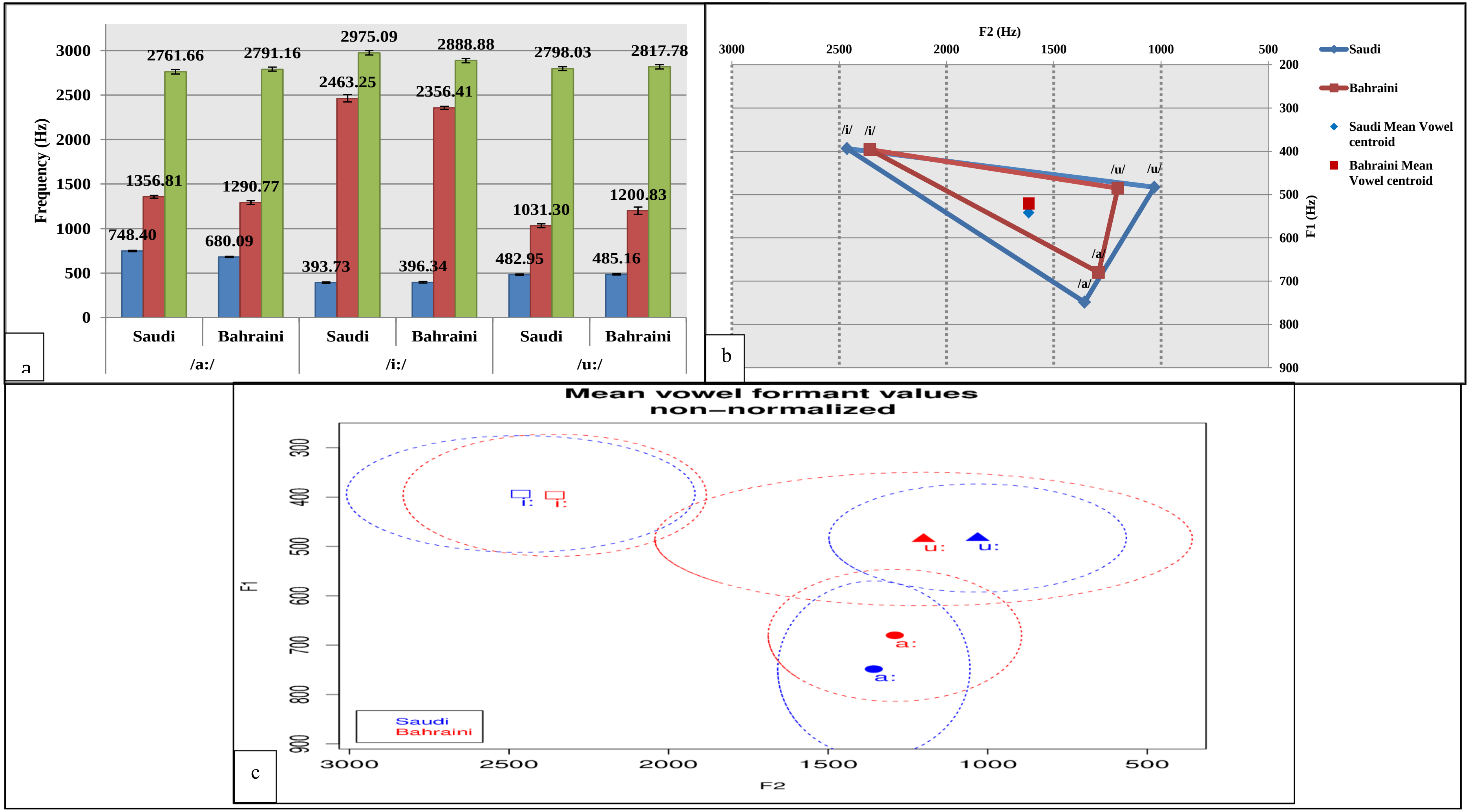


Figure 7.14 a) Mean ± S.E. for mean formants (F1-F3) in Hz for vowels /a:,i:,u:/ between 40 Saudi and 40 Bahraini Arabic speakers; b) Vowel spaces for 40 Saudi and 40 Bahraini Arabic speakers; c) Vowel centroids for vowels /a:,i:,u:/ for 40 Saudi and 40 Bahraini Arabic speakers, with ellipses representing two standard deviations from the group mean.

Results showed a significant interaction between vowels and sex for F1, F2 and F3 ($p < .001$), see Table 7.11. For F1, the patterns of males and females in terms of vowel quality seemed consistent, such that /a:/ had higher F1 values than /i:/, which had the lowest F1 values (see Figure 7.15 (b,c)). Furthermore, males exhibited lower F1 values for /a:/ (662.79 Hz), /i:/ (359.82 Hz) and /u:/ (471.93 Hz) than females (765.71 Hz, 430.25 Hz and 496.18 Hz, respectively), see Figure 7.15 (b,c). However, the interaction is possibly due to the larger difference between males and females for vowel /a:/ (103.42 Hz) in contrast to remaining vowels /i:/ (70.13 Hz) and /u:/ (24.25 Hz) (see Table 7.15).

For F2, the patterns of males and females in terms of vowel quality seemed consistent, such that /i:/ had the highest F2 values, , /u:/ had the lowest values, , and /a:/ values were between /i:/ and /u:/ as can be viewed in Figures 17.5 (b,c). Furthermore, males showed lower F1 values for /a:/ (1223.17 Hz), /i:/(2200.00 Hz) and /u:/ (1040.33 Hz) than females (1424.40 Hz, 2619.66 Hz and 1191.80 Hz, respectively), see Figure 7.15 (b,c). However, the interaction is possibly due to the larger difference between males and females for vowel /i:/ had a larger differences between males and females (414.66 Hz) than /a:/ (190.70 Hz) and /u:/ (151.47 Hz) (see Table 7.15).

For F3, the patterns of males and females in terms of vowel quality seemed consistent, such that /i:/ had higher F3 values, by contrast, /a:/ and /u:/ had lower values ,see figures 7.16 (b,c) and 7.17. Furthermore, males showed lower F1 values for /a:/ (2650.19 Hz), /i:/ (2748.93 Hz) and /u:/ (2718.94 Hz) than females (2902.64 Hz, 3115.04 Hz 2896.87 Hz, respectively), see Figure 7.15 (a). However, the interaction is possibly due to the larger difference between males and females that was larger for /i:/ (495.35 Hz) than /a:/ (252.45 Hz) and /u:/ (177.93 Hz) (see Table 7.15).

In Figure 7.15 (b,c), overlap between males and females can be seen for /u:/, while less can be seen for /a:/ and /i:/. Males showed less dispersed productions for /i:/ and /a:/ than females. By contrast, males exhibited slightly more dispersed productions for /u:/ than females.

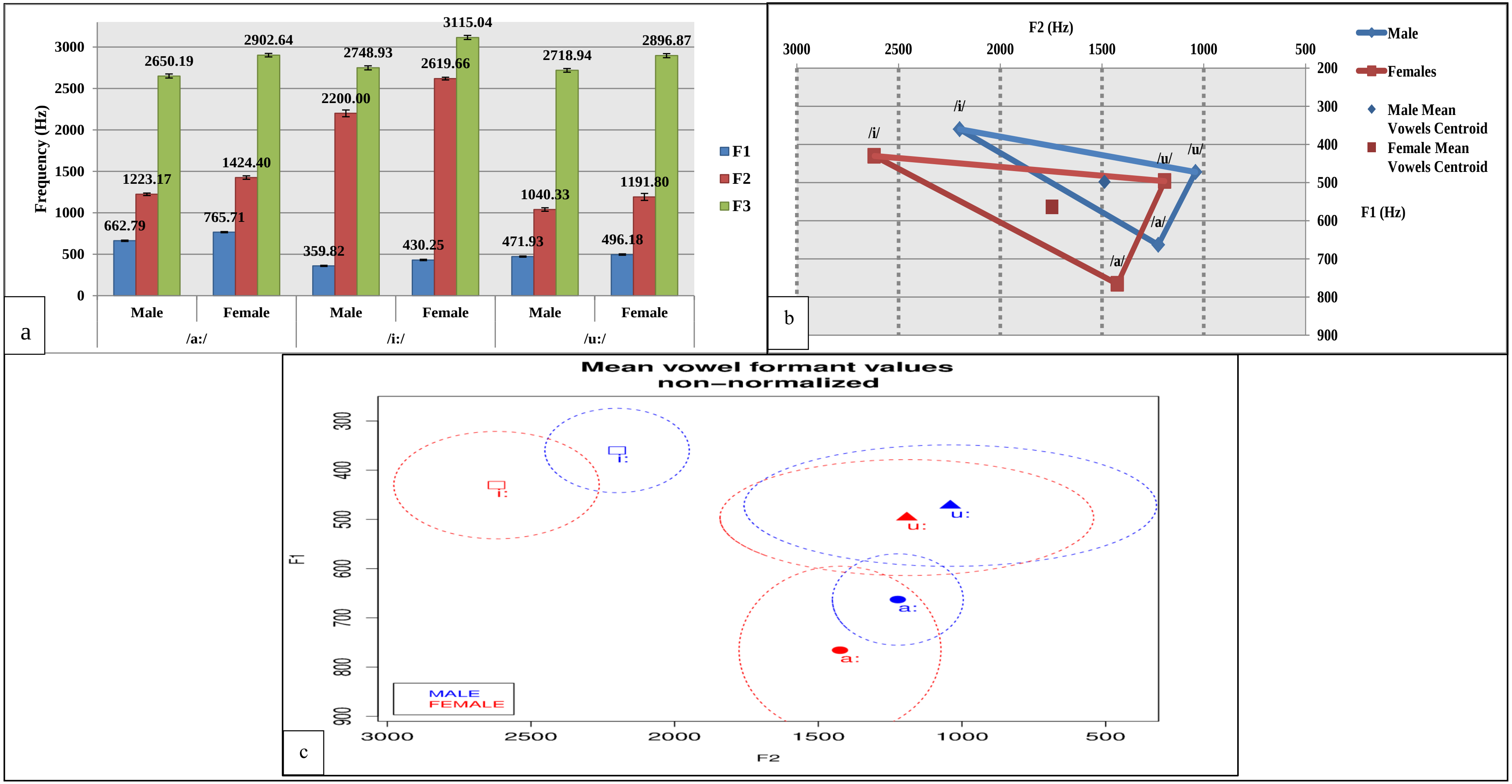


Figure 7.15 a) Mean ± S.E. for mean formants (F1-F3) in Hz for vowels /a:,i:,u:/ between 40 males and40 female Arabic speakers; b) Vowel spaces for 40 male and 40 female Arabic speakers; c) Vowel centroids for vowels /a:,i:,u:/ for 40 male and 40 female Arabic speakers, with ellipses representing two standard deviations from the group mean.

As can be observed from Table 7.11, the results showed significant interactions for vowel, dialect and sex for F1 and F3 ($p < .05$).

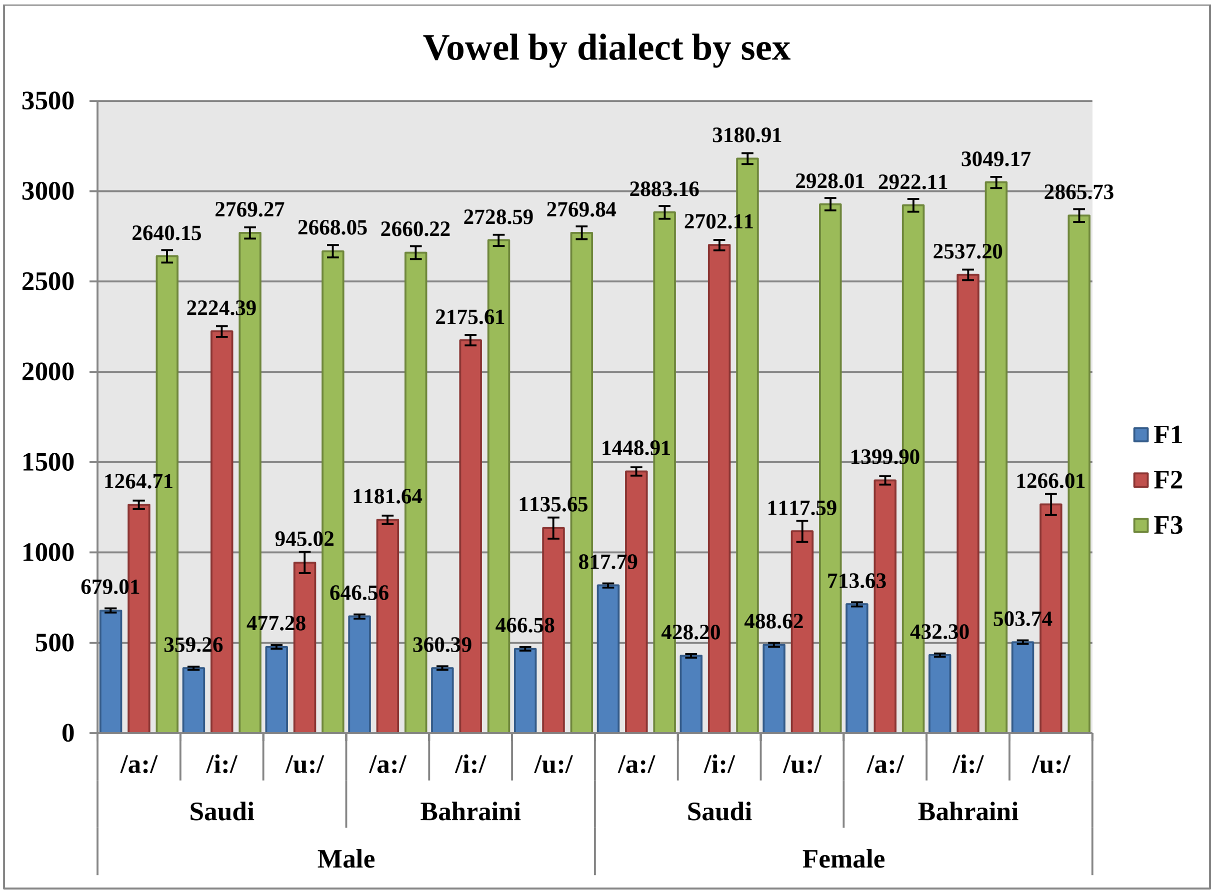


Figure 7.16 Mean ± S.E. in Hz for formant frequencies (F1-F3) for males and females between dialects (Saudi and Bahraini) with collapsed places of articulation.

In this section, interactions will be described for each vowel individually; however, a general pattern among males and females in terms of vowel quality seems consistent, such that /a:/ had higher F1 values, /i:/ had the lowest F1 values while /u:/ showed values between /a:/ and /i:/ (see Figure 7.16).

For /i/, in Figure 7.16 and Figure 7.17, it is clear that F1 values for Saudi (428.20 Hz) and Bahraini (432.30Hz) females were higher than those for males (359.26Hz and 360.39Hz, respectively). With regard to the mean F1 values, no differences between the dialects can be observed for either sex.

For /u:/, as can been seen Figure 7.16 in and Figure 7.17, male Saudis (477.28 Hz) showed higher F1 values than Bahrainis (466.58 Hz). In contrast, Bahraini females (503.74Hz) showed higher F1 values than Saudi females (488.62 Hz). With regard to Saudis, females (488.62 Hz) showed higher values than males (477.28 Hz). With regard to Bahrainis, females (503.74 Hz) showed relatively higher F1 values than males (466.58 Hz).

Figure 7.16 and Figure 7.17 for /a:/ illustrate that Saudi males (679.01 Hz) and females (817.79 Hz) have higher F1 values than Bahraini males and females (646.56 Hz and 713.6 Hz, respectively). Furthermore, Saudi (679.01 Hz) and Bahraini males (646.56 Hz) showed lower F1 frequencies than females of both dialects (817.79 Hz and 713.63 Hz, respectively). Moreover, Saudi females exhibited the highest F1 value (817.79 Hz) amongst the remaining groups.

For F3, males generally showed lower F3 values than females for vowels /a:,i:,u:/ for each dialect. Saudi males had lower F3 values for /a:/ (2640.15 Hz) and /u:/ (2640.05 Hz) than Bahraini males (2660.22 Hz, 2768.84 Hz), respectively. While, for /i:/, Bahrainis had lower F3 (2728.59 Hz) than Saudis (2769.27 Hz). For Saudi females, F3 was lower for /a:/ (2883.16 Hz) than Bahrainis (2922.11 Hz). While, for /i:/ and /u/, Bahraini females had lower F3 (3049.17 Hz , 2867.73 Hz) than Saudis (3180.91 Hz, 2928.01 Hz), respectively, see Figure 7.16 and Figure 7.17.

For /i:/ illustrated that females from both dialects exhibited more dispersion than males from both dialects. Overlap occurred only between males and Bahraini females due to a larger dispersion than the corresponding Saudi dispersion. Furthermore, Saudi females showed slightly greater peripheral quality for /i:/ and /a:/ than Bahraini females. For /u:/, Bahraini males and females showed more dispersion than Saudi speakers, resulting in overlap. For /a:/, Saudis had the least dispersion compared to Bahraini speakers except for Saudi females whom had the most dispersion. Overlap between dialects was observed for each sex; however, this occurred less in females.

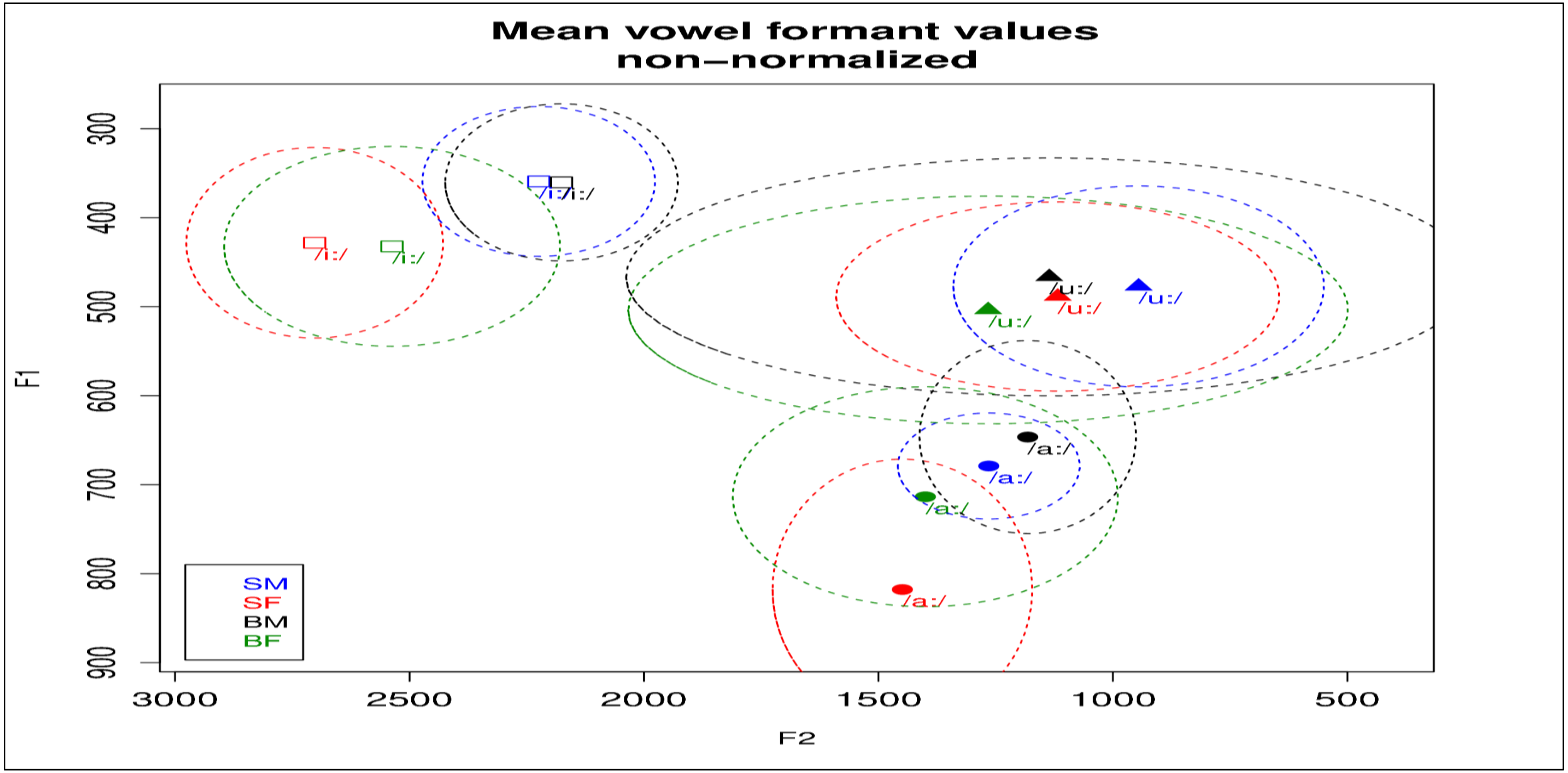


Figure 7.17 Vowel centroids for vowels /a:,i:,u:/ for 20 male and 20 female speakers for each dialect (Saudi and Bahraini), with ellipses representing two standard deviations from the group mean.

The results showed a significant interaction between place and vowel for F1 ($p < .05$), F2 and F3 ($p < .001$) (see Table 7.11).

For F1, as can be seen from Figure 7.18 (a,b,c), /b/ had lower frequencies for /i:/ (385.44 Hz) and /u:/ (478.25 Hz) than /d/ (404.624 Hz and 489.86 Hz for /i:/ and /u:/, respectively). In contrast, /d/ had lower F1 values for /a:/ (709.23 Hz) than /b/ (719.27 Hz).

From Figure 7.18 (a,b,c), for F2, /b/ had lower frequencies for /a:/ (1244.28 Hz) and /u:/ (1055.12 Hz) than /d/ (1403.29 Hz and 1177.61 Hz, respectively). However, for /i:/, /b/ (2417.92 Hz) had higher F2 value than /d/ (2401.74 Hz), suggesting an opposite trend from those for /a:/ and /u:/.

For F3, /b/ had higher F3 values for /a:/ (2870.70 Hz) and /u:/ (2874.49 Hz) than /d/ (2765.12 Hz and 2740.92 Hz, respectively). Minimal differences were observed in /i:/ between /b/ (2930.64 Hz) and /d/ (2933.33 Hz) (see Figure 7.18 (a))

According to Figure 7.18 (a,b,c) , /i:/ exhibited similar dispersion patterns between /b/ and /d/, although /u:/ for /d/ showed marginally more dispersion. For /a:/, overlapping occurred between voiced places /b,d/; however, /d/ showed a more fronted quality than /b/.

In Table 7.11, it is clear that was no significant interactions among place, vowel and dialect for F1, F2 or F3 ($p > .05$). In addition, no significant interactions among place, vowel, and sex were found for F1, F2 or F3 ($p > .05$). Finally, there were also no significant interactions among place, vowel, sex and dialect for F1, F2 or F3 ($p > .05$).

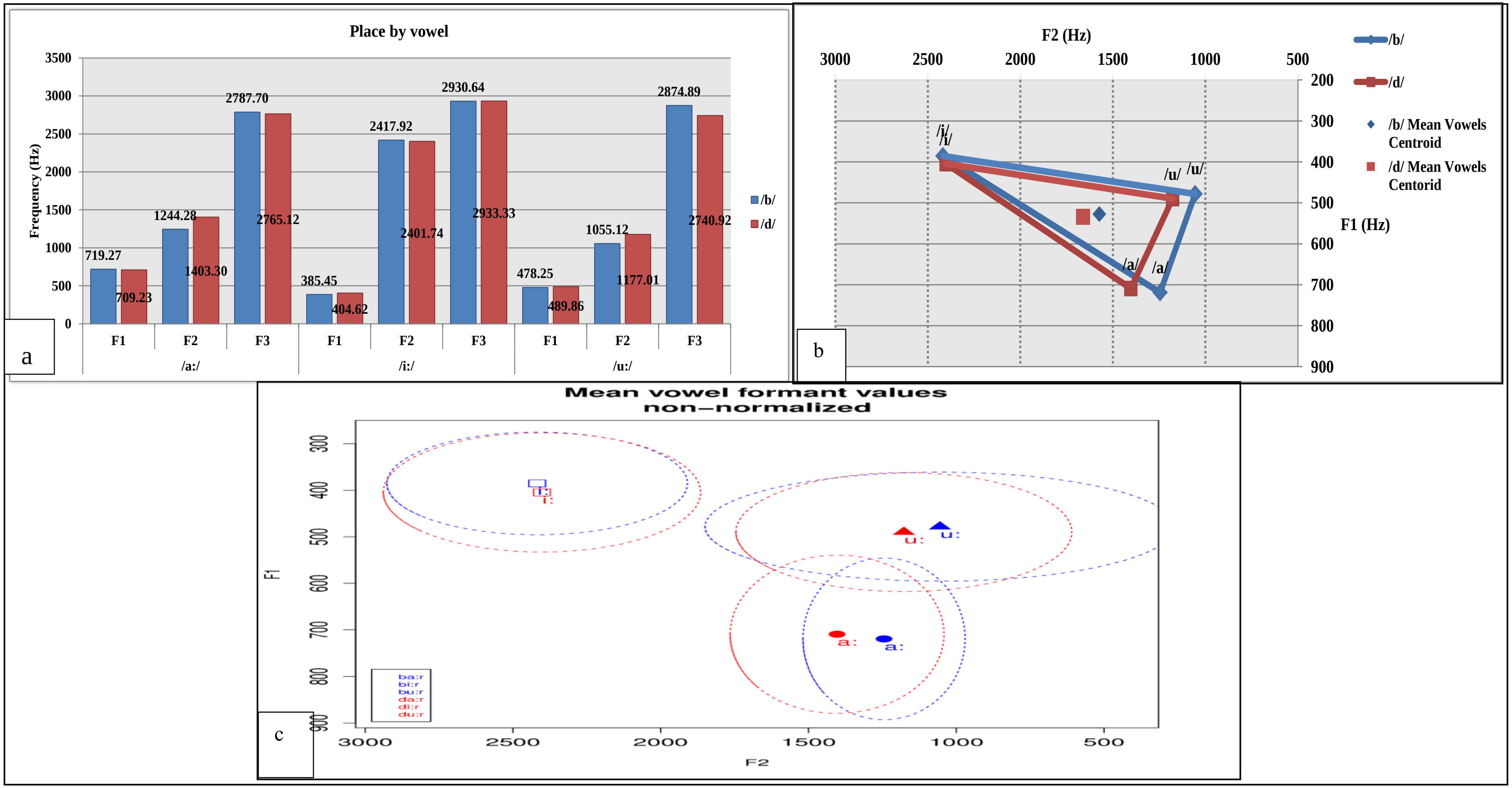


Figure 7.18 a) Mean ± S.E. for mean formants (F1-F3) in Hz for vowels /a:,i:,u:/ for words with initial voice bilabial stop /b/ and voiced alveolar stop /d/; b) Vowel spaces for initial voice bilabial stop /b/ and voiced alveolar stop /d/; c)Vowel centroids for vowels /a:,i:,u:/ for initial voice bilabial stop /b/ and voiced alveolar stop /d/, with ellipses representing two standard deviations from the group mean.

7.5.3 Voiceless stops /t,k/

Results for mean formant frequencies (F1-F3) in Hertz for two vowel contexts /i:,u:/ for words with initial voiceless stops (alveolar /t/ vs. velar /k/) are presented in Table 7.12 as a function of dialect and gender. The word contexts were as follows: (/ti:r/, /tu:r/) × (/ki:r/, /ku:r/).

				/i:/			/u:/		
				F1	F2	F3	F1	F2	F3
	Sex	N	Dialect	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)	Mean (S.D)
/t/	Male	20	Saudi	383.90 (38.06)	2178.12 (142.60)	2739.37 (139.27)	464.208 (30.96)	904.017 (100.37)	2695.96 (176.58)
		20	Bahraini	374.4 (57.19)	2177.92 (116.59)	2759.29 (161.64)	447.328 (56.99)	1063.15 (259.49)	2695.11 (154.70)
		40	Total	379.2 (48.19)	2178.02 (128.56)	2749.33 (149.27)	455.768 (46.07)	983.586 (210.25)	2695.53 (163.86)
	Female	20	Saudi	432.1 (46.57)	2708.14 (173.51)	3174.89 (161.13)	492.282 (66.71)	1150.26 (249.25)	2918.77 (131.42)
		20	Bahraini	432.9 (44.78)	2566.42 (145.85)	3019.02 (133.22)	479.477 (58.79)	1245.87 (265.73)	2881.45 (147.36)
		40	Total	432.5 (45.09)	2637.28 (173.72)	3096.96 (165.91)	485.88 (62.40)	1198.06 (258.86)	2900.11 (139.11)
	Total	40	Saudi	408.00 (48.56)	2443.13 (310.81)	2957.13 (265.96)	478.245 (53.26)	1027.14 (225.21)	2807.36 (190.62)
		40	Bahraini	403.7 (58.72)	2372.17 (235.98)	2889.15 (196.65)	463.403 (59.42)	1154.51 (275.26)	2788.28 (176.47)
		80	Total	405.8 (53.58)	2407.65 (276.51)	2923.14 (234.90)	470.824 (56.56)	1090.83 (257.97)	2797.82 (182.77)
/k/	Male	20	Saudi	387.8 (66.69)	2194.25 (168.70)	2720.76 (156.14)	477.839 (48.64)	913.593 (176.45)	2667.23 (187.94)
		20	Bahraini	370.7 (39.5)	2184.22 (138.79)	2757.58 (170.19)	472.197 (68.50)	1189.88 (535.21)	2760.74 (248.50)
		40	Total	379.2 (54.79)	2189.24 (152.56)	2739.17 (162.28)	475.018 (58.71)	1051.74 (417.48)	2713.99 (222.56)
	Female	20	Saudi	475.3 (78.25)	2541.38 (249.58)	3064.65 (101.20)	503.781 (40.02)	1032.26 (150.96)	2913.73 (193.39)
		20	Bahraini	433.7 (51.23)	2597.54 (157.74)	3110.53 (214.84)	498.727 (51.89)	1001.81 (173.43)	2817.82 (171.49)
		40	Total	454.5 (68.61)	2569.46 (208.03)	3087.59 (167.38)	501.254 (45.81)	1017.04 (161.23)	2865.78 (186.84)
	Total	40	Saudi	431.5 (84.36)	2367.82 (274.06)	2892.71 (217.23)	490.81 (45.88)	972.928 (172.86)	2790.48 (225.85)
		40	Bahraini	(402.2 (55.29)	2390.88 (255.56)	2934.05 (261.80)	485.462 (61.47)	1095.85 (404.07)	2789.28 (212.71)
		80	Total	416.9 (72.39)	2379.35 (263.54)	2913.38 (239.93)	488.136 (53.96)	1034.39 (314.93)	2789.88 (217.99)

Table 7.12 Mean formant frequencies values F1-F3 in Hz and standard deviation values in parentheses for words with initial voiceless stops (t/k) in two vowel contexts (/i:,u:/) for male and female participants from two Arabic dialects (Saudi and Bahraini).

A mixed-model ANOVA was conducted in which the place of articulation and the vowels were the repeated measures, the mean formant frequencies (F1-F3) were the measures of analysis, and dialect and sex were the between-subject factors.

7.5.3.1 Dialect and sex

Univariate tests for dialect showed no significant effects for all formant frequencies (F1-F3) (p>.05), as seen in Table 7.13.

Between subjects	Dialect			Sex			Dialect and sex		
Formant	*df*	F	p	*df*	F	p	*df*	F	p
F1	1,76	2.416	0.124	1,76	28.466	0.001*	1,76	0.019	0.89
F2	1,76	3.228	0.076	1,76	81.862	0.001*	1,76	3.911	0.052
F3	1,76	0.207	0.65	1,76	104.426	0.001*	1,76	3.633	0.06

Table 7.13 Results for univariate tests for formant frequencies (F1-F3) for vowels /i:,u:/ in the context of voiceless stops /t,k/ for between-subject factors (dialect, sex and the interaction between sex and dialect); * denotes significance.

Univariate tests revealed a significant effect of sex for F1 ($p < .001$), F2 ($p < .001$) and F3 ($p < .001$), as shown in Table 7.13. Post hoc Bonferroni tests showed significant differences ($p < .001$) for all formant frequencies (F1-F3), such that males had lower F1 (422.29 Hz), F2 (1600.65 Hz) and F3 (2724.51 Hz) values than females F1 (468.54 Hz), F2 (1855.46 Hz) and F3 (2987.61 Hz) values (see Figure 7.19).

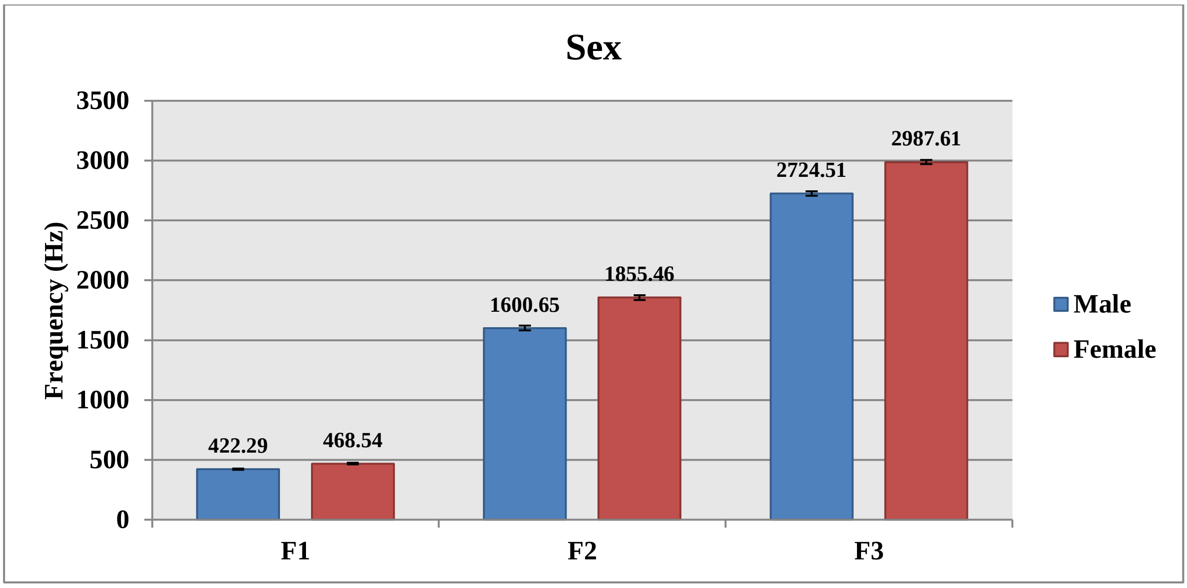


Figure 7.19 Mean ± S.E. formant frequencies (F1-F3) in Hz for male and female Arabic speakers for voiceless stops.

However, there was no significant interaction between sex and dialect for all formant frequencies (p > .05).

7.5.3.2 Place of voiceless stops

Univariate tests for place showed a significant effect for F1 (p < .001) and F2 (p < .05), as seen in Table 7.14 and Figure 7.20.

	Place			Place by dialect			Place by sex			Place by dialect by sex		
Formants	*df*	F	p	*df*	F	p	*df*	F	p	*df*	F	p
F1	1,76	11.913	0.001*	1,76	0.894	0.347	1,76	1.21	0.275	1,76	1.364	0.246
F2	1,76	5.925	0.017*	1,76	1.655	0.202	1,76	22.223	0.000*	1,76	0.065	0.799
F3	1,76	0.432	0.513	1,76	5.575	0.021*	1,76	0.932	0.338	1,76	0.088	0.768

Table 7.14 Results for univariate tests for formants (F1-F3) for places for voiceless stops and their interactions with sex, dialect and place, sex and dialect; * denotes significance.

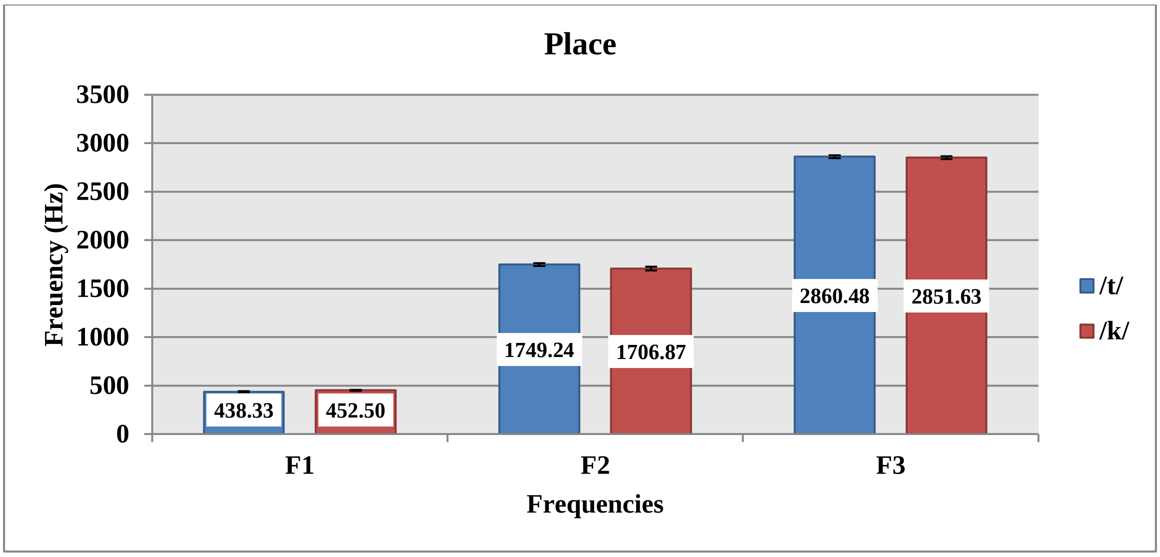


Figure 7.20 Mean formant frequencies (F1-F3) ± S.E. in Hz for bilabial /b/ and alveolar /d/ from collapsed vowels.

Post hoc Bonferroni tests showed significant differences for F1 ($p < .001$) and F2 ($p < .001$), such that /t/ had lower F1 values (438.33 Hz) than /k/ (452.50 Hz). However, /t/ had higher F2 values (1749.24 Hz) than /k/ (1706.87 Hz) (see Figure 7.20).

Place and dialect exhibited significant interaction only for F3 ($p < .05$), as can be seen in Table 7.11. The results showed that Saudis had higher F3 frequencies for /t/ (2882.25 Hz) than Bahrainis (2838.72 Hz). In contrast, Saudis showed lower F3 frequencies for /k/ (2841.60 Hz) than Bahrainis (2861.67 Hz) (see Figure 7.21).

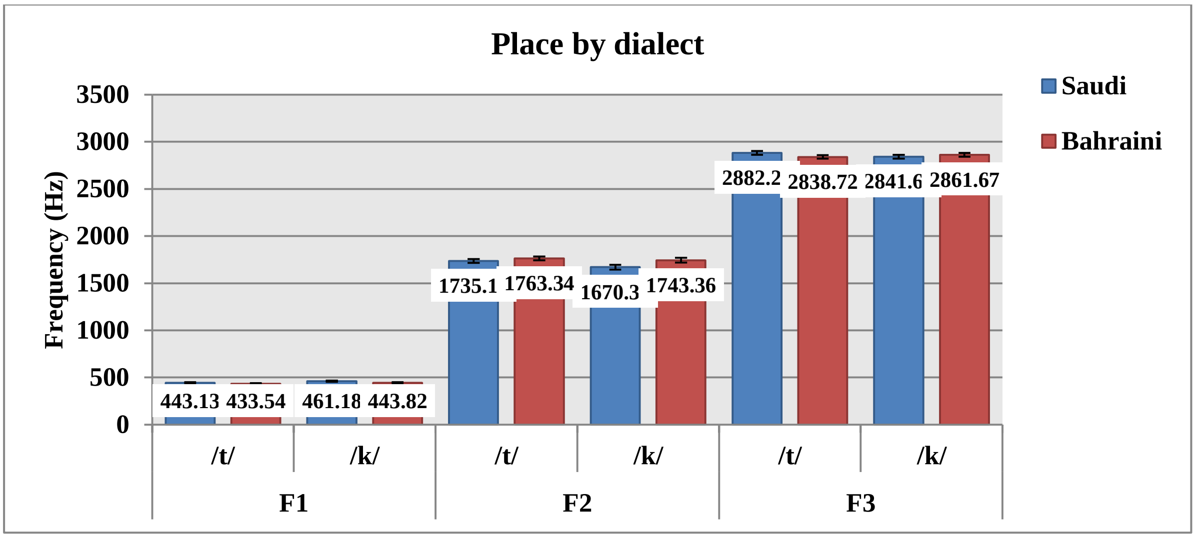


Figure 7.21 Mean formant frequencies (F1-F3) ± S.E. in (Hz) for alveolar /t/ and velar /k/ from collapsed vowels and their interaction with dialect.

Place and sex exhibited a significant interaction only for F2 ($p < .001$), as can be seen in Table 7.14. The results showed that males had lower F2 frequencies for /t/ (1580.80 Hz) than for /k/ (1620.49 Hz). In contrast, females had lower F2 frequencies for /k/ (1793.25Hz) than for /t/ (1917.67 Hz) (see Figure 7.22).

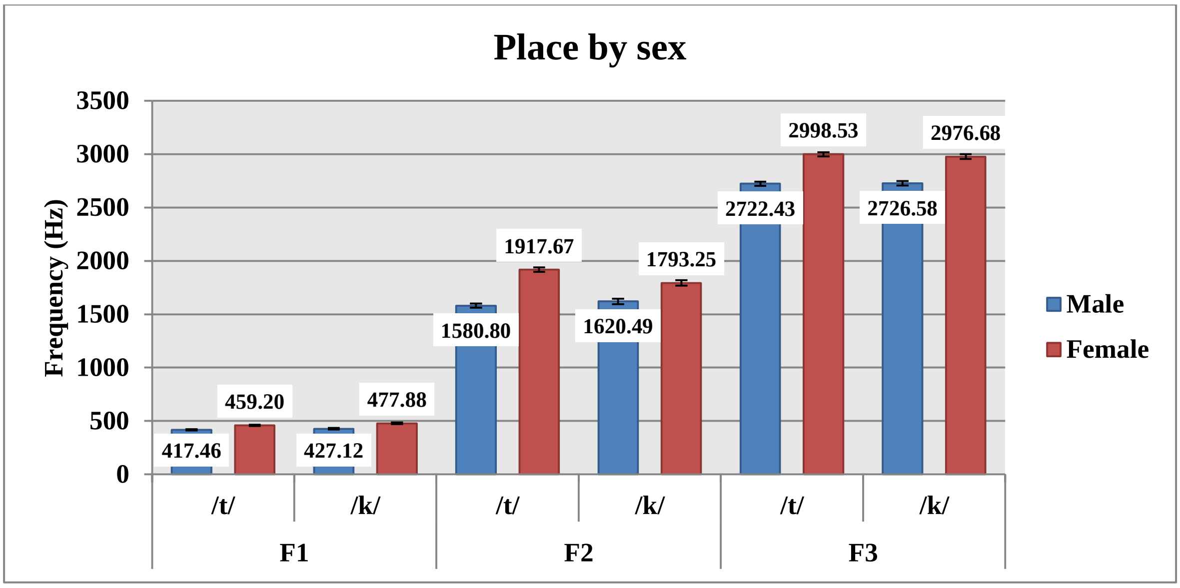


Figure 7.22 Mean formant frequencies (F1-F3) ± S.E. in Hz for alveolar /t/ and velar /k/ from collapsed vowels and their interaction with sex.

However, place, sex and dialect exhibited no significant interaction for F1, F2 or F3 ($p > .05$) (see Table 7.14).

7.5.3.3 Effect of vowel context and the interaction between place and vowel context

Univariate results for each formant frequency (F1-F3) for within-subjects vowel context and the interaction between place and vowel are shown in Table 7.15.

Within subject	F1			F2			F3		
	df	F	p	*df*	F	p	*df*	F	p
Vowels	1,76	123.79	0.001*	1,76	1714.75	0.001*	1,76	44.65	0.001*
Vowels and dialect	1,76	0.305	0.583	1,76	5.38	0.023*	1,76	0.007	0.932
Vowels and sex	1,76	8.713	0.004*	1,76	26.33	0.001*	1,76	20.80	0.001*
Vowels and dialect and sex	1,76	0.149	0.7	1,76	1.316	0.255	1,76	0.158	0.692
Place and vowels	1,76	0.557	0.458	1,76	0.53	0.469	1,76	0.003	0.953
Place, vowel and dialect	1,76	4.192	0.044*	1,76	1.623	0.207	1,76	2.204	0.142
Place, vowel and sex	1,76	2.344	0.13	1,76	4.845	0.031*	1,76	0.757	0.387
Place, vowel, dialect and sex	1,76	0.866	0.355	1,76	8.508	0.005*	1,76	7.519	0.008*

Table 7.15 Results for univariate tests for formant frequencies (F1-F3) for vowels /i:,u:/ in the context of voicelss stops /t,k/ as well as interactions with sex, dialect and sex and dialect, as well as the interactions between place and vowel context with dialect, sex and sex and dialect; * denotes significance.

In this section, vowels will be discussed in terms of their relations with each formant frequency, since the measures of analysis were formants (F1-F3).

For vowels, a significant effect of vowels on F1 ($p < .001$) can be seen in Table 7.15. Post hoc Bonferroni tests showed differences between the two vowels, such that F1 values were higher for /u:/ (479.48 Hz) than for /i:/ (411.35 Hz) ($p < .001$), (see Figure 7.23(a,b)).

In addition, a significant effect of vowels was found on F2 ($p < .001$) (see Table 7.11). Post hoc Bonferroni tests showed differences between the two vowels, such that F2 was higher for /i:/ (2393.50 Hz) than for /u:/ (1062.61 Hz) ($p<.001$), (see Figure 7.23 (a,b)).

Furthermore, a significant effect of vowels was found on F3 ($p < .001$). Post hoc Bonferroni tests showed significantly higher F3 values for /i:/ (2918.26 Hz) than for /u:/ (2793.85 Hz) ($p<.001$), (see Figure 7.23 (a)).

By combining the results of F1 and F2 and examining Figures Figure 7.23 (a,b,c) for vowel spaces and F2xF1 plots, the phonetic differences in vowel quality can be seen, such that /i:/ has a more close quality than /u:/. In addition, /i:/ is more fronted than /u:/.

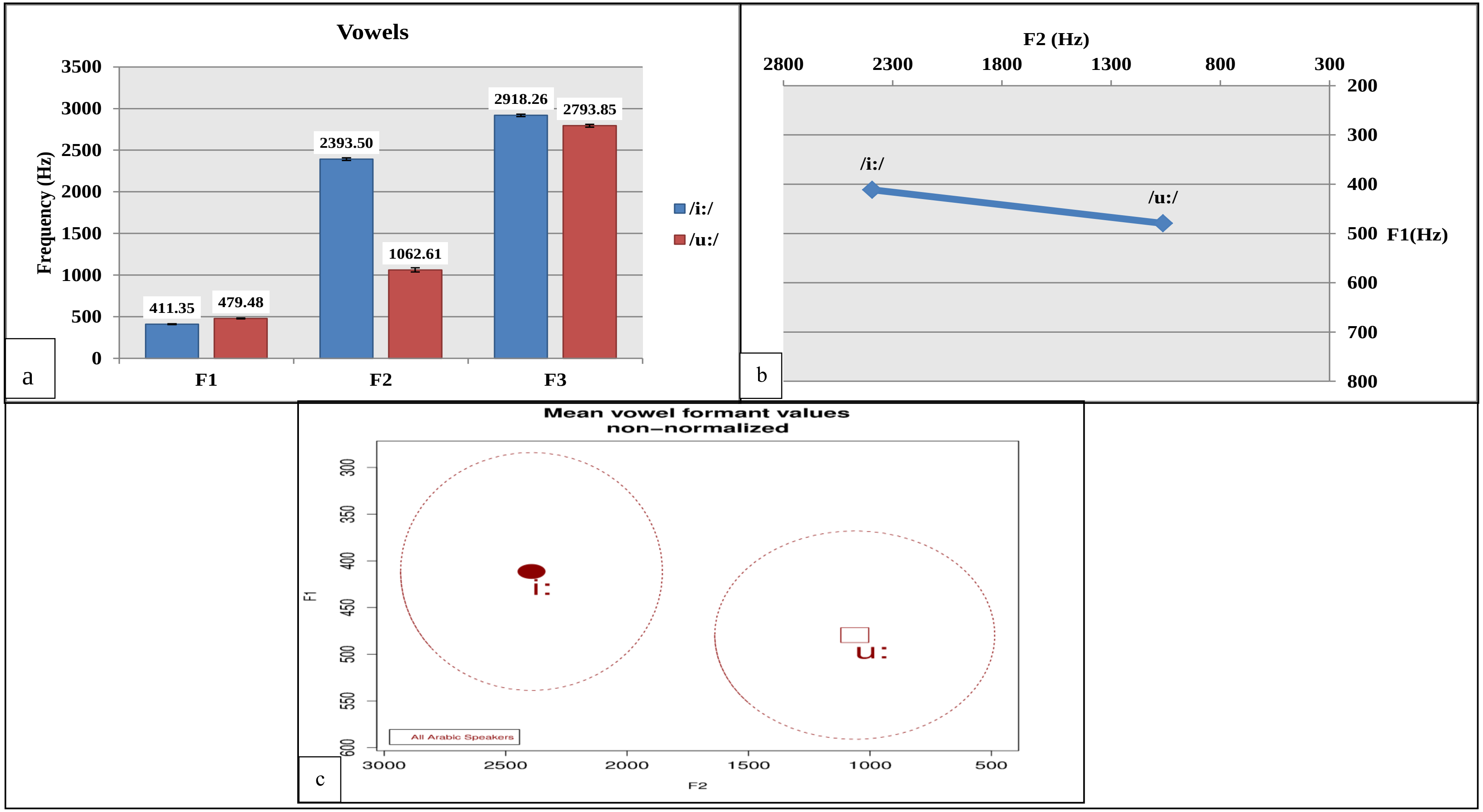


Figure 7.23 a) Mean ± S.E. for mean formants (F1-F3) in Hz for vowels (/i:,u:/) for words with collapsed places of articulation, sex and dialect for Arabic speakers; b) Vowel spaces for Arabic speakers; c)Vowel centroids for vowels (/i:,u:/) for Arabic speakers, with ellipses representing two standard deviations from the group mean with Hz as units of measurement.

The results showed no significant interaction between vowels and dialects for F1 and F3 ($p > .05$) (see Table 7.15).

However, there was a significant interaction between vowels and dialect for F2 ($p < .05$) (see Table 7.15). For /i:/, Saudis exhibited higher F2 values (2662.47 Hz) than Bahrainis (2640.02 Hz). However, for vowel /u:/, Bahrainis had higher F2 values (1125.183 Hz) than Saudis (1000.03 Hz), (see Figure 7.24 (a,b,c)).

By combining the results of F1 and F2 and examining Figure 7.24 (a,b,c) and for vowel spaces and F2xF1 plots, the phonetic differences in vowel quality between the two dialects become clear. Saudis showed greater dispersion for /i:/ than Bahrain speakers, while the opposite was true for /u:/ (i.e., Bahrainis showed more dispersion than Saudis).

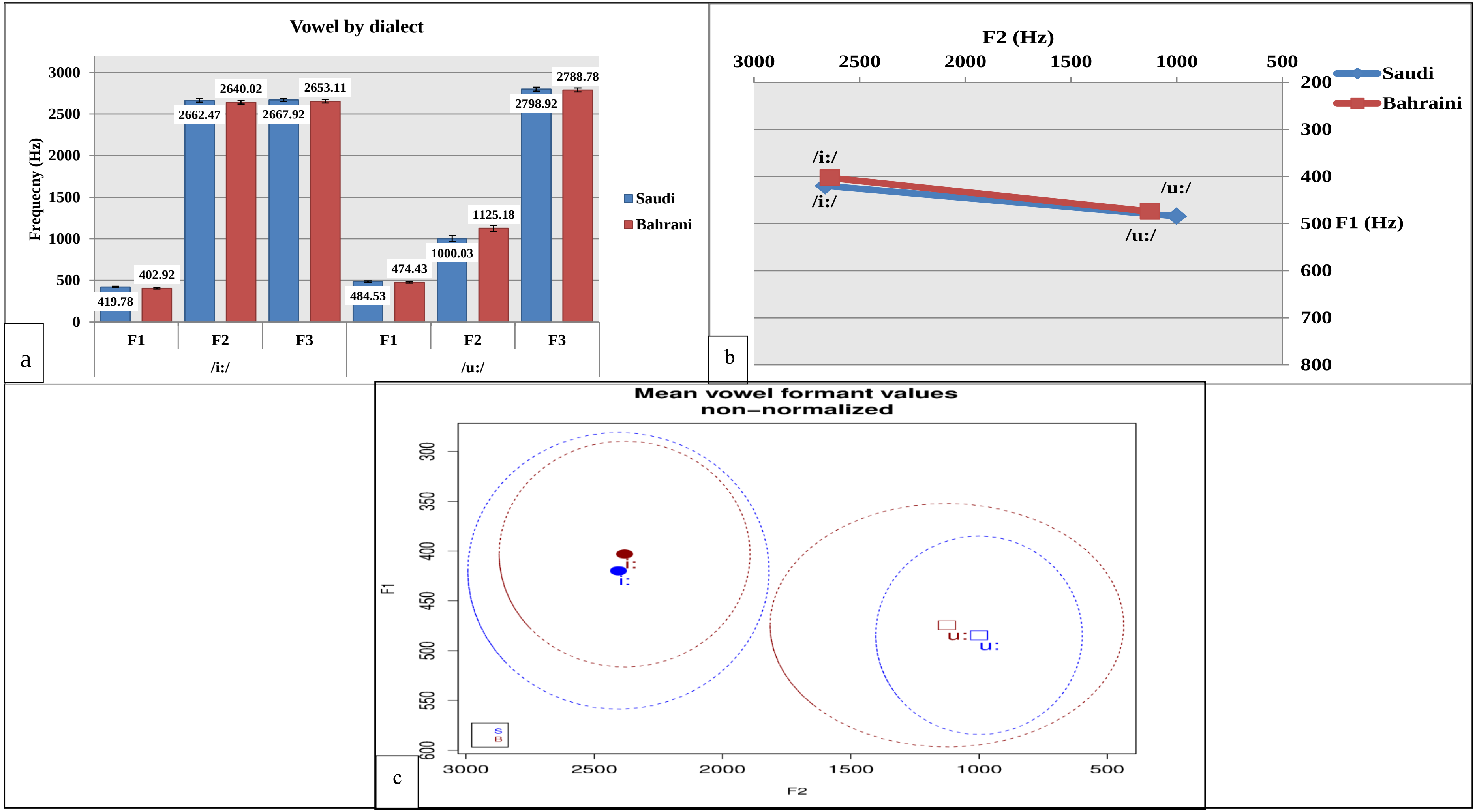


Figure 7.24 a) Mean ± S.E. for mean formants (F1-F3) in Hz for vowels (/i:,u:/) between 40 Saudi and 40 Bahraini Arabic speakers; b) Vowel spaces for 40 Saudi and 40 Bahraini Arabic speakers; c) Vowel centroids for vowels /i:,u:/ for 40 Saudi and 40 Bahraini Arabic speakers, with ellipses representing two standard deviations from the group mean.

The results, as seen in Table 7.15, showed a significant interaction between vowels and sex for F1 ($p < .05$), such that males had lower F1 frequencies for /i:/ (379.19 Hz) and /u:/ (465.39 Hz) than females frequencies for /i:/ (443.51 Hz) and /u:/ (493.57 Hz), (see Figure 7.25 (a,b,c)). The interaction is possibly due to the larger difference between males and females for vowel /i:/ (64.32 Hz) than /u:/ (28.18 Hz), (see Table 7.25 (a)).

Furthermore, there was a significant interaction between vowels and sex for F2 ($p < .001$) (see Table 7.15), such that males exhibited lower F2 frequencies for /i:/ (2183.63 Hz) and /u:/ (1017.66 Hz) than females frequencies for /i:/ (2603.37 Hz) and /u:/ (1107.55 Hz), (see Figure 7.25 (a,b,c)). The interaction is possibly due to the larger difference between males and females for vowel /i:/ (420.00 Hz) than /u:/ (89.89 Hz), (see Table 7.25 (a)).

For F3, there was a significant interaction between vowels and sex ($p < .001$), such that males had lower F3 frequencies for /i:/ (2744.05 Hz) and /u:/ (2704.76Hz) than female frequencies for /i:/ (3092.27 Hz) and /u:/ (2882.95 Hz), (see Figure 7.25(a)). The interaction is possibly due to the larger difference between males and females for vowel /i:/ (384.02 Hz) than /u:/ (178.19 Hz), (see Table 7.25 (a)).

Combining the results from F1 and F2 and examining Figure 7.25 (a,b,c) for vowel spaces and F2xF1 plots illustrates the phonetic differences in vowel quality between the two sexes, such that F1 and F2 values are lower for males than for females for both vowels (/i:/,/u:/). Furthermore, there is greater overlap across ellipses between males and females for /u:/ than there is for /i:/.

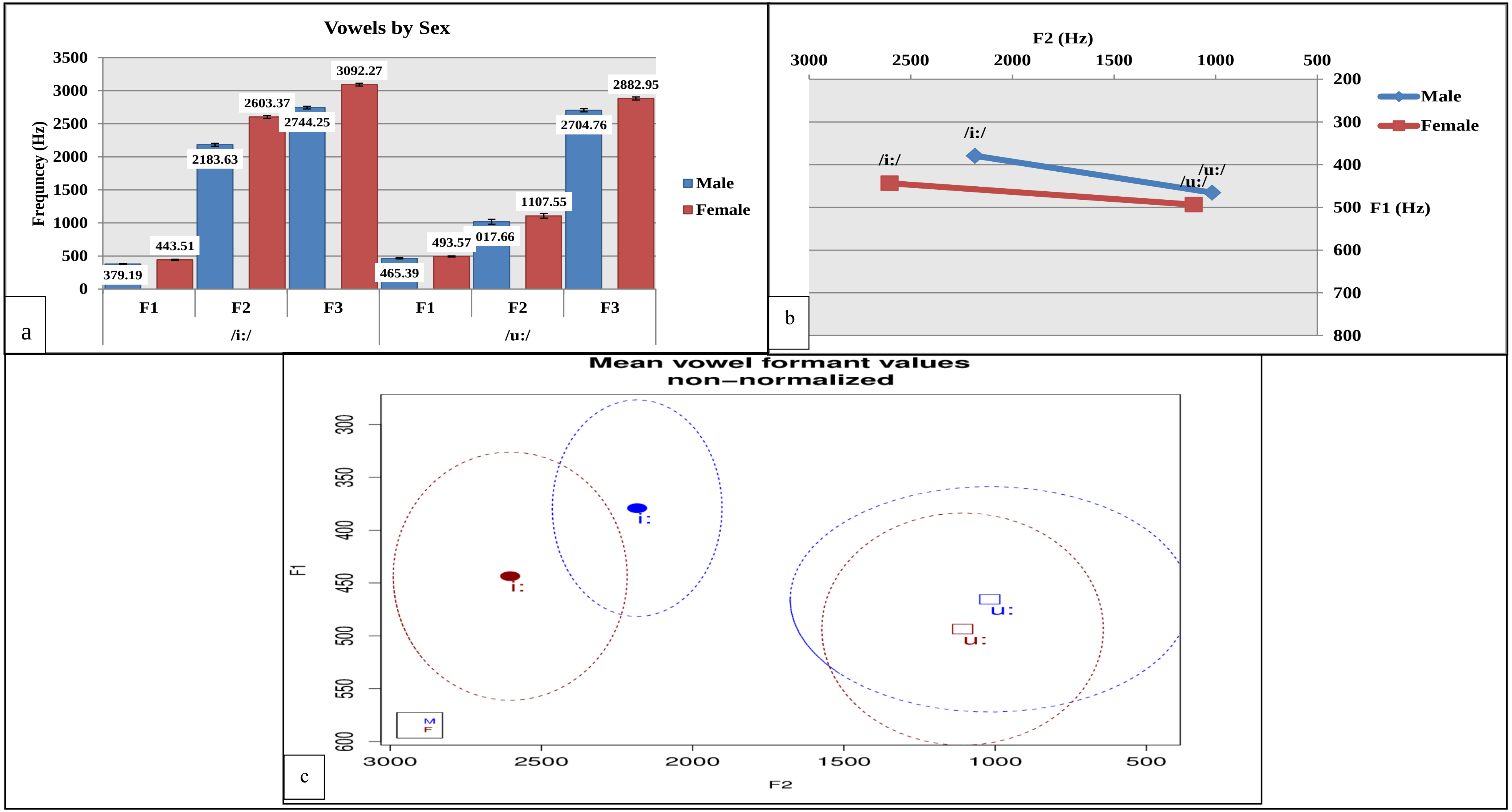


Figure 7.25 a) Mean ± S.E. for mean formants (F1-F3) in Hz for vowels (/i:,u:/) between 40 males and 40 female Arabic speakers; b) Vowel spaces for 40 male and 40 female Arabic speakers c) Vowel centroids for vowels /a:,i:,u:/ for 40 male and 40 female Arabic speakers, with ellipses representing two standard deviations from the group mean.

However, the results showed no significant interactions between vowel and dialect and sex for F1, F2 or F3 (p > .05) (see Table 7.15). In addition, the results showed no significant interaction between place and vowel for F1, F2 or F3 (p > .05) (see Table 7.15).

The results also showed no significant interaction between place and vowel and dialect for F2 (p > .05) (see Table 7.15). However, there was a significant interaction between place and vowel and dialect for F1 (p < .05) (see Table 7.15).

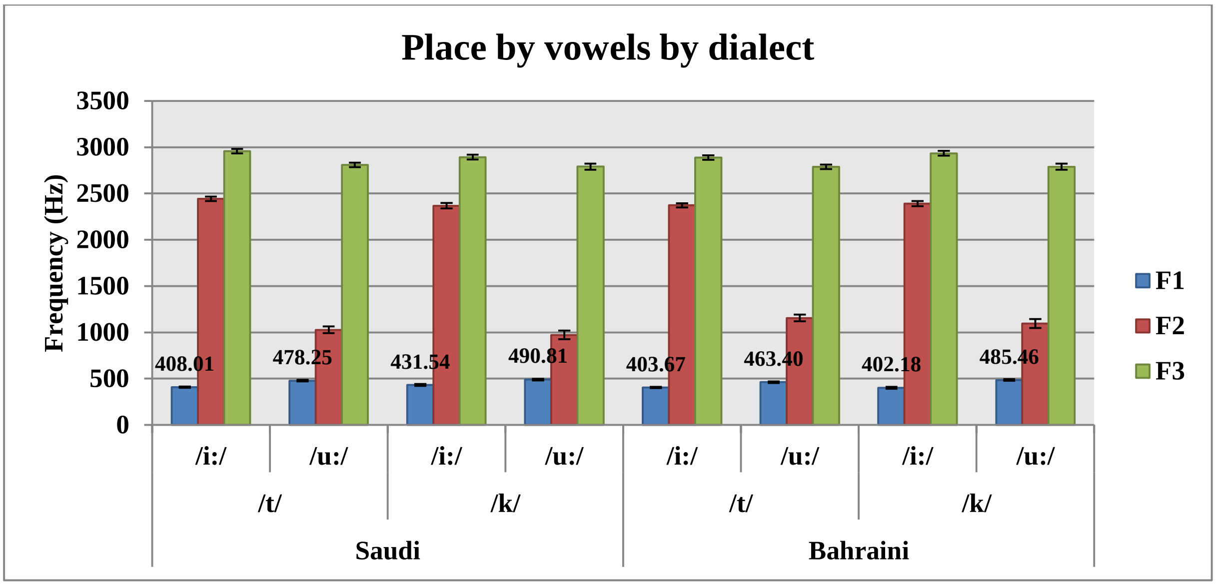


Figure 7.26 Mean ± S.E. for mean formants (F1-F3) in Hz for vowels (/i:,u:/) for voiceless stops /t,/k/ between 40 Saudis and40 Bahraini Arabic speakers.

The results seen in Figure 7.26 and Table 7.12 show that Saudis exhibited lower F1 frequencies for /i:/ for /t/ (408.01 Hz) than /k/ (431.54 Hz). However, for Bahrainis, /t/ showed slightly higher /i:/ values (403.67 Hz) than /k/ (402.18 Hz). In contrast, /u/ for Saudis for /t/ (478.25 Hz) showed lower F1 frequencies than /k/ for /t/ (490.80 Hz). Similarly, Bahrainis showed the same pattern, that /u/ for /t/ (463.40Hz) was lower than /k/ for /t/ (485.46 Hz). This would indicate similar qualities with regard to Bahrainis /i/ productions for /t/ and /k/, whereas, for Saudis, in the /k/ would have a more open quality for /i/ than that for /t/. This can be clearly seen in Figure 7.27, where overlapping is evident between the mean vowel centroids for /i/ for both /t/ and /k/ productions for Bahraini speakers on the left hand side.

Furthermore, an analysis of the F2xF1 plots in Figure 7.27 clearly shows that there is overlapping between the productions for Bahraini and Saudi speakers. However, /ki:r/ and /tu:r/ are more dispersed for Saudis than Bahraini productions for /i:/. In contrast, Bahraini productions for /u:/ show more dispersion than Saudi productions. Moreover, /ku:r/ for Bahrainis exhibits overlap with productions of /i:/ for both Saudis and Bahrainis.

The results also showed no significant interaction between place and vowels and sex for F1, F2 or F3 ($p > .05$) (see Table 7.15).

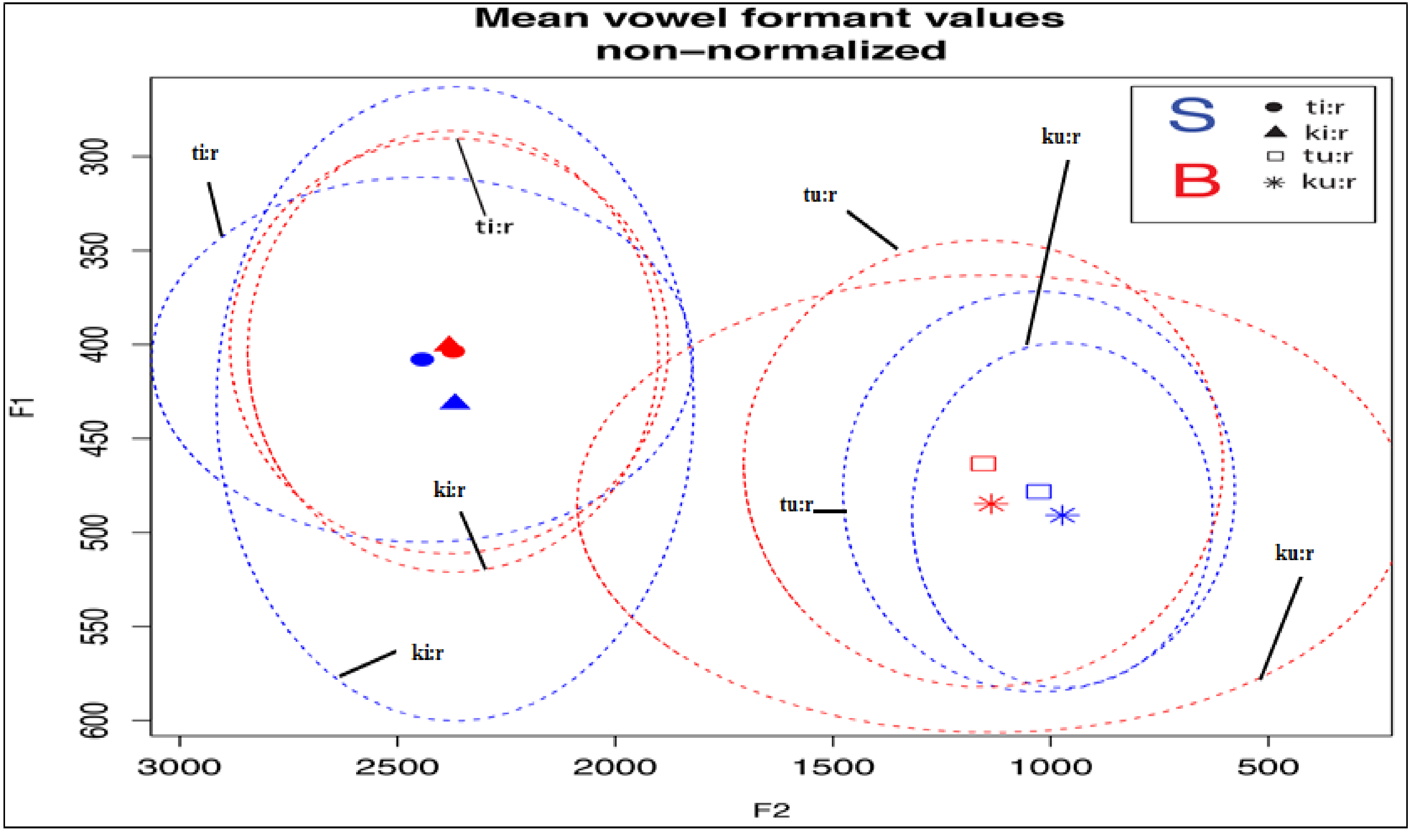


Figure 7.27 Vowel centroids for vowels (/i:,u:/) for initial voiceless alveolar stop /t/ and velar /k/ for 40 Saudis and 40 Bahrainis in Hz, with ellipses representing two standard deviations from the group mean. Note: Ellipsis for /ti:r/ was marked in order to distinguish between /ti:r/ and /ki:r/ for Bahraini speakers.

However, there was a significant interaction between place and vowel and sex for F2 ($p < .05$) (see Table 7.15).

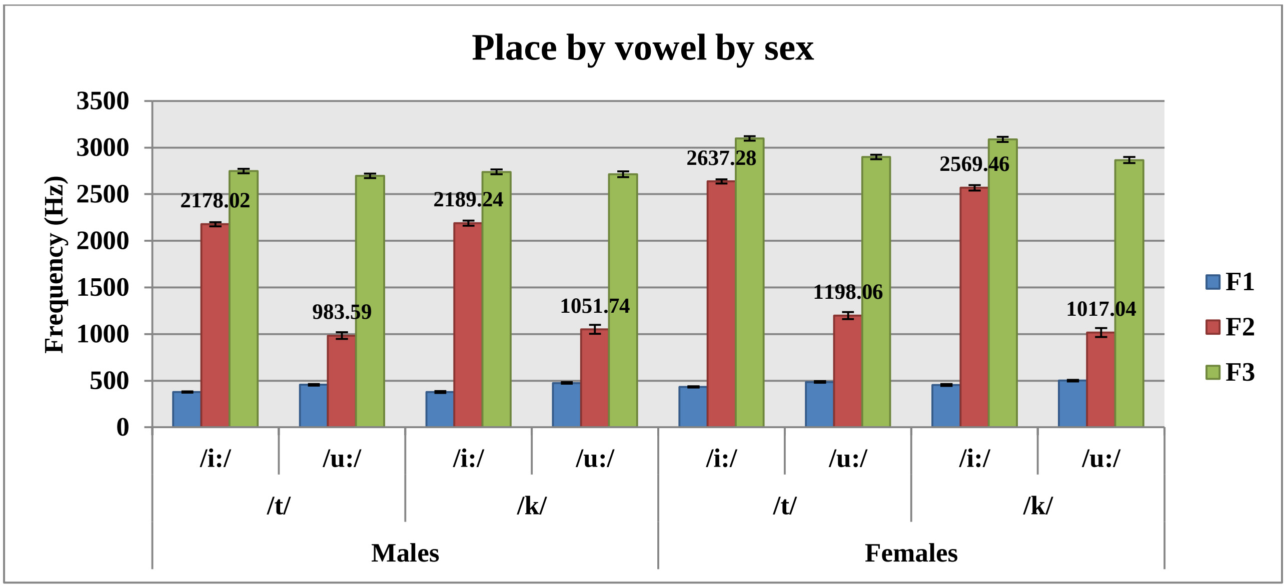


Figure 7.28 Mean ± S.E. for mean Formants (F1-F3) in Hz for vowels (/i:,u:/) for voiceless stops (/t,k/) between 40 males and 40 female Arabic speakers

The results seen in Figure 7.28 and Table 7.12 show that males exhibit lower F2 frequencies for /t/ in /i:/ (2178.02 Hz) and /u:/ (983.59 Hz) than for /k/ in /i:/ (2189.24 Hz) and /u:/ (1051.75 Hz). In contrast, females showed higher F2 frequencies for /t/ in /i:/ (2637.28 Hz) and /u/ (1198.06 Hz) than for /k/ in /i:/ (2569.46 Hz) and /u:/ (1017.04 Hz), (see). Furthermore, an analysis of the F2xF1 plots in Figure 7.29 clearly shows that there is an overlap between the productions of male and female speakers. However, /ti:r/ and /ki:r/ are more dispersed for females than for males.

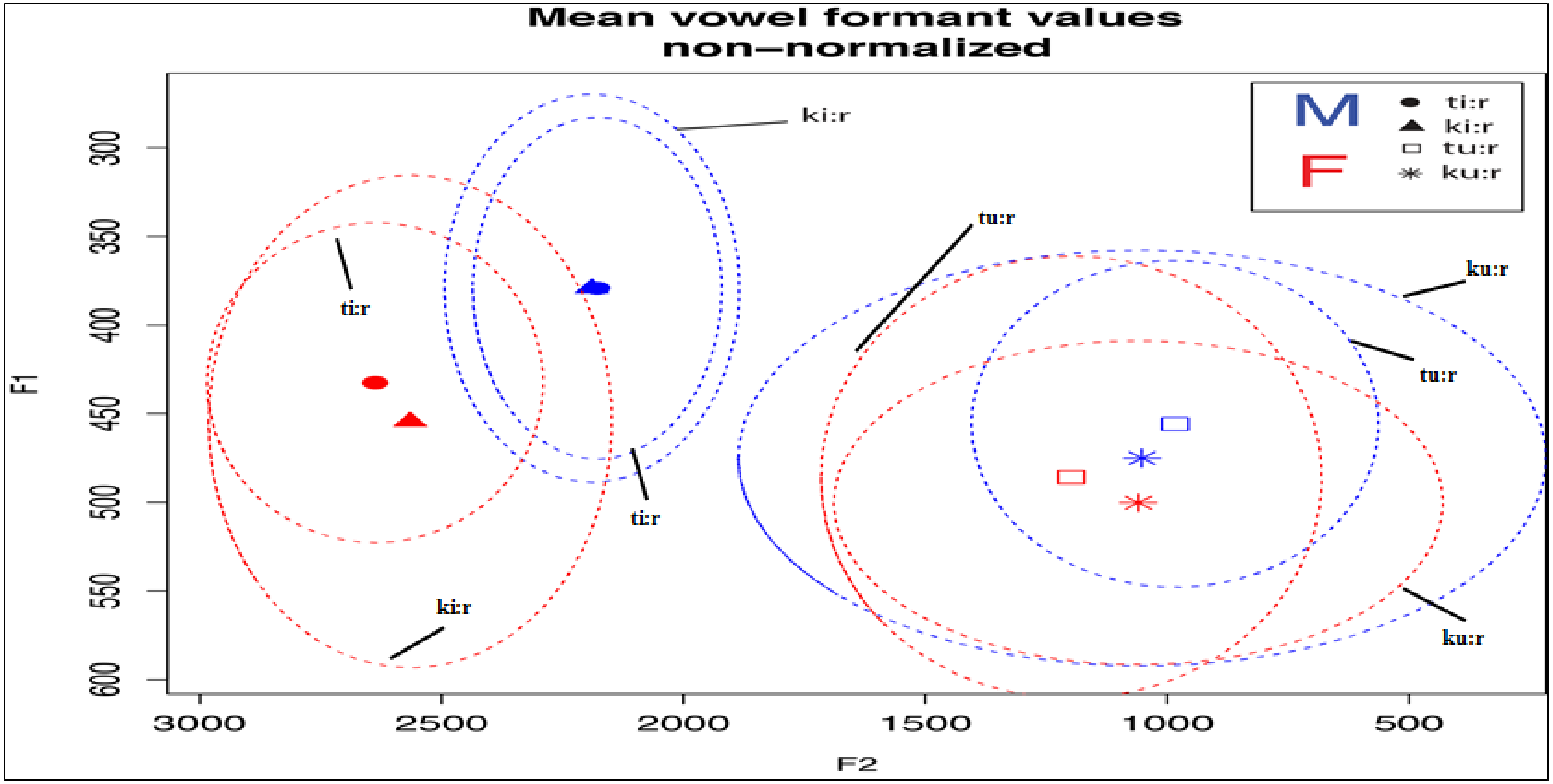


Figure 7.29 Vowel centroids for vowels (/i:,u:/) In Hz for initial voiceless alveolar stop /t/ and velar /k/ for 40 males and 40 females, with ellipses representing two standard deviations from the group mean. Note: Ellipsis for /ki:r/ was marked in order to distinguish between /ti:r/ and /ki:r/ for male speakers.

Place, vowel, sex and dialect showed no significant interaction for F1 ($p > .05$); however, there was a significant interaction for F2 and F3 ($p < .05$) (see Table 7.15).

For F2, the results shown in Table 7.12 and Figure 7.30 illustrate that Saudi males exhibited lower F2 frequencies for /t/ in /i:/ (2178.12 Hz) and /u:/ (904.02 Hz) than for /k/ in /i:/ (2194.26 Hz) and /u:/ (913.59 Hz). Similarly, Bahraini males showed lower F2 frequencies for /t/ in /i:/ (2177.92 Hz) and /u:/ (1063.16 Hz) than for /k/ in /i:/ (2184.22 Hz) and /u:/ (1189.88 Hz). Furthermore, for males, as can be seen in the F2xF1 plot in Figure 7.31, there is clearly an overlap between Saudi and Bahrainis with regard to /t/ and /k/ for /i:/ and /u:/ productions. However, the trend for Bahraini males for /i:/ is less dispersed than that for Saudi males. In contrast, in /u:/ productions, Bahraini males show more dispersion than Saudi males. In addition, /ku:r/ productions for Bahraini males overlap with /i:/ productions for Saudi and Bahraini males.

Saudi females, as can be seen in Table 7.12 and Figures 7.30 and 7.32 , showed higher F2 frequencies for /t/ in /i:/ (2708.15 Hz) and /u/ (1150.26 Hz) than for /k/ in /i:/ (2541.38 Hz) and /u:/ (1032.26 Hz). Moreover, Bahraini females showed a similar trend for only /u:/, such that /t/ (1245.87 Hz) was higher than /k/ (1001.81 Hz). However, Bahraini females showed a similar trend to males for /i/, such that /t/ (2566.42 Hz) was lower than /k/ (2597.54 Hz). In addition, Saudi females only produced a higher F2 than Bahraini females for /t/ in /i/ (2194.26 Hz, in comparison to 2566.42 Hz for Bahraini females). In contrast, Bahraini females showed higher F2 frequencies for /t/ in /u/ (1245.87 Hz) than Saudi females (1032.26 Hz), as well as higher F2 frequencies for /k/ in /i:/,/u:/ (3110.53, 2817.82 Hz) than Saudi females (2541.38, 1032.26 Hz), respectively.

In addition, the trend for Saudi females for /t/ in /i:/ (2708.15 Hz) and /u:/ (1150.26 Hz), as well as for Bahraini females for /t/ in /u:/ (1245.87 Hz), had slightly higher values than those for Saudi females for /k/ in /i:/ (2541.38 Hz) and /u:/ (1032.26 Hz) and for Bahraini females for /k/ in /u:/ (1001.81 Hz). However, for Bahraini females, there was an opposite trend for /i:/, such that /k/ (2579.54 Hz) was slightly higher than /t/ (2566.42 Hz) (see Figure 7.32).

Furthermore, for females (as opposed to the case for males), as can be seen in the F2xF1 plots in Figure 7.32, no overlapping between vowels occurred. However, overlapping between Saudi and Bahraini females occurred for the productions of /i:/ and /u:/. For /i:/ productions, Bahraini females showed less dispersion than Saudi females, while /ki:r/ productions for Saudi females showed more dispersion than the production of /i:/ for Saudi and Bahraini females. For /u:/, Saudi females' productions of /ku:r/ showed the least dispersion, when compared to the Saudi females' productions of /tu:r/ and the /u/ productions of Bahraini females. Meanwhile, a similar dispersion quality was found for the remaining productions for /u:/ for /t/ and /k/ for both Saudi and Bahraini females.

For F3, according to the results in Table 7.12 and Figure 7.30, a trend was present for males and females of both dialects, such that /i:/ generally had higher F3 frequencies than /u/, with the exception of the case of Bahraini males for /ki:r/ (2757.58 Hz), which showed F3 values similar to those of /u:/ (2760.74 Hz).

With regard to a comparison between Saudi and Bahraini dialects, Saudi males showed lower F3 frequencies for /ti:r/ (2739.37 Hz), /ki:r/ (2720.76 Hz) and /ku:r/ (2667.23 Hz) than Bahraini males /ti:r/ (2759.29 Hz), /ki:r/ (2757.58 Hz) and /ku:r/ (2760.74 Hz) frequencies. However, for /tu:r/, Saudi males (2695.96 Hz) showed an F3 value similar to that of Bahraini males (2695.11 Hz) (see Figure 7.39). For females, an opposite trend appeared, such that Saudi females had higher F3 values for /ti:r/ (3174.89 Hz), /tu:r/(2918.77 Hz) and /ku:r/ (2913.73 Hz) than Bahraini females' values for /ti:r/, /tu:r/ and /ku:r/ (3019.02 Hz, 2881.46 Hz and 2817.82 Hz, respectively). However, for /ki:r/, Bahraini females produced higher F3 frequencies (3110.53 Hz) than Saudi females (3064.65 Hz),(see Figure 7.30).

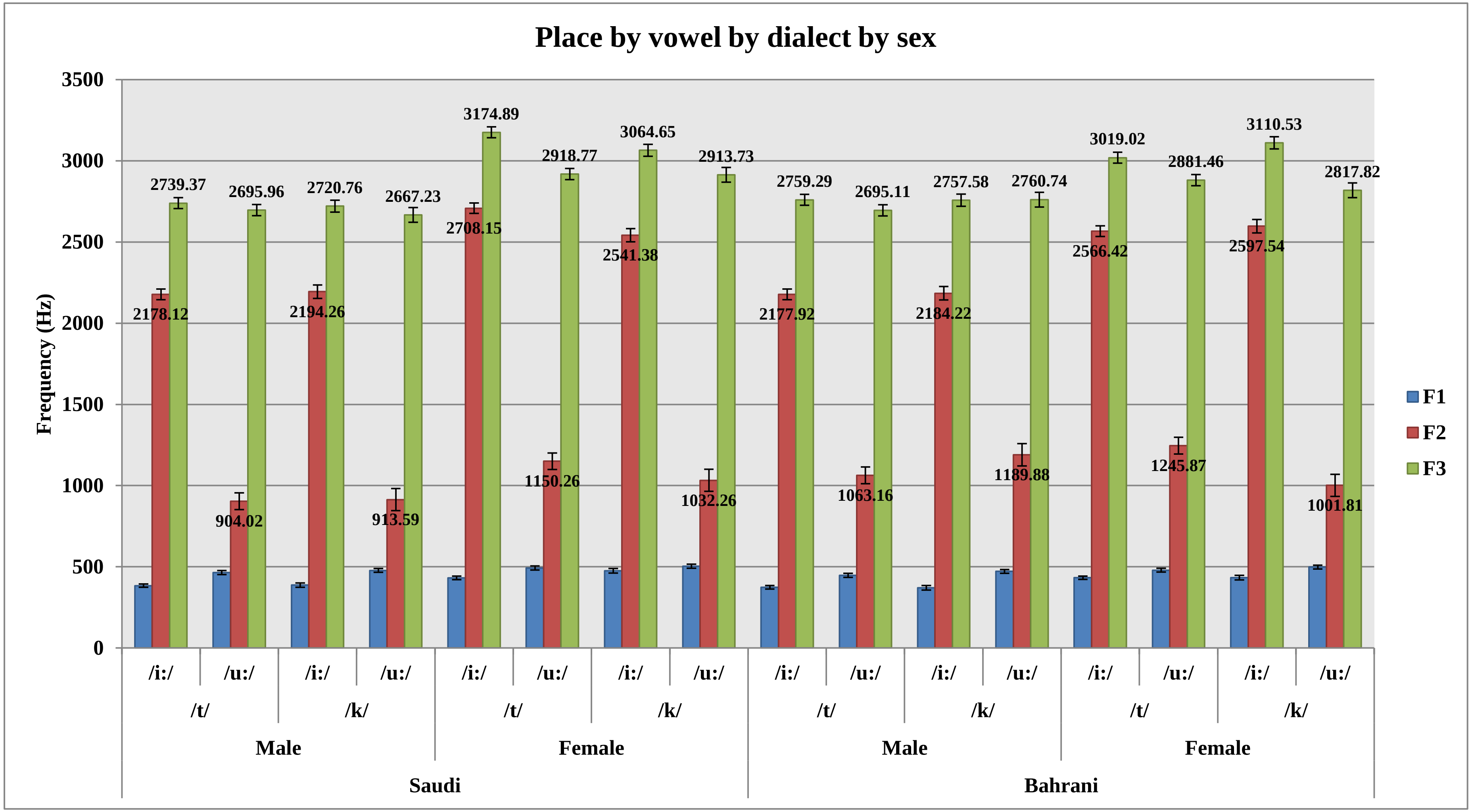


Figure 7.30 Mean ± S.E. for mean formants (F1-F3) in Hz for vowels (/i:,u:/) for voiceless stops (/t,k/) between sexes (males and female) and dialects (Saudi and Bahraini) for Arabic speakers.

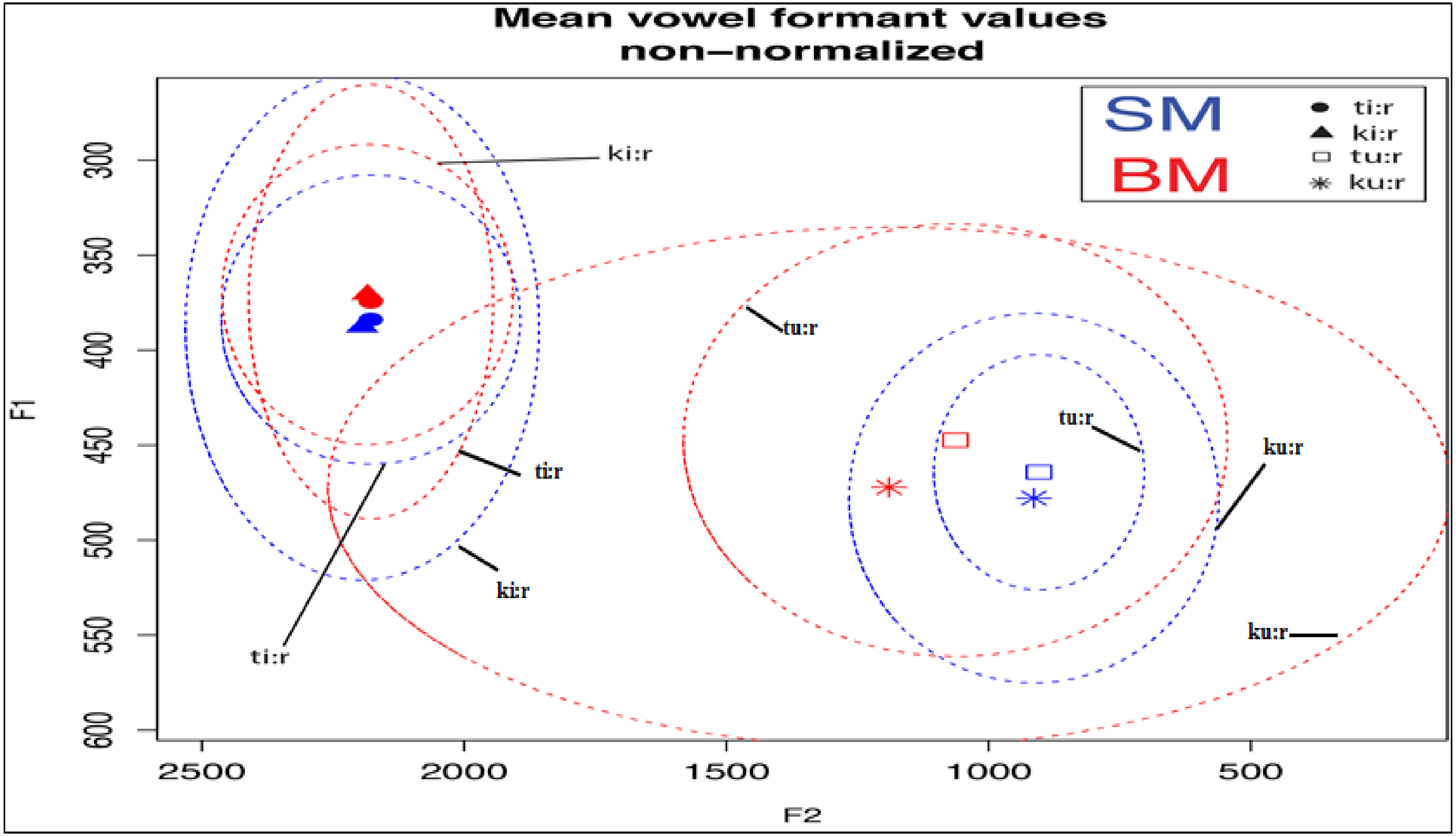


Figure 7.31 Vowel centroids in Hz for vowels (/i:,u:/) for initial voiceless alveolar stop /t/ and velar /k/ for 20 Saudi males and 20 Bahraini males, with ellipses representing two standard deviations from the group mean. Note: Ellipsis for /ti:r/ and /ki:r/ were marked for Saudi male and Bahraini males, respectively , in order to distinguish between dialects.

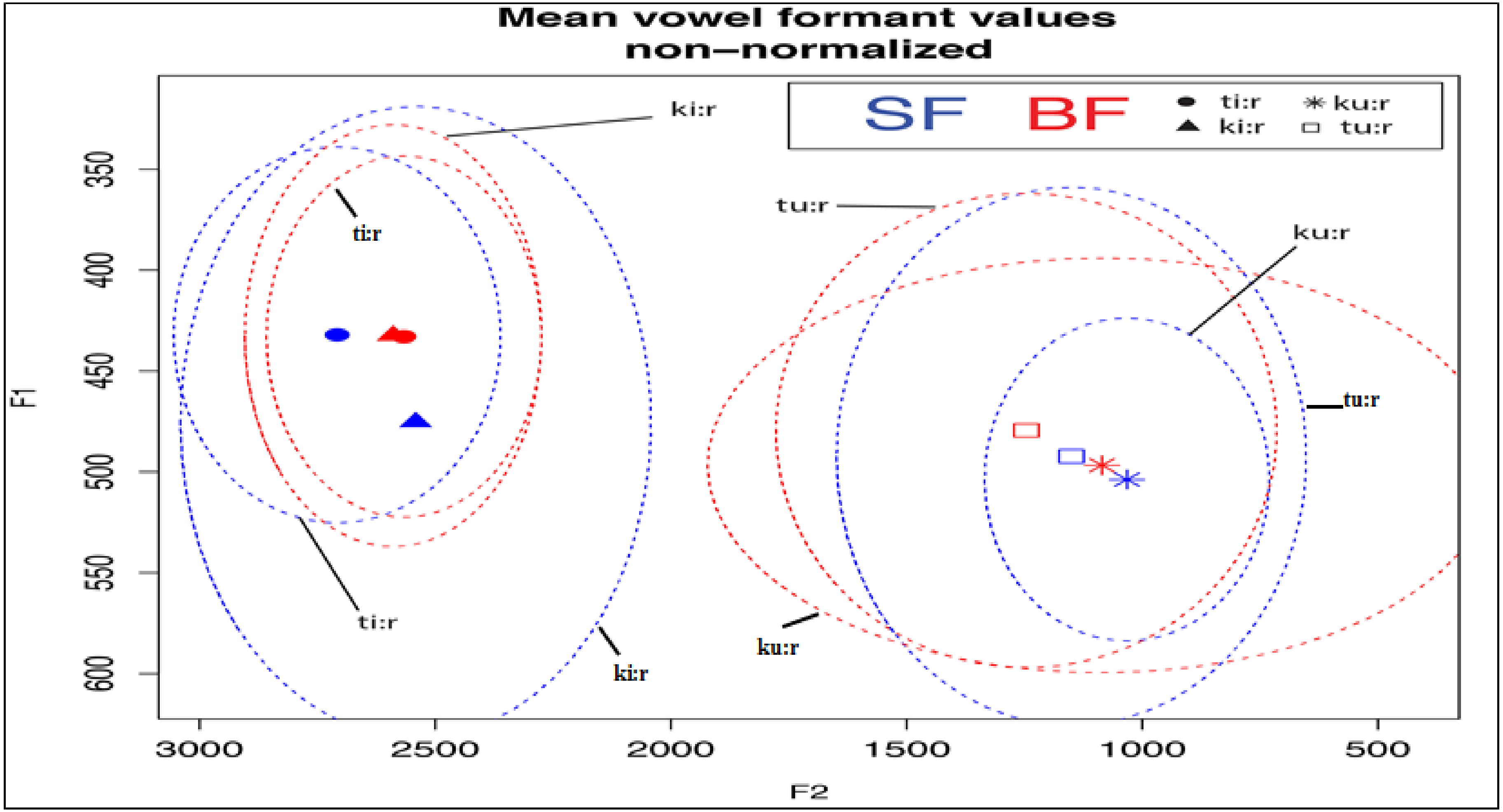


Figure 7.32 Vowel centroids in Hz for vowels (/i:,u:/) for initial voiceless alveolar stop /t/ and velar /k/ for 20 Saudi females and 20 Bahraini females, with ellipses representing two standard deviations from the group mean. Note: Ellipsis for (/ti:r/,/tu:r/) and (/ki:r/,/kur/) were marked for Saudi female and Bahraini females, respectively , in order to distinguish between dialects.

7.5.4 Plain and emphatic stops

Results for mean formant frequencies (F1-F3 in Hertz) for two vowel contexts /i:,u:/ for words with the initial voiceless plain stop /t/ and voiceless emphatic /tˤ/ are presented in Table 7.16 as a function of dialect and gender. The word contexts were as follows: (/ti:r/, /tu:r/) × (/tˤi:r/,/tˤu:r/).

				/i/			/u/		
				F1	F2	F3	F1	F2	F3
	Sex	Dialect	N	Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.	Mean S.D.
/t/	Male	Saudi	20	383.90 (38.06)	2178.12 (142.60)	2739.37 (139.27)	464.208 (30.96)	904.017 (100.37)	2695.96 (176.58)
		Bahraini	20	374.4 (57.19)	2177.92 (116.59)	2759.29 (161.64)	447.328 (56.99)	1063.15 (259.49)	2695.11 (154.70)
		Total	40	379.2 (48.19)	2178.02 (128.56)	2749.33 (149.27)	455.768 (46.07)	983.586 (210.25)	2695.53 (163.86)
	Female	Saudi	20	432.1 (46.57)	2708.14 (173.51)	3174.89 (161.13)	492.282 (66.71)	1150.26 (249.25)	2918.77 (131.42)
		Bahraini	20	432.9 (44.78)	2566.42 (145.85)	3019.02 (133.22)	479.477 (58.79)	1245.87 (265.73)	2881.45 (147.36)
		Total	40	432.5 (45.09)	2637.28 (173.72)	3096.96 (165.91)	485.88 (62.40)	1198.06 (258.86)	2900.11 (139.11)
	Total	Saudi	40	408.00 (48.56)	2443.13 (310.81)	2957.13 (265.96)	478.245 (53.26)	1027.14 (225.21)	2807.36 (190.62)
		Bahraini	40	403.7 (58.72)	2372.17 (235.98)	2889.15 (196.65)	463.403 (59.42)	1154.51 (275.26)	2788.28 (176.47)
		Total	80	405.8 (53.58)	2407.65 (276.51)	2923.14 (234.90)	470.824 (56.56)	1090.83 (257.97)	2797.82 (182.77)
/tˤ/	Male	Saudi	20	463.24 (44.68)	1983.5 (117.61)	2671.02 (116.46)	482.33 (48.08)	821.3 (103.68)	2762.36 (125.57)
		Bahraini	20	461.69 (77.45)	1940.47 (220.86)	2680.89 (132.87)	479.51 (54.62)	894.97 (239.75)	2792.55 (152.59)
		Total	40	462.47 (62.41)	1961.99 (176.00)	2675.95 (123.42)	480.92 (50.81)	858.13 (186.10)	2777.45 (138.78)
	Female	Saudi	20	539.66 (84.17)	2306.68 (242.21)	3064.29 (159.04)	511.84 (62.58)	1178.38 (391.11)	3074.93 (199.29)
		Bahraini	20	558.59 (119.61)	2257.31 (315.16)	3031.05 (141.28)	525.2 (92.21)	1101.15 (209.8)	3368.41 (1521.65)
		Total	40	549.13 (102.53)	2281.99 (278.56)	3047.67 (149.43)	518.52 (78.08)	1139.77 (312.24)	3221.67 (1081.42)
	Total	Saudi	40	501.45 (76.95)	2145.09 (249.20)	2867.65 (242.05)	497.08 (57.08)	999.84 (335.34)	2918.64 (228.22)
		Bahraini	40	510.14 (110.9)	2098.89 (312.88)	2855.97 (223.08)	502.35 (78.30)	998.06 (245.65)	3080.48 (1106.53)
		Total	80	505.8 (94.94)	2121.99 (282.00)	2861.81 (231.35)	499.72 (68.13)	998.95 (292.07)	2999.56 (797.99)

Table 7.16 Mean formant frequency values F1-F3 (Hz) and standard deviation values in parentheses for words with initial plain and emphatic stops (/t/tˤ/) in two vowel contexts (/i:,u:/) for male and female participants from two Arabic dialects (Saudi and Bahraini).

A mixed-model ANOVA was conducted in which emphasis and the vowels were the repeated measures, with the mean formant frequencies (F1-F3) serving as the measure of analysis, while dialect and sex were the between-subject factors.

7.5.4.1 Dialect and sex

Univariate tests for dialect showed no significant effects for all formant frequencies (F1-F3) (p > .05), as seen in Table 7.17.

Between subjects	Dialect			Sex			Dialect and sex		
Formant	*df*	F	Sig.	*df*	F	Sig.	*df*	F	Sig.
F1	1,76	0.018	0.894	1,76	28.239	0.001*	1,76	0.426	0.516
F2	1,76	0.007	0.94	1,76	149.24	0.001*	1,76	3.01	0.09
F3	1,76	0.104	0.75	1,76	49.02	0.001*	1,76	0	0.98

Table 7.17 Results for univariate tests for formant frequencies (F1-F3) for between subject factors (dialect, sex and the interaction between sex and dialect) for plain and emphatic stops; * denotes significance.

Univariate tests revealed a significant effect of sex for F1, F2 and F3 (p < .001), as shown in Table 7.17. Post hoc Bonferroni tests showed significant differences (p < .001) for all formant frequencies (F1-F3), such that males had lower F1 (444.58 Hz), F2 (1495.43 Hz) and F3 (2724.57 Hz) frequencies than females F1 (496.51 Hz), F2 (1814.28 Hz) and F3 (3066.60 Hz) frequencies, respectively (see Figure 7.33).

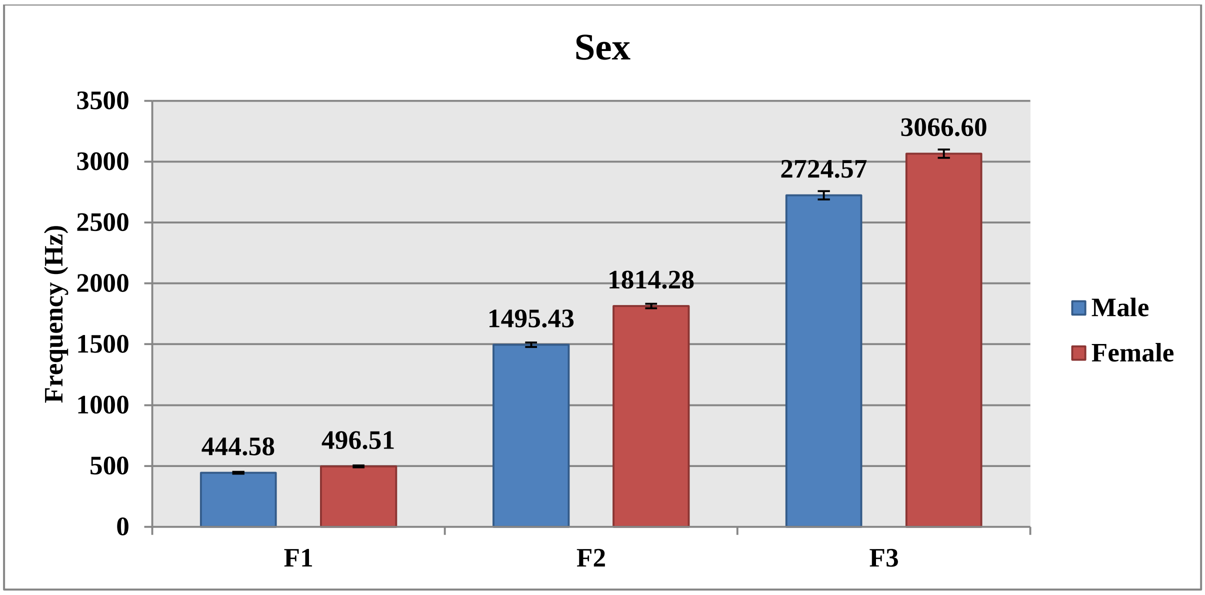


Figure 7.33 Mean ± S.E. formant frequencies (F1-F3) in Hz for male and female Arabic speakers for plain and emphatic /t,tˤ/ stops.

However, as can be viewed in Table 7.17, there was no significant interaction between sex and dialect for all formant frequencies ($p > .05$).

7.5.4.2 Emphasis

Univariate tests for place showed a significant effect of emphasis for F1 ($p < .001$) and F2 ($p < .05$), as can be seen in Table 7.18 and Figure 7.34.

	Emphasis			Emphasis and dialect			Emphasis and sex			Emphasis by dialect by sex		
Formant	*df*	F	Sig.	*df*	F	Sig.	*df*	F	Sig.	*df*	F	Sig.
F1	1,76	95.777	0.001*	1,76	1.585	0.212	1,76	2.4	0.126	1,76	0.179	0.673
F2	1,76	75.018	0.001*	1,76	1.434	0.235	1,76	0.684	0.411	1,76	0.075	0.785
F3	1,76	2.562	0.114	1,76	1.828	0.18	1,76	2.26	0.137	1,76	1.519	0.222

Table 7.18 Results for univariate tests for formants (F1-F3) for emphasis and for interaction with sex, dialect and place, sex and dialect; * denotes significance.

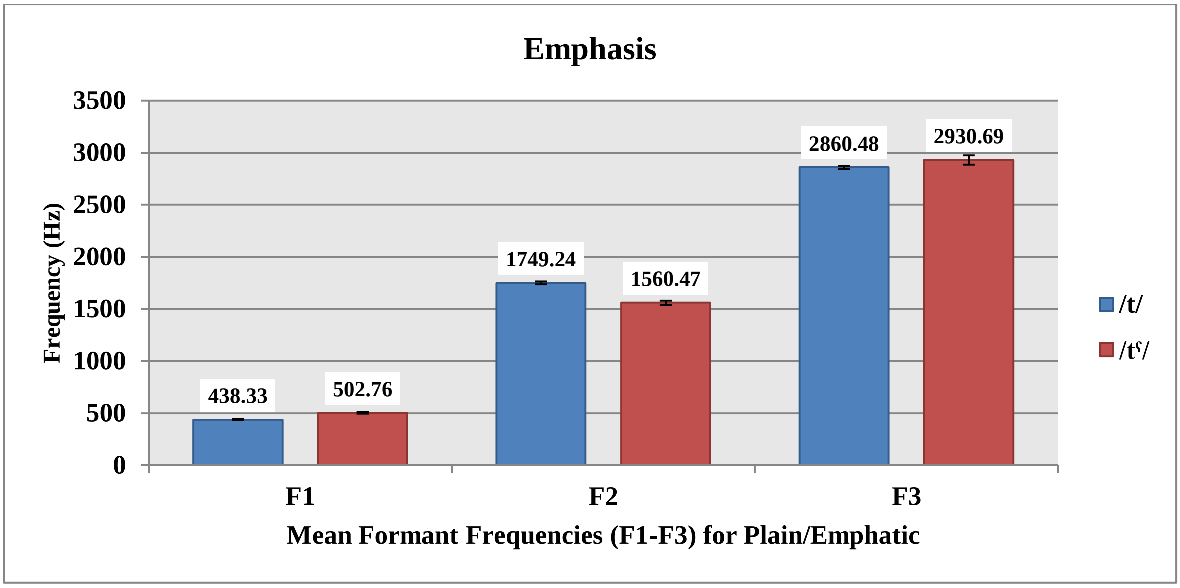


Figure 7.34 Mean formant frequencies (F1-F3) ± S.E. in Hz for plain /t/ and emphatic /tˤ/ from collapsed vowels.

Post hoc Bonferroni tests showed significant differences for F1 ($p < .001$) and F2 ($p < .001$), such that /t/ had lower F1 frequencies (438.33 Hz) than /tˤ/ (502.76 Hz). However, /t/ had higher F2 frequencies (1749.24 Hz) than /tˤ/ (1560.47 Hz) (see Figure 7.34).

Emphasis and dialect showed no significant interaction for F1, F2 and F3 ($p > .05$), as well as no significant interaction between emphasis and sex for F1, F2 and F3 ($p > .05$) and no significant interaction between emphasis, dialect and sex for F1, F2 and F3 ($p > .05$) (see Table 7.18).

7.5.4.3 Effect of vowel context and interaction between emphasis and vowel context

Univariate results for each formant frequency (F1-F3) for within-subject vowel context and the interaction between place and vowel are shown in Table 7.19.

Within subjects	F1			F2			F3		
	df	F	p	*df*	F	p	*df*	F	p
Vowel	1,76	21.299	0.001*	1,76	1508.158	0.001*	1,76	0.02	0.889
Vowel and dialect	1,76	0.297	0.587	1,76	3.733	0.057	1,76	1.573	0.214
Vowel and sex	1,76	8.022	0.006*	1,76	5.078	0.027*	1,76	0.158	0.692
Vowel, sex and dialect	1,76	0.043	0.837	1,76	0.07	0.792	1,76	1.58	0.213
Emphasis and vowel	1,76	37.958	0.001*	1,76	31.454	0.001*	1,76	8.571	0.005*
Emphasis, vowel and dialect	1,76	0.094	0.76	1,76	4.961	0.029*	1,76	0.481	0.49
Emphasis, vowel and sex	1,76	1.252	0.267	1,76	8.921	0.004*	1,76	1.439	0.234
Emphasis, vowel, sex and dialect	1,76	0.002	0.967	1,76	2.593	0.111	1,76	0.216	0.643

Table 7.19 Results for univariate tests for formant frequencies (F1-F3) for vowel context /i:,u:/ with initial plain and emphatic stop /t,tˤ/ in as it interacts with sex, dialect and sex and dialect. In addition, the results for the interaction between emphasis and vowel context with dialect, sex and sex and dialect; * denotes significance. Note that p values displayed in this table are exact values.

In this section, vowels will be discussed in terms of their relation to each formant frequency, since the measures of analysis were formants (F1-F3).

For vowels, a significant effect of vowels on F1 frequencies was found ($p < .001$) (see Table 7.19). Post hoc Bonferroni tests showed differences between the two vowels, such that F1 was higher for /u:/ (485.27 Hz) than for /i:/ (455.82 Hz) ($p < .001$), (see Figure 7.35 (a,b,c)).

In addition, a significant effect of vowels was found on F2 ($p < .001$), see Table 7.19. Post hoc Bonferroni tests showed differences between the two vowels, such that F2 was higher for /i:/ (2264.82 Hz) than for /u:/ (1044.89 Hz) ($p < .001$), (see Figure 7.35 (a,b,c)). However, no significant effect of vowels was found for F3 ($p > .05$) (see Table 7.19).

Combining the results of F1 and F2 and viewing Figure 7.35 (a,b,c) for vowel spaces and F2xF1 plots illustrates the phonetic differences in vowel quality, /i:/ had a marginally more close quality than /u:/. In addition, /i:/ was more fronted than /u:/. In terms of dispersion, /i:/ showed a more dispersed production than /u:/, and no overlapping occurred between vowels.

With regard to vowel and dialect, there was no significant interaction for F1, F2 or F3 ($p > .05$) (see Table 7.19). In addition, there was no significant interaction between vowel, dialect and sex for F1, F2 or F3 ($p > .05$) (see Table 7.19).

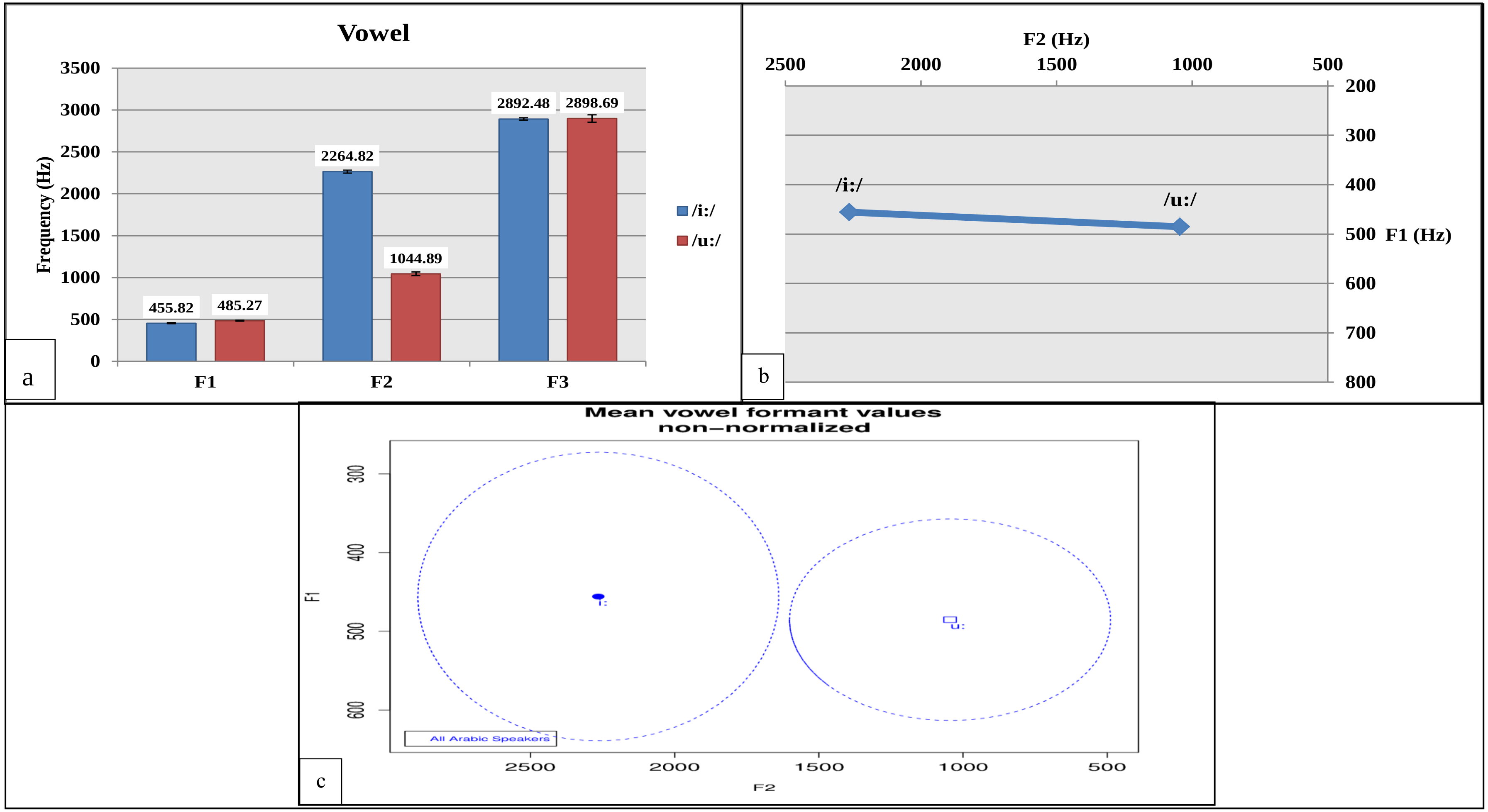


Figure 7.35 a) Mean ± S.E. for mean formants (F1-F3) in Hz for vowels (/i:,u:/) for emphatic and non- emphatic data for Arabic speakers; b) Vowel spaces in Hz for Arabic speakers; c) Vowel centroids in Hz for vowels (/i:,u:/) for Arabic speakers, with ellipses representing two standard deviations from the group mean.

For vowel and sex, there was a significant interaction for F1 and F2 ($p < .05$); however, there was no significant interaction for F3 ($p > .05$) (see Table 7.19).

The results showed a significant interaction between vowel and sex for F1 ($p < .05$), such that males had lower F1 frequencies for /i:/ (420.81 Hz) and /u:/ (468.34 Hz) than females did for /i:/ (490.82 Hz) and /u:/ (502.20 Hz), (see Figure 7.36 (a,b,c)). However, the interaction is possibly due to the larger difference between males and females for vowel /i:/ (70.01 Hz) than /u:/ (33.86 Hz), (see Figure 7.36 (a)).

Furthermore, there was a significant interaction between vowels and sex for F2 ($p < .05$), such that males showed lower F2 frequencies for /i:/ (2070.00 Hz) and /u:/ (920.86 Hz) than females did for /i:/ (2459.64 Hz) and /u:/ (1168.92 Hz), (see Figure 7.36 (a,b,c)). However, the interaction is possibly due to the larger difference between males and females for vowel /i:/ (394.64 Hz) than /u:/ (248.06 Hz), (see Figure 7.36 (a)).

Combining the results from F1 and F2 and examining Figure 7.36 (a,b,c) vowel spaces and F2xF1 plots, it is clear that there are phonetic differences in vowel quality between the two sexes, such that F1 and F2 values are lower for males than for females for both vowels (/i:/,/u:/). Furthermore, there is greater overlapping across ellipses between males and females for /u:/, while less overlapping is seen for /i:/. In addition, females tend to show more dispersed productions of /i:/ and u:/ than males.

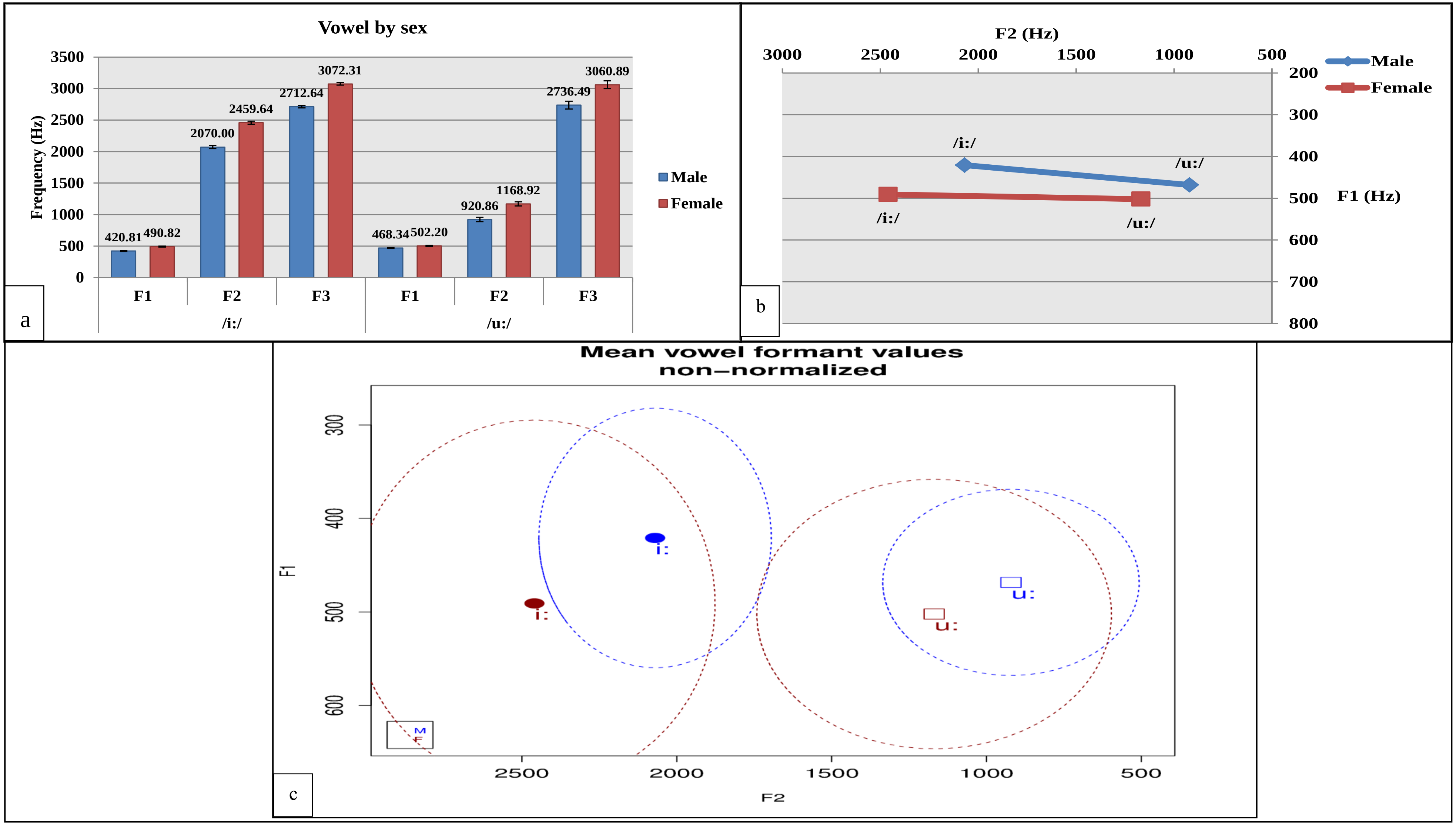


Figure 7.36 a) Mean ± S.E. for mean formants (F1-F3) in Hz for vowels (/i:,u:/) between 40 male and 40 female Arabic speakers; b) Vowel spaces in Hz for 40 male and 40 female Arabic speakers; c) Vowel centroids in Hz for vowels (/i:,u:/) for 40 male and 40 female Arabic speakers, with ellipses representing two standard deviations from the group mean.

As can been seen in Table 7.19, there was a significant interaction between vowels and emphasis for F1, F2 ($p < .001$) and F3 ($p < .05$).

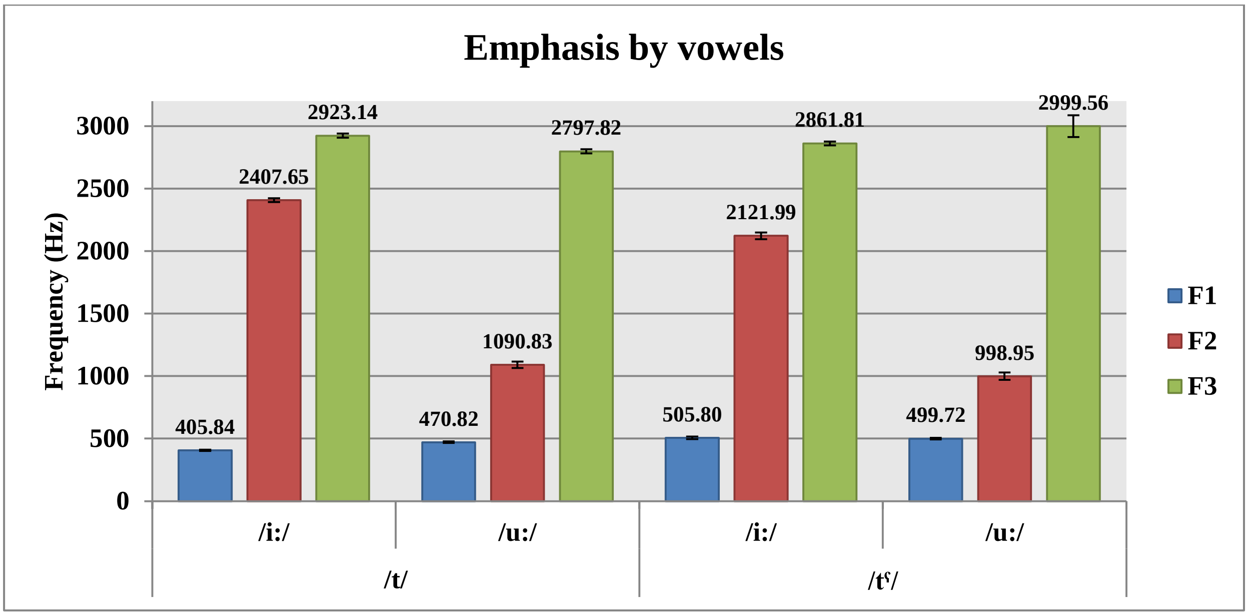


Figure 7.37 Mean ± S.E. for mean formants (F1-F3) in Hz for vowels (i:,u:) for words with initial plain/emphatic /t,tˤ/ stops for 80 Arabic speakers.

For F1, as can be seen in Figure 7.37, in /t/, /i/ had lower F1 frequencies (405.84 Hz) than /u:/ (470.82 Hz), while /tˤ/ had slightly lower F1 frequencies for /u:/ (499.72 Hz) than for /i:/ (505.80 Hz). However, the interaction is possibly due to the larger difference between the plain and emphatic in the context of vowel /i:/ (99.96 Hz) than /u:/ (28.90 Hz) which showed an increase in F1 values in the context of the emphatic stop /tˤ/ compared with the plain /t/ (see Figure 7.37). In terms of vowel quality, overlap occurred between /ti:r/ and /tˤu:r/. Vowels adjacent to the plain stop /t/ showed less dispersion than vowels adjacent to the emphatic /tˤ/ (see Figure 7.38).

For F2, as can be seen in Figure 7.37 and Figure 7.38, /i:/ in /t/ (2407.65 Hz) and /tˤ/ (2121.99 Hz) had higher F2 frequencies than /u:/ in /t/ (2121.99Hz) and /tˤ/ (998.95Hz). However, the interaction is possibly due to the larger difference between the plain and emphatic in the context of vowel /i:/ (- 284.66 Hz) than /u:/ (- 91.88 Hz) which showed a decrease in F2 values in the context of the emphatic stop /tˤ/ compared with the plain /t/, (see Figure 7.37). As can be seen in Figure 7.38, /ti:r/ exhibited a more peripheral quality than the remaining productions.

For F3, the interaction is possibly due to the larger difference between the plain and emphatic which showed an increase in the context of vowel /i:/ (- 61.33 Hz), while for /u:/, an increase occurred in the context of /tˤ/ compared to plain /t/ (201.74 Hz), (see Figure 7.37).

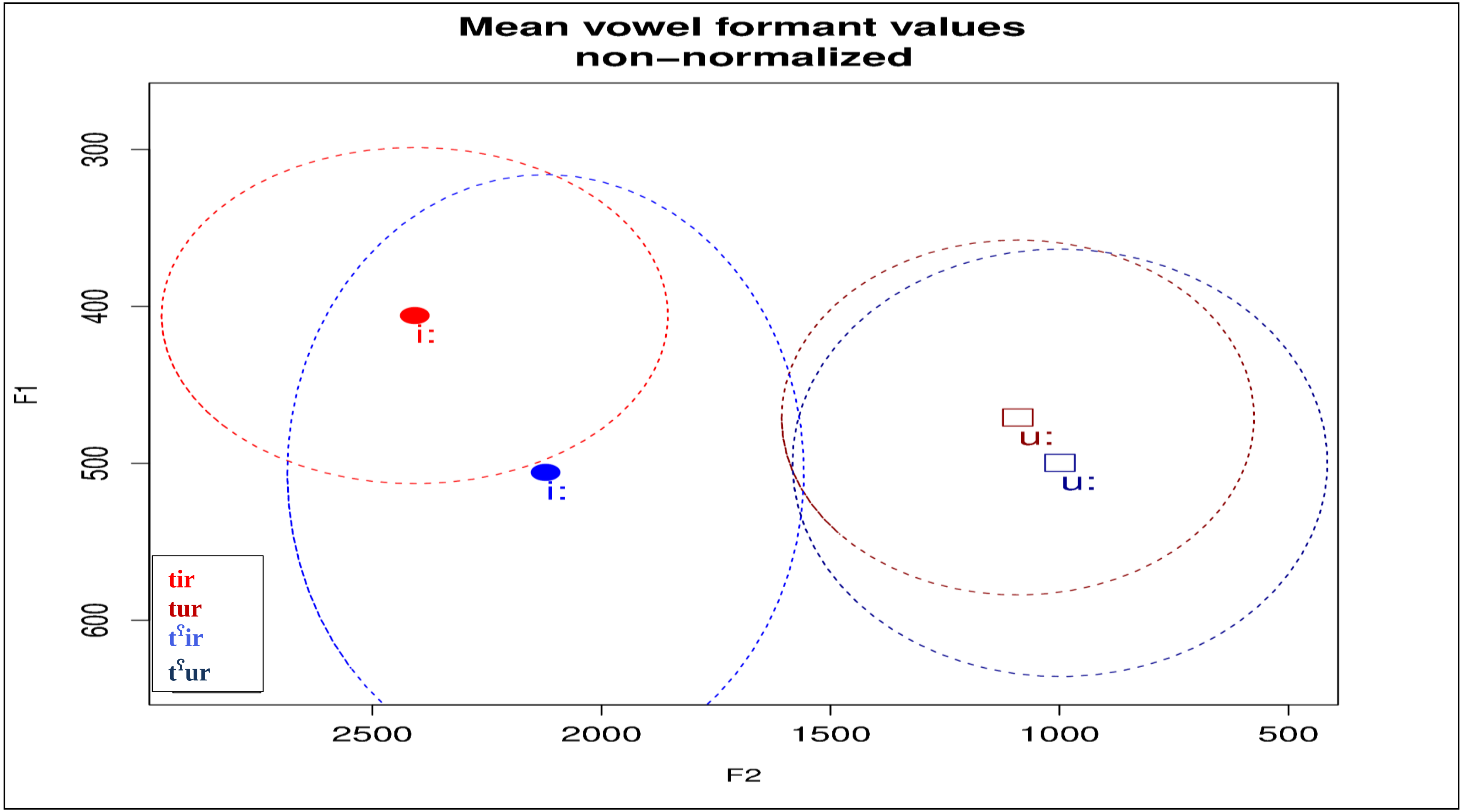


Figure 7.38 Vowel centroids in Hz for vowels (/i:,u:/) for initial plain stop /t/ and emphatic /tˁ/ for all 80 Arabic speakers with ellipses representing two standard deviations from the group mean.

The results showed no significant interaction between emphasis and vowels and dialect for F1 and F3 ($p > .05$). However, there was a significant interaction between place and vowel and dialect for F2 ($p < .05$) (see Table 7.19).

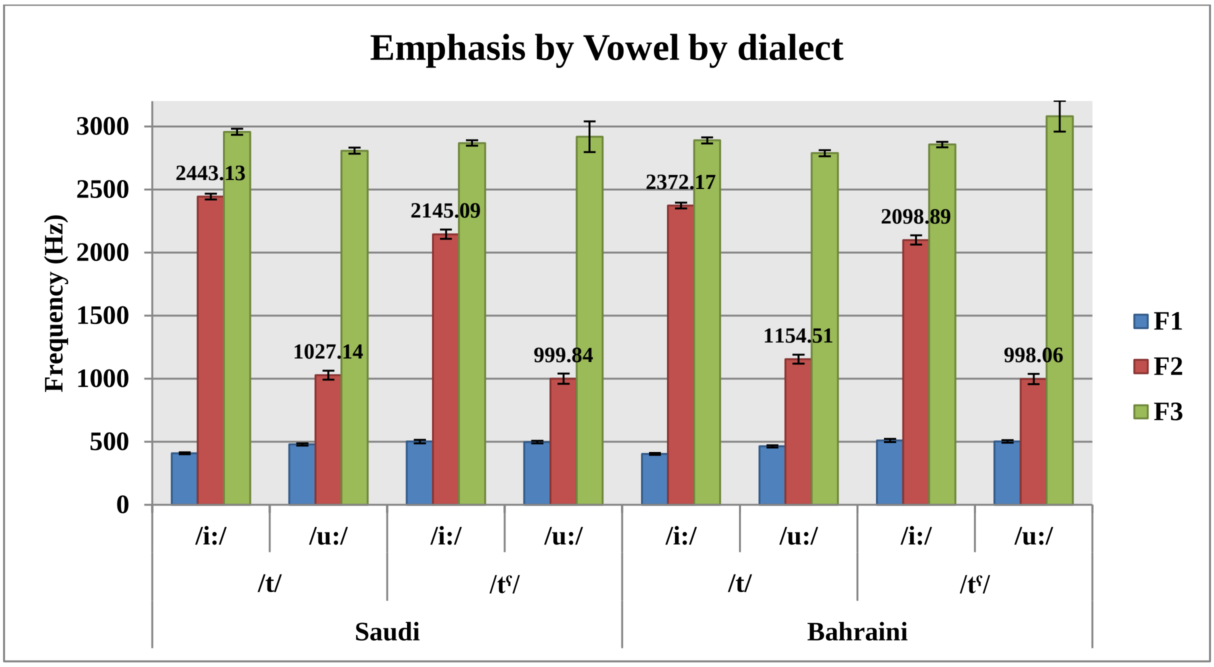


Figure 7.39 Mean ± S.E. for mean formants (F1-F3) in Hz for vowels (i:,u:) for voiceless stops /t,k/ between 40 Saudi and 40 Bahraini Arabic speakers

The results seen in Figure 7.39 and Table 7.16 show that, for Saudis, /i:/ for /t/ (2443.13 Hz) and /tˤ/ (2145.09 Hz) had higher F2 frequencies than /u:/ for /t/ (1024.14 Hz) and /tˤ/ (999.84 Hz). A similar trend occurred with Bahrainis, such that /i:/ for /t/ (2372.17 Hz) and /tˤ/ (2098.89 Hz) had higher values than /u/ for /t/ (1154.51 Hz) and /tˤ/ (998.06 Hz). However, the interaction is possibly due to the larger difference between the plain and emphatic which showed more decrease in the context of vowel /u:/ for Bahrainis (- 156.45 Hz) than Saudis (- 27.30 Hz). While, the differences were observed between the plain and emphatic stop for /i:/ Saudis was slightly larger (- 298.04 Hz) than Bahraini speakers (- 273.28 Hz), (see Figure 7.39).

In Figure 7.39 and Figure 7.40, it is clear that Saudis showed higher F2 frequencies for /i:/ in /t/ (2443.13 Hz) and /tˤ/ (2145.09 Hz) than Bahrainis did for /i:/ in /t/ (2372.17 Hz) and /tˤ/ (2098.89 Hz). However, for /u:/, Bahrainis showed higher F2 values for /t/ (1154.51 Hz) than Saudis did for /t/ (1027.14Hz). Moreover, minimal differences were observed for /u/ for /tˤ/ between Saudis (999.84 Hz) and Bahrainis (998.06 Hz), suggesting some overlapping between the mean vowel centroids of Saudis and Bahrainis /tˤu:r/, see Figure 7.40.

Furthermore, an examination of the F2xF1 plots in Figure 7.40 shows that there is overlap between Bahraini and Saudi productions of plain /t/ and emphatic /tˤ/. Plain /t/ productions for /i:/ for Saudis and Bahrainis show a more peripheral and a more closed quality than emphatic /tˤ/ productions for /i:/. Saudi and Bahraini productions for /ti:r/ are less dispersed than those for /tˤir/. However, /tˤir/ for Bahrainis is more dispersed among the productions for /i:/ for plain and emphatic stops. In contrast, for /u:/ production, less dispersion occurs for both Saudis and Bahrainis, while some overlapping from /tu:r/ arises for /tˤi:r/.

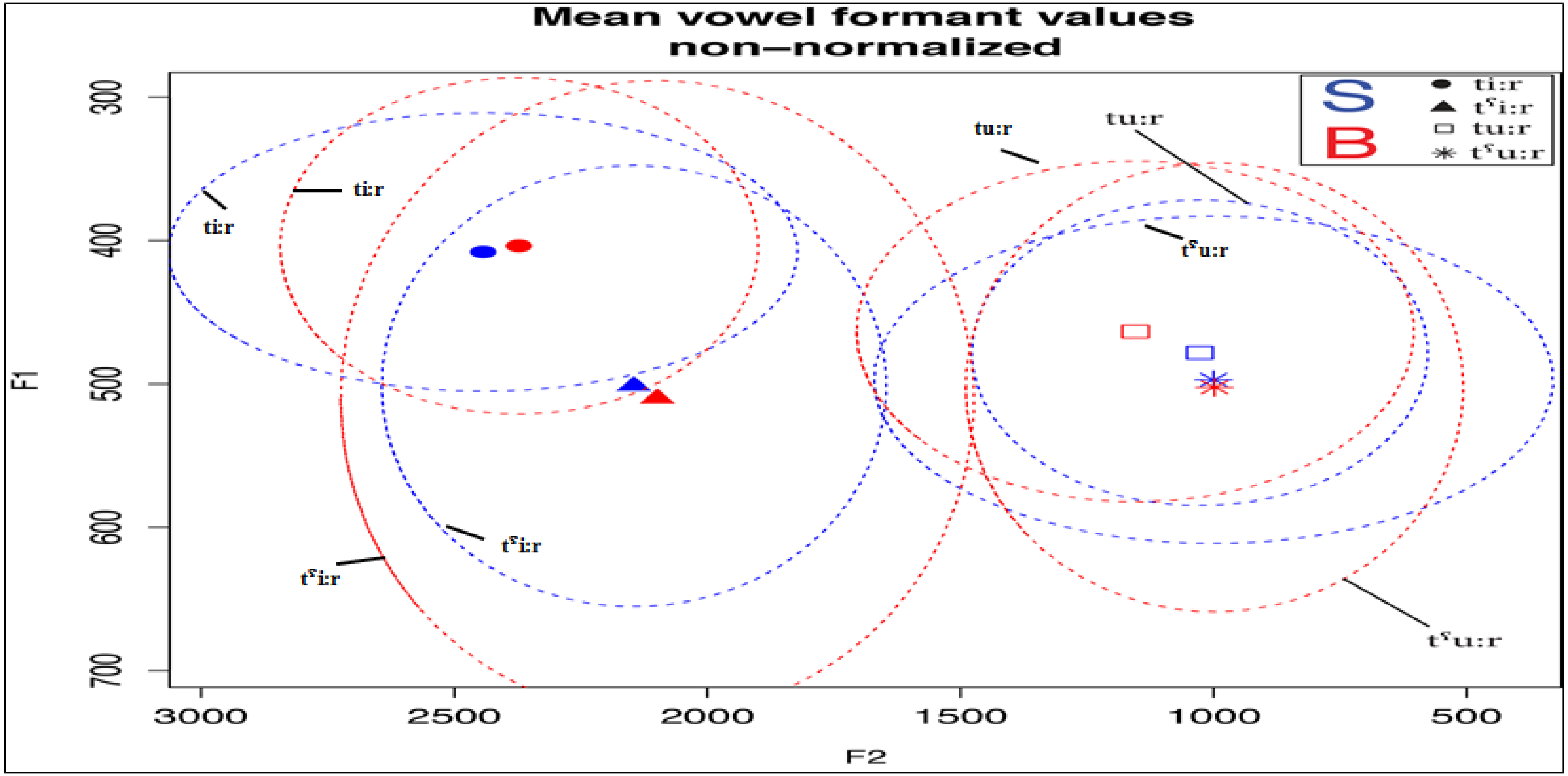


Figure 7.40 Vowel centroids in Hz for vowels (/i:,u:/) for initial voiceless plain /t/ and emphatic /tˤ/ stops for 40 Saudis and 40 Bahrainis, with ellipses representing two standard deviations from the group mean. Note: Ellipsis for /tu:r/ and /tˤur/ were marked for Saudi and Bahraini, respectively, in order to distinguish between dialects.

Results also showed no significant interaction between emphasis and vowel and sex for F1 and F3 (p > .05). However, there was a significant interaction between emphasis and vowel and sex for F2 (p < .05) (see Table 7.19).

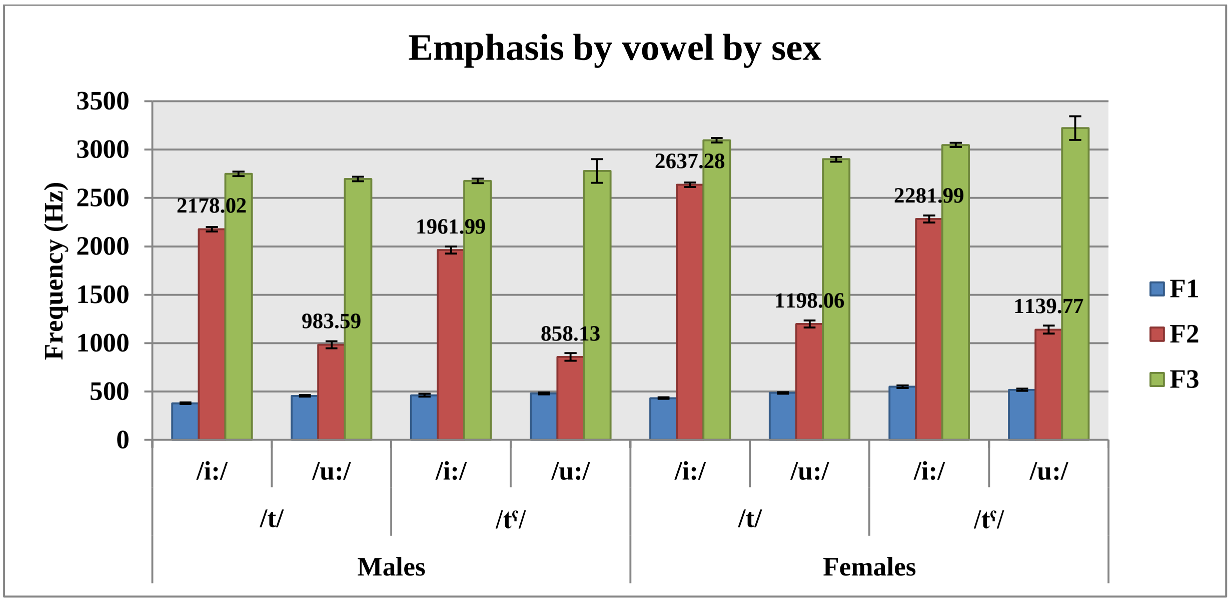


Figure 7.41 Mean ± S.E. for mean formants (F1-F3) in Hz for vowels (i:,u:) for plain and emphatic stops /t,tˤ/ for 40 male and 40 female Arabic speakers.

The results in Figure 7.41 and Table 7.16 showed that males exhibited higher F2 values for /t/ in /i:/ (2178.02 Hz) and /u:/ (983.59 Hz) than for /tˤ/ in /i:/ (1961.99 Hz) and /u:/ (858.13 Hz). Similarly, females showed higher F2 values for /t/ in /i:/ (2637.28 Hz) and /u/ (1198.06 Hz) than for /tˤ/ in /i:/ (2281.99 Hz) and /u:/ (1139.77 Hz),(see Figure 7.57). However, the interaction is possibly due to the larger difference between the plain and emphatic which showed an decrease in the context of vowel /i:/ for males (216.03 Hz) and females (355.29 Hz) in the context of the emphatic /tˤ/ in comparison with lesser differences observed in vowel /u:/ for males (125.46 Hz) and females (58.29 Hz), (see Figure 7.41).

Furthermore, according to the F2xF1 plots in Figure 7.42 , there is a slight overlap between the productions of male and female speakers—and, specifically, between males' and females' /tˤir/ and females' /tu:r/ and /tˤur/. Females' /ti:r/ showed a more peripheral quality than the remaining production of /i:/; however, females' /tu:r/ and /tˤi:r/ had more fronted qualities than those for males. In terms of dispersion, females were more dispersed than males. However, there was no significant interaction between emphasis, vowel, sex and dialect for F1, F2 or F3 ($p>.05$) (see Table 7.19).

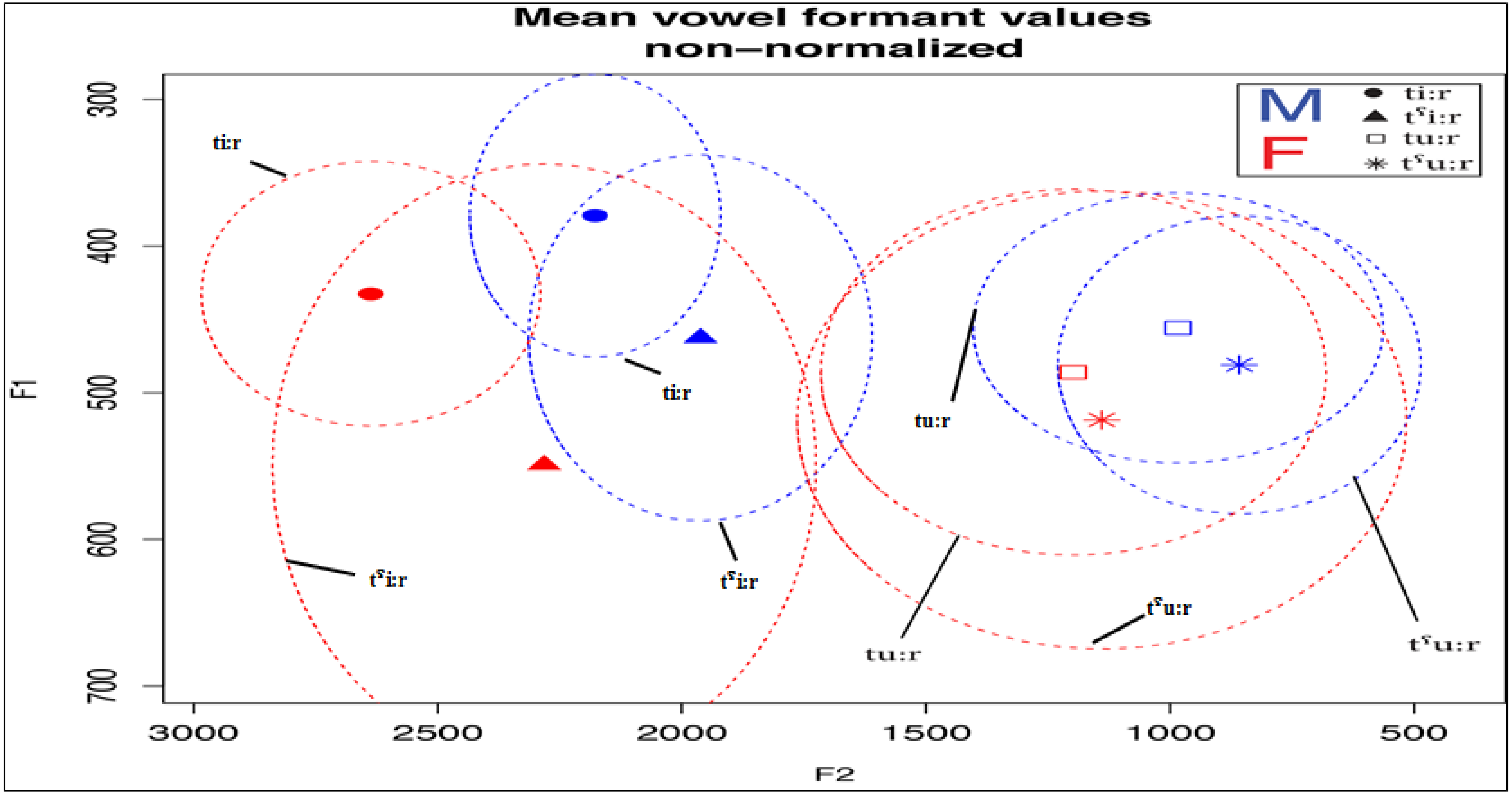


Figure 7.42 Vowel centroids in Hz for vowels (/i:,u:/) for initial plain /t/ and emphatic /tˤ/ stops for 40 males and 40 females, with ellipses representing two standard deviations from the group mean. Note: Ellipsis for /tˤu:r/ and /tur/ were marked for males and females, respectively, in order to distinguish between sexes.

7.6 Discussion

The aim of this study was to produce normative data which has been successfully achieved in Tables 7.5, 7.8, 7.12 and 7.16. It also aimed to determine the effects of dialect (Saudi and Bahraini) and sex on the mean formant frequencies (F1-F3) of vowels (a, i, u) in sustained phonation data and in words with the initial plain stops /b, d, t, k/ as well as the emphatic stops /$t^ʕ$/ produced by Arabic speakers. This chapter also examined the effects of vowel quality, place of articulation and emphasis on formant frequencies. Significant results and interactions for the mean formant frequencies (F1-F3) can be seen in Table 7.20. In addition, Table 7.21 illustrates the hypotheses predicted for this study as well as the outcomes. The discussion begins by examining the linguistic differences related to dialect and sex identified in the study and the hypotheses that have been proposed. This will be followed by a discussion of the within-subject measures of vowel quality, place of articulation and emphasis, and the hypotheses proposed for them. Finally, a summary of the findings is provided at the end of the chapter.

7.6.1 Dialect

The results showed no statistical main effect between Saudi and Bahraini speakers for the formant frequencies (F1-F3) in sustained vowels, and in words with the initial voiceless stops /t, k/ and the emphatic/plain stops /t, $t^ʕ$/. However, a significant difference was found for F1 in words with initial voiced /b, d/, where Saudi speakers had higher mean values than Bahraini speakers, as can be seen in Table 7.20 and Table 7.21. In addition, in the sustained phonation data there was an interaction between dialect and vowel quality for F2 and F3 (Table 7.20 and Table 7.21). Furthermore, in words with initial voiced /b, d/, there was an interaction between dialect and vowel quality for F1-F3 (Table 7.20 and Table 7.21). Moreover, for words with the initial voiceless stops /t, k/, there was an interaction between dialect and vowel quality for F2. In addition, a significant interaction between dialect and sex was observed; therefore, this section will overlap with other sections (sex, vowel quality, place of articulation and emphasis) in order to be able to fully grasp the effects of dialect. The section is divided into two parts according to the stimuli used to describe the significant differences found, as well as the significant interactions. This will be followed by a general summary of the results according to dialect.

7.6.1.1 Sustained phonation

As observed in §7.5.1.2 and in Table 7.20 and Table 7.21, dialect did not have a significant effect on the F1-F3 values. However, an interaction between vowel quality and dialect was reported in §7.5.1.2 and in Table 7.20 and Table 7.21.

7.6.1.2 Words

7.6.1.2.1 Words with initial voiced stops /b, d/

Regarding the results presented in Table 7.20 and Table 7.21, beginning with the F1 of vowels in words with the initial voiced stops /b, d/, there was a significant effect from dialect for F1, as observed earlier in §7.5.2.1. In addition, the F1 values showed a significant interaction between place of articulation and dialect, as seen earlier in §7.5.2.2. Furthermore, a significant interaction between dialect and vowel quality for F1 occurred, as mentioned earlier in §7.5.2.3. Finally, for F1 there was a significant interaction between vowel quality, dialect and sex, as mentioned earlier in §7.5.2.3. Males had lower mean F1 values than females, as expected, which will be elaborated on in §7.6.2.

For F2, there was a significant interaction between place of articulation, dialect and sex. This has been previously described in §7.5.2.2. Furthermore, there was a significant interaction between dialect and vowel quality, as described earlier in §7.5.2.3.

	Vowels			Words									
				Plain							Plain/Emphatic contrast (/t/,/tˤ/)		
				Voiced (/b/,/d/)			Voiceless (/t/,/k/)						
	F1	F2	F3	F1	F2	F3	F1	F2	F3		F1	F2	F3
Dialect	n.s	* w/ vowel (/a/,/u/) S<B /i/ S>B	* w/ vowel (/a/,/u/) S<B /i/ S>B	S>B (p<.05) * w/ vowel /a:/ S>B (/i:,u:/) B>S * place & dialect /b/ (S>B) /d/(S<B) • w/ vowel, sex & dialect /i:/ M<F (S=B), /u:/ M (S>B) F(B>S), /a:/ M,F (S>B)	* w/ vowel (/a:,i:/) S>B /u:/ B>S * Place, sex & dialect M/b/(S<B) /d/(S>B) F/b/(S>B) /d/(S<B)	* w/ vowel (/a:,u:/) S<B /i:/ S>B * w/ vowel, sex & dialect M(a:,u:)(S<B) /i:/(B<S), F(i:,u:)(S>B) /a:/ (S<B) * Place & dialect /b/(S<B) /d/(S>B)	* Place, vowel & dialect S (i:,u:) (t<k) B(i:) (t>K) B(u:) (t<K)	* w/ vowel /i:/(S>B) /u:/(S<B) * Place, vowel & dialect & sex M /t,k/(u:) B>S,/i:/B=S F /t/(i:)(S>B), /t/(u:),/k/(i:,u:) (B>S)	* Place & dialect /t/(S>B) /k/(S<B) * Place,vowel & dialect & sex M t(i:),k(i:,u:) (SM<BM) t(u:) (SM>BM) Ft(i:,u:),k(u:) (SF>BF) k(i:) (SF<BF)		n.s	*Emphasis, vowel & dialect t/tˤ(i:)(S>B) t/(u:)(B>S) tˤ(u:)(S=B)	n.s
Sex	M<F (p<.001)	M<F (p<.001)	M<F (p<.001)	M<F (p<.001)	M<F (p<.001)	M<F (p<.001)	M<F (p<.001)	M<F (p<.001)	M<F (p<.001)		M<F (p<.001)	M<F (p<.001)	M<F (p<.001)
Vowel	/a/>/i/=/u/ (p<.001)	/i/>/a/>/u/ (p<.001)	/i/>/a/=/u/ (p<.001)	/a:/>/u:/>/i:/ (p<.001) *w/ sex /a:/>/u:/>/i:/ M<F	/i:/>/a:/>/u:/ (p<.001) * w/ sex /i:/>/a:/>/u:/ M<F	/i:/>/a:/=/u:/ (p<.001) * w/ sex /a:/>/u:/>/i:/ M<F	/u:/>/i:/ (p<.001) * w/sex M<F /u:/>/i:/	/i:/>/u:/ (p<.001) * w/sex M<F /i:/>/u:/	/i:/>/u:/ (p<.001) * w/sex M<F /i:/>/u:/		/u:/>/i:/ (p<.001) * w/sex M<F /u:/>/i:/	/i:/>/u:/ (p<.001) * w/sex M<F /i:/>/u:/	n.s
Place/ Emphasis	NA	NA	NA	* w/ vowel /b/</d/ (i:,u:) /b/>/d/ (a:)	/b/</d/ (p<.001) * w/ sex /b/</d/ (M<F) * w/ vowel /b/</d/ (a:,u:) /b/>/d/ (i:)	/b/>/d/ (p<.001) * w/ vowel /b/>/d/ (a:,u:) /b/=/d/ (i:)	/t/</k/ (p<.001)	/t/>/k/ (p<.05) * w/ sex M /t/</k/ F/t/>/k/ * w/ vowel & sex M t(i:,u:)<k(i:,u:),F t(i:,u:)>k(i:,u:)	* w/dialect /t/(S>B) /k/(S<B)		/ tˤ />/t/ (p<.001) *w/ vowel /tˤ/(i:,u:)> /t/(i:,u:)	/ tˤ /</t/ (p<.001) *w/ vowel /tˤ/(i:,u:) < /t/(i:,u:) *w/ vowel & sex M<F /tˤ/(i:,u:) < /t/(i:,u:)	*w/ vowel (i:)/tˤ/</t/ (u:)/tˤ/>/t/

Table 7.20 Significant results and interactions for formant frequencies (F1-F3) in sustained vowels (a, i, u) and in words with voiced /b, d/, voiceless /t, k/, and plain/emphatic /t, tˤ/ according to dialect, sex, place of articulation, and vowel quality. (S and B denote Saudi and Bahraini speakers while M and F denote male and female,*w/ denotes significant interaction with).

		Formants	Dialect		Sex		Vowels		Place of articulation/Emphasis*	
			Hypothesis	**Results**	**Hypothesis**	**Results**	**Hypothesis**	**Results**	**Hypothesis**	**Results**
Sustained phonation		**F1**	Differences will not be found between dialects	S=B	Males will have lower Mean F1 than females	M<F	Vowel quality to determine F1	/a/>/i/=/u/	NA	
		F2	Differences will not be found between dialects	(/a/, /u/) S<B /i/ S>B	Males will have lower Mean F2 than females	M<F	Vowel quality to determine F2	/i/>/a/>/u/		
		F3	Differences will not be found between dialects	(/a/, /u/) S<B /i/ S>B	Males will have lower Mean F2 than females	M<F	Vowel quality to determine F3	/i/>/a/=/u/		
Words	**Voiced (b, d)**	**F1**	Differences will not be found between dialects.	S>B (Refer to table)	Males will have lower Mean F1 than females	M<F	Vowel quality to determine F1	/a:/>/u:/>/i:/	Place will have no effect	* w/ vowel /b/</d/ (i:,u:) /b/>/d/ (a:)
		F2	Differences will not be found between dialects	(/a:,i:/) (S>B), /u:/ B>S (Refer to table)	Males will have lower Mean F2 than females	M<F	Vowel quality to determine F2	/i:/>/a:/>/u:/	Place will have no effect	/b/>/d/ * w/ vowel /b/</d/ (a:,u:) /b/>/d/ (i:)
		F3	Differences will not be found between dialects	(/a:,u:/) (S<B), /i:/ S>B (Refer to table)	Males will have lower Mean F2 than females	M<F	Vowel quality to determine F3	/i:/>/a:/=/u:/	Place will have no effect	/b/>/d/ * w/ vowel /b/>/d/ (a:,u:) /b/=/d/ (i:)
	Voiceless (t, k)	**F1**	Differences will not be found between dialects.	(Refer to table)	Males will have lower Mean F1 than females	M<F	Vowel quality to determine F1	/u:/>/i:/	Place will have no effect	/t/</k/
		F2	Differences will not be found between dialects	/i:/ (S>B), /u:/ (S<B)	Males will have lower Mean F2 than females	M<F	Vowel quality to determine F2	/i:/>/u:/	Place will have no effect	/t/>/k/
		F3	Differences will not be found between dialects	(Refer to table)	Males will have lower Mean F3 than females	M<F	Vowel quality to determine F3	/i:/>/u:/	Place will have no effect	/t/=/k/
	Plain/emphatic (t, tˤ)	**F1**	Differences will not be found between dialects	S=B	Males will have lower Mean F1 than females	M<F	Vowel quality to determine F1	/u:/>/i:/	/tˤ />/t/	/tˤ />/t/
		F2	Differences will not be found between dialects	t/tˤ (i:) (S>B) .t (u:) (B>S) tˤ (u:) (S=B)	Males will have lower Mean F2 than females	M<F	Vowel quality to determine F2	/i:/>/u:/	/tˤ /</t/	/tˤ /</t/
		F3	Differences will not be found between dialects	S=B	Males will have lower Mean F3 than females	M<F	Vowel quality to determine F3	/i:/=/u:/	/tˤ />/t/	(i:) /tˤ/</t, (u:) /tˤ/>/t/

Table 7.21 Comparison of hypotheses predicted for the study of mean formant frequencies (F1-F3) for vowels in sustained phonation and in words with initial voiced (b, d), voiceless (t, k), and plain/emphatic stops (t, tˤ) and the outcomes of the statistical analysis. (S and B denote Saudi and Bahraini speakers while M and F denote male and female and NA reflects not applicable, refer to table denotes results showed significant interactions. However, due to the nature of the results (refer to Table 7.20) * denotes the effect of emphatics compared to plain alveolar stops tˤ/t, which is shown in the three lower rows.

For F3, there was a significant interaction between place of articulation and dialect, as was illustrated earlier in §7.5.2.2. Moreover, there was a significant interaction between dialect and vowel quality, as explained earlier in §7.5.2.3. Finally, there was a significant interaction between vowel quality, dialect and sex, which was also described in §7.5.2.3.

7.6.1.2.2 Words with initial voiceless stops /t, k/

Continuing the examination of the data in Table 7.20 and Table 7.21, for vowels in words with the initial voiceless stops /t, k/, there was no significant effect of dialect on F1-F3. However, several interactions occurred for F1, F2 and F3, which will be discussed with respect to the data for each formant.

For F1, there was a significant interaction between place of articulation, vowel quality and dialect, which was described earlier in §7.5.3.2. Moreover, for F2 there was a significant interaction between vowel quality and dialect, as described earlier in §7.5.3.3. Furthermore, there was an interaction between place, vowel quality, dialect and sex, which was previously illustrated in §7.5.3.3. For F3, there was a significant interaction between place of articulation and dialect, which was described earlier in §7.5.3.2. In addition, there was a significant interaction between place of articulation, vowel quality, dialect and sex for F3, which was also described earlier in §7.5.3.3.

7.6.1.2.3 Words with initial emphatic/plain stops /tˤ, t/

For vowels in words with the initial emphatic/plain stops /tˤ, t/, the results in Table 7.20 and Table 7.21 according to emphasis, vowel quality and dialect showed an interaction, as mentioned earlier in §7.5.4.3; this will be described further in §7.6.5.

7.6.1.3 General

The results showed no statistical main effect of dialect, with the exception of the F1 values of vowels in words with the initial voiced stops /b, d/, whereby Saudis had higher values than Bahraini speakers. However, the significant interactions found elsewhere were more revealing of the effect of dialect, as was described previously in §7.5.1 to 7.5.4 and in §7.6.1.1 to §7.6.1.2.3. The results for sustained phonation were indicative of the effect of dialect on vowel quality. This can also be observed in the production of vowels in the context of the voiced stops /b, d/. However, this does not eliminate the possibility that there may be an effect of dialect in the production of the voiced stops /b, d/, as seen in §7.5.2.3 and Table 7.20. The place and dialect interaction in F1 and F3 might be indicative of Saudi speakers producing /b/ with a slight protrusion of the lips in contrast to Bahrainis' production of /b/, as well as being indicative of an interaction with vowels. In contrast, Bahrainis' production of /d/ might be with a slightly retracted tip of the tongue on the alveolar ridge; however, this needs further investigation for confirmation. In addition, the effect of rhotic /r/ in the context of /b, d/ for F3 shows that Saudis might have a more anterior point of constriction in the context of /b/, further supporting the argument above, in contrast to Bahrainis who have lesser influence from the rhotic /r/.

For vowels in the context of the voiceless stops /t, k/, dialect showed more interactions with place of articulation, indicating that differences in the production of the voiceless stops between Saudi and Bahraini speakers might have a greater or equal effect from vowels. The first hypothesis proposed initially anticipated no differences in formant frequencies (F1-F3) between the Saudi and Bahraini Arabic dialects in the sustained phonation of the vowels /a, i, u/ and in words with the initial voiced stops /b, d/, the voiceless stops /t, k/, and the emphatic and plain stops /tˤ, t/. However, the results from this study have meant that the first hypothesis has been substantially rejected to varying degrees depending on the stimuli, similar to the results presented for F0 (§6.8.1.4). As to the causes of these differences between the Najdi and Bahraini dialects, a possibility is that the Bahraini dialect might be influenced by the Arabic dialects as well as other languages (e.g. English and Persian) spoken within their community (see §2.3.2.2). In addition, Saudi Najdi might be going through some changes as described earlier (see §2.3.2.1). Further analysis is required from a diachronic and synchronic view in order to determine this.

Comparing the results from this study with those of some Arabic studies (Alghamdi, 1998; Kotby et al., 2010; Amir et al., 2014) is difficult for a number of reasons; the structure of the words was different in these studies and the data from different contexts were collapsed together, in addition to the presence of methodological differences. However, the sustained phonation results from this study can be compared to results for the Jordanian Arabic dialect (Natour et al., 2011) as can be seen in Table 7.22 and Figure 7.43, which showed the following: for the vowels /a/ and /i/ for males and /u/ for females, there minimal F1 differences between the dialects investigated in this study and Jordanian Arabic. However, for /u/ in males, both Saudis and Bahrainis had higher F1 values than Jordanians. For the vowel /a/ in females, both Saudis and Bahrainis had lower F1 values but this was more so with Bahraini females. In contrast, with the vowel /i/, both Saudi and Bahraini females had higher F1 values than Jordanian females.

Saudi males and females had lower F2 values than Jordanian males and females in the vowels /a/ and /u/; however, females had significantly lower values than Jordanian females. For /i/, Saudi males and females had higher values than Jordanians; however, a similar trend for Saudi females showed significantly higher F2 values than Jordanian females. It might be inferred that there is no imala in Saudi Najdi dialect.

With the vowels /a, i, u/, Bahraini males had higher values than Jordanian males; however, Bahraini females had lower values for the vowel /a/ than Jordanian females, whereas their /i/ and /u/ F2 values were higher than those of Jordanian females, especially for /i/.

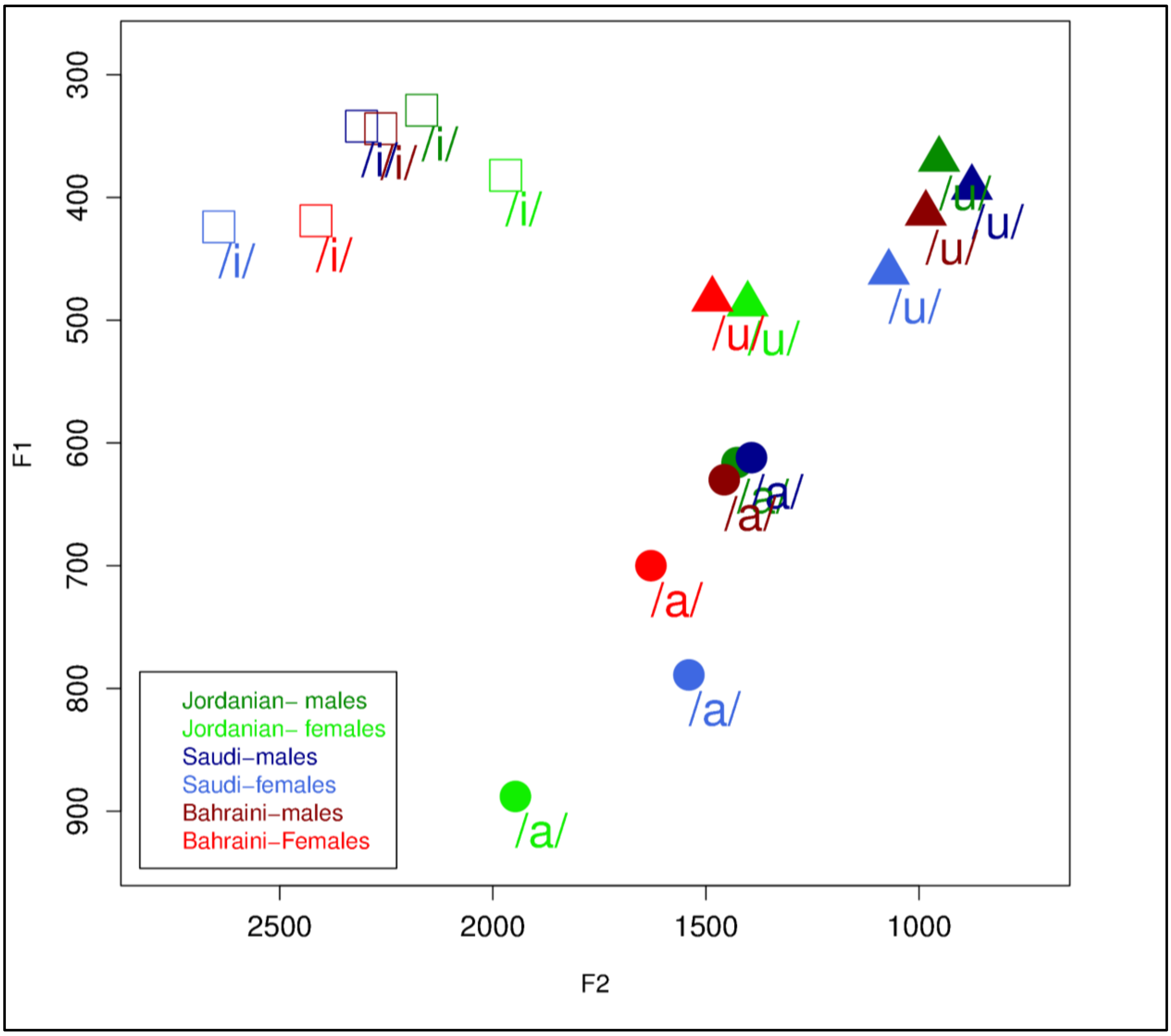


Figure 7.43 Vowel centroids in Hz for male and feamle Saudi and Bahriani spkeras from this study as well as Jordainin male and feamles speakers (Natour et al., 2011).

		Vowels		/a:/			/i:/			/u:/		
	Study	Formants	Sex	F1	F2	F3	F1	F2	F3	F1	F2	F3
Sustained phonation	Natour et al. (2010)	Jordanian	M	616	1427	2644	329	2167	2869	369	953	2502
			F	888	1947	3089	382	1970	2760	487	1402	2586
	Current study	Saudi	M	612	1393	2635	342	2308	2789	392	876	2566
			F	789	1540	2920	424	2643	3159	461	1071	2769
		Bahraini	M	630	1457	2682	344	2263	2760	413	984	2587
			F	700	1629	3052	419	2415	3012	483	1485	2997
In context (pooled*)	Alghamdi (1998)	Saudi	M	573	1537	2260	402	1841	2646	451	1302	2427
			F	-	-	-	-	-	-	-	-	-
		Sudanese	M	525	1564	2624	331	2066	2674	354	1308	2505
			F	-	-	-	-	-	-	-	-	-
		General Egyptian	M	468	1505	2537	357	1749	2565	270	1285	2483
			F	-	-	-	-	-	-	-	-	-
	Kotby et al. (2011)	Cairene Egypt	M	611	1043	-	287	2202	-	241	857	-
			F	666	1130	-	356	2662	-	269	876	-
	Amir et al. (2014)	Muthalath Dialect (MD)	M	591	1296	-	375	1931	-	391	1023	
			F	770	1541	-	456	2345	-	382	965	-
		Galiliean Dialect (GD)	M	597	1270	-	361	2013	-	382	965	-
			F	728	1593	-	411	2416	-	444	1086	-

Table 7.22 Formant frequency F1-F3 (Hz) results for vowels /a, i, u/ in sustained phonation data from the current study for Saudis and Bahrainis from both sexes compared to Jordanians (Natour et al., 2011) as well as results for the long vowels /a:, i:, u:/ from the remaining studies (Alghamdi, 1998; Kotby et al., 2010; Amir et al., 2014). (Note[1]: results were rounded to the nearest zero, Note[2] - : indicates that it was not assessed in the study).

For F3, Saudi and Bahraini males showed a similar pattern for the higher vowels /i/ and /u/, whereby they had higher F3 values than Jordanian males. However, for /a/ Saudi males had similar F3 values to Jordanian males while Bahraini males had higher values than Jordanian males. For females, a similar pattern emerged where for the high vowels /i/ and /u/ both Saudi and Bahraini females had significantly higher values than Jordanian females. For /a/, both showed lower F3 values than Jordanian females; this was especially the case for Saudi females. The difference between the Jordanian speakers from Natour et al. (2011) and the Saudi and Bahraini speakers in the present study might be due to the characteristics of Jordanian Arabic. Jordanian Arabic in its current form has had many influences from other Arabic dialects such as Palestinian Arabic (Al-Wer, 1999). In addition, it has been exposed to different languages such as Turkish and English; Jordan became independent from Turkey and Britain in 1918 and 1946, respectively. As described earlier, the difference might be due to changes in Bahraini Arab and Saudi Najdi dialects as well. This needs additional assessment supplemented by a diachronic and synchronic view.

As seen in Table 7.23, the study by Bin-Muqbil (2006) offers another comparison between F1 and F2 values in males in vowels in words with initial /d/, /t/, /k/ and the emphatic /$t^{ʕ}$/. In the context of /d/, the F1 values of /a/ were similar within the Saudi data; however, the F1 value was lower for Bahrainis. The F2 values were lower for the Saudis from the current study in comparison to the Bahrainis who had much lower F2 values than in Bin-Muqbil (2006) (results from Bin-Muqbil (2006) will be referred to as SN, henceforth). The vowel /i:/ had a higher F1 and lower F2 value in both dialects; however, both values were significantly lower amongst the Saudis compared to SN. For the Saudis and Bahrainis, /u:/ had significantly higher F1 and F2 values than in SN. In the context of /t/, /i:/ had similar F1 values for Bahrainis and Saudis and in SN; however, the F2 value was much lower for both the Saudis and Bahrainis compared to SN.

The F1 value of /u:/ was significantly higher for both dialects than in SN; however, the F2 value was lower for the Saudis and higher for the Bahrainis than in SN. In the context of /k/, the F1 of /i/ was higher for both dialects than in SN, while the F2 values in the Saudi data were significantly lower than in SN whereas the Bahrainis showed higher F2 values than in SN.

The vowel /u:/ had significantly higher F1 and F2 values than in SN. In the context of the emphatic /tˤ/, /i:/ had higher F1 values in both dialects than in SN. The F2 values were significantly lower for Saudis than in SN while the F2 Bahraini result was more significant than in SN. For the vowel /u:/, both dialects had higher F1 values than in SN; however, the Saudi data had similar F2 values to those in SN whereas the Bahrainis had significantly higher F2 values than in SN.

The results in Table 7.22 and Table 7.23 and Figure 7.43 sugesst linguistic differences between Jordanian, Saudi and Bahraini males and females as well as differences between SN and the Saudis and Bahrainis in the present study. The results further support the presence of vowel formant frequency differences between the Arabic dialects. However, this should be interpreted with caution as inconsistencies in methodologies might have been the cause of these differences. To take the Saudi results from this study and those reported by Bin-Muqbil (2006) as an example, the differences might have been caused by variation in the structure of words used in the analysis. In the present study the words used were minimal pairs, whereas those used by Bin-Muqbil (2006) were not minimal pairs. Perhaps the differences arose between the studies because participants were instructed to produce the stimuli in MSA rather than in their dialect (Bin-Muqbil, 2006, p. 86). The data may support Embarki et al.'s (2007) finding that MSA is distinguished from dialects, although the method of analysis differs between the studies. Furthermore, Bin-Muqbil (2006) indicated that some speakers were not native speakers of the Riyadh dialect, which might have caused the differences between the results from his study and the present study; the differences found in relation to the place of

	Vowels			/a:/			/i:/			/u:/		
Study	Formants		Consonant	F1	F2	F3	F1	F2	F3	F1	F2	F3
Bin-Muqbil (2006)	MSA Najdi Saudi	M	/d/	688	1679	-	331	2293	-	370	920	-
			/t/	730	1594	-	382	2386	-	378	960	-
			/k/	737	1934	-	332	2309	-	402	868	-
			/tˤ/	757	1179	-	360	2310	-	426	812	-
Current study	Saudi	M	/b/	684	1199	2649	343	2239	2779	455	868	2699
			/d/	674	1330	2632	376	2210	2759	500	1023	2637
			/t/	-	-	-	384	2178	2739	464	904	2696
			/k/	-	-	-	374	2178	2759	447	1063	2695
			/tˤ/	-	-	-	463	1984	2671	482	821	2762
		F	/b/	819	1382	2882	415	2711	3167	474	1045	2977
			/d/	817	1516	2884	441	2693	3195	503	1190	2879
			/t/	-	-	-	432	2708	2749	456	984	2919
			/k/	-	-	-	475	2541	3065	504	1032	2914
			/tˤ/	-	-	-	540	2307	3064	512	1178	3075
	Bahraini	M	/b/	655	1136	2686	350	2171	2704	477	1171	2879
			/d/	638	1228	2634	371	2180	2753	456	1100	2661
			/t/	-	-	-	374	2178	2759	447	1063	2695
			/k/	-	-	-	371	2184	2758	472	1190	2761
			/tˤ/	-	-	-	462	1940	2681	480	895	2793
		F	/b/	720	1260	2934	434	2550	3073	507	1137	2944
			/d/	708	1539	2910	430	2524	3026	501	1395	2787
			/t/	-	-	-	433	2566	3175	492	1150	2881
			/k/	-	-	-	434	2598	3111	499	1002	2818
			/tˤ/	-	-	-	559	2257	3031	525	1101	3368

Table 7.23 Formant frequency results (Hz) for the vowels /a:,i:,u:/ in different initial contexts /b,d,t,k,tˤ/ for both Saudi and Bahraini males and females from the current study and results for five male participants in Bin-Muqbil (2006) for the vowels /a:,i:,u:/ in different initial contexts /d,t,k,tˤ/. (Note[1]: results were rounded to the nearest zero for the current study, Note[2] - : indicates that it was not assessed in the study).

articulation of vowels in words with initial voiceless stops (see §7.6.4) might support this argument.

To comment on the effect of emphatics on formant frequencies, it can be stated that the literature review showed some variation amongst dialects (Kahn, 1975; Khattab et al., 2006; Embarki et al., 2007). In addition, the results from the present study showed that the effect of emphatics might be an important tool in the identification and classification of different dialects of Arabic. The degree of emphasis (shown by an increase in F1 and lowering of F2) might be sensitive to different dialects as well as varieties of Arabic, in this case MSA. This supports Embarki et al.'s (2007) finding that MSA is distinguished from dialects, although the method of analysis differs in the studies. Later on (in §7.6.5), the different effects on Arabic dialects resulting from emphasis correlates will be discussed further.

7.6.2 Sex

The results for sex-related linguistic differences showed that for all stimuli (sustained phonation, words) males had lower mean formant frequencies (F1-F3) than females, as observed in Table 7.20 and Table 7.21. The results can be explained by the anatomical differences in the vocal tracts of men and women (Fant, 1960; Traunmüller, 1984, 1988; Whiteside, 2001). The results further support the sustained phonation results for vowels and words observed in the few Arabic studies reporting on sex differences (Khattab et al., 2006; Al-Masri, 2009; Natour et al., 2011; Jongman et al., 2011; Amir et al., 2014). The exception is Kotby et al.'s study (2010), which showed no differences between males and females in the production of long vowels (/a:, u:/) in words embedded in a sentence; the authors did not provide any explanation for their results. The explanation for this might be related to an interplay between gender and dialect, where females might have similar speech characteristics to males, as observed in the Wu Chinese dialect (see §6.3.5.4). Another possible explanation might be related to the authors’ method of analysis; as explained previously, the point of analysis in the vowels in the words was not specified. As the methodologies are different between the two studies, it is not fruitful to compare the results of this study with those of Kotby et al.'s study (2010). The results from Kotby et al.'s study (2010) on Egyptian Cairene Arabic demonstrate that studies on different dialects of Arabic need to be conducted. Furthermore, the results support the general sex-related linguistic differences found in different languages that have shown males to have lower mean formant frequencies (F1-F3) than females in many languages (e.g., Peterson & Barney, 1952; Hillenbrand et al., 1995; Hagiwara, 1997; Adank et al., 2007; Escudero et al., 2009; Chládková et al., 2011).

As described in 7.5.2.3, vowels in words with the initial voiced stops /b, d/ showed an interaction between sex and vowel quality for F1-F3. The results for the vowel /a:/ showed a greater difference between males and females than the remaining vowels, which might be attributed to the larger pharyngeal cavity of males compared to females (Traunmüller, 1984, 1988; Fitch & Giedd, 1999; Whiteside, 2001). For F2 and F3, there were greater differences for /i:/ between males and females than the remaining vowels, which also can be attributed to males' increased vocal tract length compared to females (Traunmüller, 1984, 1988; Fitch & Giedd, 1999; Whiteside, 2001). This also might explain the interaction between sex and vowels in words with the initial voiceless stops /t, k/ (see §7.5.3.3), where there were greater differences for /i:/ between males and females than was the case for /u:/. In addition, it explains the same pattern that emerged for F1 and F2 in the sex and vowel interaction in vowels in words with the initial plain and emphatic stops /t, tˤ/ (see §7.5.4.3).

In addition, there was an interaction between place of articulation and sex for F2 in words with the initial voiced stops /b, d/ (see §7.5.2.2) and in words with the initial voiceless stops /t, k/ (see §7.5.3.2). The results for the alveolar stops, regardless of voicing, show greater differences between males and females. Further support comes from the differences between males and females for the velar /k/ that were fewer than the differences between sexes for the alveolar stops. The most probable cause for these interactions might be the larger vocal cavity of males than females. The significant effect from sex as well as the interactions showed consistent sex-related linguistic differences in both dialects, which supports the second hypothesis in which males have lower mean formant frequencies (F1-F3) than females for all stimuli.

7.6.3 Vowel quality

The results showed that the formant frequencies (F1-F3) are dependent on vowel quality, as observed in Table 7.20 and Table 7.21, which is in agreement with the formant frequencies expected for the vowels /a, i, u/ as described by Raphael et al. (2007). The vowel /a/, which was present in the sustained phonation data (see §7.5.1.2) and in words with the initial voiced stops /b, d/ (see §7.5.2.3), had the highest F1 amongst the vowels, an F2 value between /i/ and /u/, and an F3 value with no differences between /a/ and /u/; however, both had lower F3 values than /i/. The vowel /a/ had an open quality, as exhibited by the formant frequencies in this study. The results for the vowel /a/ were similar for both males and females; however, males had lower F1-F3 values than females. In addition, greater differences between sexes were observed in the context of /b, d/ as explained earlier in §7.6.2.

The high front vowel /i/ had similar F1 values to /u/ in the sustained phonation data (see §7.5.1.2), although both had lower F1 values than /a/, indicating a close quality. However, in the context of voiced stops (see §7.5.1.2), /i/ had a lower F1 value than /u/. In the context of voiceless stops (see 7.5.3.3), /i:/ had a lower F1 value than /u:/ The vowel /i/ had the highest F2 values of all the vowels in all contexts, indicative of it having the most fronted quality. With regard to F3, /i/ in all contexts was shown to have the highest values amongst the vowels, indicative of a more anterior constriction. The vowel /i/ clearly had a high front quality, as exhibited by the formants in this study. The results for the high front vowel /i/

were similar for both males and females; however, males had lower formant frequencies (F1-F3) than females. In addition, greater differences between sexes were observed in all contexts, as explained earlier in §7.6.2.

For the vowel /u/, there were no F1 differences in the sustained phonation data on /i/ (see §7.5.1.2). In the context of voiced, voiceless and emphatic/plain stops, /u/ had a higher F1 value than /i/, indicating a less close quality than /i/. However, this vowel had the lowest F2 values compared to the other vowels. Furthermore, this vowel had the lowest F3 values amongst the vowels, even if these were not significant in the sustained phonation data and in the context of plain/emphatic stops. The results for the high back vowel /u/ were similar for both males and females; however, males had lower formant frequencies (F1-F3) than females.

The formant frequencies (F1-F3) in this study showed different properties depending on the vowel quality; therefore, the third hypothesis is supported in this study. However, the results are restricted to the high vowels /iː, uː/ for words with initial voiceless /t, k/ and plain/emphatic stops /t, tˤ/, thereby limiting the generalizability of results from this study.

7.6.4 Place of articulation for voiced /b, d/ and voiceless stops /t, k/

Examining the results for place of articulation seen in Table 7.20 and Table 7.21, for vowels in the context of the voiced stops /b, d/, a main significant effect for place of articulation was seen in the F2 and F3 data (see §7.5.2.2). In addition, there was a significant interaction between place of articulation and vowel quality for F1-F3 (see §7.5.3.3). Furthermore, as previously explained in §7.6.2, place of articulation had an interaction with sex.

For vowels in the context of the voiceless stops /t, k/, a main significant effect for place of articulation was seen in the F1 and F2 data (see §7.5.3.2). In addition, there was a significant interaction between place of articulation and dialect as well as place of articulation and sex (see §7.5.3.2). Furthermore, there was a significant interaction between place of articulation, vowel and sex for F2 (see §7.5.3.3).

The results from this study for both dialects do not support the results from Bin-Muqbil's (2006) study. One of the possible explanations for this might relate to the methodology, as the stimuli used in his study were not minimal pair words. A more likely explanation lies in the fact that the Najdi speakers participating in his study were not all native speakers of the Riyadh Najdi dialect (Bin-Muqbil, 2006, p. 86). This fact might highlight dialectal differences as the reason that differences arose according to the place of articulation in the present study as the speakers selected from both dialects were homogenous Riyadh Najdi dialect and Bahraini dialect speakers. The fourth hypothesis is therefore rejected, as place of articulation was shown to have an effect on formant frequencies (F1-F3) in vowels with initial voiced and voiceless stops in the Saudi and Bahraini Arabic dialects for both male and female speakers. However, it is difficult to draw a firm conclusion as the vowel /a:/ was not present in words with initial voiceless stops.

7.6.5 Emphasis

The results seen in Table 7.20 and Table 7.21 showed a main significant effect of increasing F1 in the presence of the emphatic /tˤ/ (see §7.5.4.2). In addition, there was an interaction with the high vowels /i:, u:/, which showed greater differences for F1 and F2 between plain and emphatic contexts for the high front vowel /i:/ than the high back vowel /u:/ (see §7.5.4.3). However, the F3 results showed an interaction with vowel quality, where the high front vowel /i:/ in the context of /tˤ/ had lower values than in the context of plain /t/, whereas the high back vowel /u:/ in the context of /tˤ/ had higher F3 values than in the context of plain /t/ (see §7.5.4.3). In addition, for Saudi and Bahraini males and females, there was a lowering of F2 in vowels with an initial alveolar emphatic /tˤ/ compared to the plain alveolar stop /t/, indicating a more backed quality when in the presence of a neighbouring emphatic /tˤ/ (see §7.5.4.3).

An increase in F1 in high vowels when adjacent to emphatics is a result of the raised tongue position involved in the secondary articulation, which is in agreement with the majority of previously conducted studies (Al-Masri & Jongman, 2004; Bin-Muqbil, 2006; Khattab et al., 2006; Al-Masri, 2009; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011). However, Card (1983) reported no effect on F1 in her analysis of Palestinian Arabic, which might be a finding resulting from dialect. This suggests that Arabic dialects could be classified according to emphasis correlates, though this needs to be examined in future studies on Palestinian and other Arabic dialects.

Furthermore, the results showed a lowering of F2 in high vowels, reflecting the effect of emphasis as a result of the secondary articulation, a finding which is shared with the majority of the previously conducted studies (Al-Masri & Jongman, 2004; Khattab et al., 2006; Al-Masri, 2009; Bin-Muqbil, 2006; Abudalbuh, 2010; Shar & Ingram, 2010; Jongman et al., 2011). In addition, F2 was shown to have the least effect from emphasis in the high back vowel /u:/ in Jordanian Arabic in two studies (Al-Masri, 2009; Abudalbuh, 2010); the results from the present study also showed an interaction with vowel quality, where the effects of emphasis were greater in the high front vowel /i:/ (see Figure 7.38). This might indicate that Jordanian and both Saudi and Bahraini Arabic might have similar correlates of emphasis as they are considered to be of a Bedouin origin (Bellem, 2008). This is further confirmed by the interaction between emphasis, vowel quality and dialect, as previously described in §7.5.4.3. However, the results for the vowel /u: / showed that Bahrainis showed more effects of emphasis than Saudis. This shows that F2 might be sensitive to dialect in terms of vowel quality, which further supports the results found in Embarki et al.'s study (2007).

This again can be called into question as for both dialects examined in this study, the high front vowel /i:/ had lower F3 values in the context of the emphatic /tˤ/ compared to plain /t/; this contrasts with the findings of studies on Jordanian Arabic (Al-Masri, 2009; Abudalbuh, 2010). This could possibly be due to the stimuli design in the study, where rhoticity from the presence of /r/ in final position might have less influence and might be neutralized in the context of emphatics in higher front vowels. This study is in agreement with the results on Jordanian Arabic (Al-Masri, 2009; Abudalbuh, 2010), where the high back vowel /u:/ was shown to have higher F3 values in the context of emphatics than in the plain context.

The fifth hypothesis is substantially supported by the F1 and F2 results, where there was an increase in F1 and a decrease in F2 in both the vowel contexts of /i/ and /u:/. The F3 results showed an interaction between emphasis and vowel quality, as described earlier.

7.7 Summary

The results from this chapter have revealed differences in formant frequencies (F1-F3) in vowels according to dialect. However, this is dependent on the nature of the stimuli as well as the vowel context. In addition, sex-related linguistic differences were found in the formant frequencies (F1-F3) of the sustained phonation data and within words with initial voiced /b, d/, voiceless /t, k/ and plain/emphatic /t, tˤ/. Moreover, formant frequencies (F1-F3) play a major role in differentiating vowel quality in the Bahraini and Saudi Arabic dialects. The effects of emphasis on vowels were characterised by an elevated F1 and a lowering of F2 for the Arabic dialects in the study. In addtion, F2 in the context of the empahtic played a role in diffrenatting the Arabic diaelcts in this study. Although, F3 values were attempted to controlled by tracking errors and outliers (see §7.4.5), it is imperative to reiterate that recordings were made in WMA format which might have an effect on F3 values in this study (Schilling, 2013).

Chapter 8. Conclusion

8.1 Introduction

This chapter brings together the outcomes of the four parameters presented in Chapter 4 (DDK), Chapter 5 (VOT), Chapter 6 (F0) and Chapter 7 (formant frequencies) in order to address the main aims and to answer the following two main research questions of this thesis:

1. Are there differences between the two Gulf Arabic dialects (Saudi Najdi and Bahraini Bahraini) in the speech of males and females?
2. Are there differences in the speech of males and females in the Saudi Najdi and the Bahraini Bahraini Arabic dialects?

In addition, this chapter includes information on the implications of the current research, its limitations and suggests areas for future research.

8.2 Addressing the aims and research questions

One of the main aims of this thesis was to establish normative data for four parameters of speech (DDK, VOT, F0 and formant frequencies) for male and female Arabic speakers of two Arabic Gulf dialects (Saudi Najdi and Bahraini Bahraini). The normative data was collected to aid speech and language pathologists in clinics in both Saudi Arabia and Bahrain. This research has successfully achieved the first aim, where normative data for Saudi Najdi and Bahraini Bahraini Arabic speakers from both sexes were presented in response to a range of stimuli for DDK (§4.5), VOT (§5.8), F0(§6.7) and formant frequencies (§7.6).

Having established the normative data, the research aimed to answer the two main research questions. A summary of the results from Chapters 4 to 7 for the different tasks is presented Table 8.1.

Type of analysis				Durational measures				Spectral measures							
Stimuli type		Stimuli	Target analysis	DDK Chapter 4		VOT Chapter 5		F0 Chapter 6		F1-F3 Chapter 7					
				Dialect	Sex	Dialect	Sex	Dialect	Sex	Dialect			Sex		
										F1	F2	F3	F1	F2	F3
Syllables	Monosyllables /ba, da, ga/	NA		Yes (M)	No	NA		NA		NA					
Syllables	Multisyllabic /badaga/	NA		No	No	NA		NA		NA					
Sustained phonation	/a, i, u/			NA		NA		No	Yes (M)	No	Yes	Yes	Yes (M)	Yes (M)	Yes (M)
Words	Voiced	/b, d/	/a:, i:, u:/	NA		No	No	Yes (M)	Yes (M)	Yes (M)	Yes	Yes	Yes (M)	Yes (M)	Yes (M)
Words	Voiceless	/t, k/	/i:, u:/	NA		Yes (M)	Yes (M)	Yes (M)	Yes (M)	Yes	Yes	Yes	Yes (M)	Yes (M)	Yes (M)
Words	Emphatic/plain	/tˤ, t/	/i:, u:/	NA		Yes	Yes (M)	No	Yes (M)	No	Yes	No	Yes (M)	Yes (M)	Yes (M)
Words	Voiced/voiceless	/d, t/	/i:, u:/	NA		Yes	Yes (M)	Yes (M)	Yes (M)	NA					
Sentences	Reading	NA		NA				No	Yes (M)	NA					
Sentences	Quran	NA		NA				No	Yes (M)	NA					

Table 8.1 A summary of the results on dialect and sex from Chapters 4-7. (Note: 'Yes' indicates either a significant effect or interaction while 'No' indicates no effect, 'M' indicates a main significant effect, 'NA': not applicable).

8.2.1 Q1: Are there differences between the two Gulf Arabic dialects (Saudi Najdi and Bahraini Bahraini) in the speech of males and females?

As presented in Table 8.1, durational measures were assessed by two parameters (DDK, VOT). The results for the DDK rates as seen in §4.6.1 were dependent on the stimuli used. For the multisyllabic sequence, no differences were exhibited between the dialects, while there were differences between the dialects for the monosyllabic sequences where Saudi speakers had faster rates than Bahraini speakers. In addition, the results for VOT durations showed dialect (see §5.9.1) to have a significant effect in words with the initial voiceless stops /t, k/ as well as an interaction effect with words with a voiced/voiceless /d, t/ contrast and words with the initial plain/emphatic stops /t, $t^ʕ$/. Furthermore, the results for emphatic /$t^ʕ$/ showed an interplay between dialect and sex (this is explained further in the next section). However, there were no differences between the dialects for words with the initial voiced stops /b, d/. VOT results depending on stimuli were described earlier in §5.9.1.

Before discussing the results related to dialect for the spectral measures, results for DDK and VOT for the voiced stops /b,d/ are in contrast where Saudis had higher DDK rates than Bahrainis whereas VOT results showed no differences between the dialects. This might not come as a surprise as the stimuli used and the method of production of the DDK data were different than VOT data for voiced stops. Firstly, the stimuli used for gathering the results on the DDK rates consisted of pseudo-speech stimuli which had no meaning. Therefore, it did not reflect natural speech as opposed to the production of real words used for the VOT stimuli. Secondly, the speech samples for DDK rate were produced in a rapid manner which might not reflect rate in speech production. Finally, the lack of differences between the dialects may possibly be due to the nature of the minimal pair words in the VOT results. This is further supported by the lack of differences seen for the multisyllabic DDK sequence.

Therefore, for each of the durational measures it can be argued that dialect differences between the Saudi Najdi and Bahraini Bahraini Arabic dialects were present, and were dependent on the nature of the stimuli.

Regarding the spectral measures of F0 and formant frequencies, the results were similar in terms of their dependence on the stimuli used for analysis. Furthermore, for F0 as seen in §6.9.1, the sustained phonation of the vowels /a, i, u/ showed no differences between the dialects; this was also the case for the vowels in words with the initial plain/emphatic stops /t, tˤ/. In addition, there were no differences between the dialects in question for sentences from the reading passage and sentences from the Quran. However, for vowels in words with the initial voiced /b, d/ and voiceless /t, k/ stops, the results showed that Saudi Najdi had lower mean F0 values than the Bahraini Bahraini dialect. For formant frequencies as seen in §7.7.1, the sustained phonation results showed no main effect of dialect. However, dialect was found to have an effect depending on vowel quality for F2 and F3. In addition, for vowels in words with initial voiced /b, d/, F1 was shown to have a significant effect. Furthermore, with regards to the F2 and F3 values of vowels with initial voiced /b, d/ and the F1-F3 of vowels with voiceless /t, k/ stops as well as the F2 values of vowels in words with initial plain/emphatic /t, tˤ/, there was a significant interaction with dialect. Similar to each of the durational measures, dialect differences were also dependent on the tasks undertaken for each of the spectral meauers.

The initial hypothesis proposed that no differences would be present between the Saudi Najdi and the Bahraini Bahraini Arabic dialects. The results from each of the parameters for DDK, VOT, F0 and formant frequencies show that this hypothesis has been to some extent rejected. This study has shown that the stimulus type played a major factor in the dialectal differences between the two Gulf Arabic dialects selected for analysis in the study.

The nature of the differences between the dialects in this study is due to the characteristics of the Bahraini Bahraini speakers as well as those from the Najdi Saudi dialect. Najdi Saudi dialect has been described to be closest to classical Arabic (Ingham, 1994). In the opinion of the author of this thesis, this still stands for the Riyadh Najdi dialect in this study. However, this does not eliminate that the Riyadh Najdi diaelct might have undergone some change as described in 2.3.2.1. The Bahraini Bahraini (Bahraini Arabs) daielct might have been influenced by the Bahrani Bahraini dialect that has been largely influenced by Persian (Holes, 2001). In addition, *Huwlah* who are Arab descendants from the Iranian coast might have shaped the current form of Bahraini Bahraini Arabic. Furthermore, Bahraini is a multicultural community where different languages are spoken. This includes Persian, English, different dialects of Arabic speakers who have immigrated to Bahrain (e.g. Levantine and Egyptian), (see §2.1.1.2.1.1). All of these factors might have influenced the Bahraini Bahraini dialect in its current form. Further studies are recommended to inspect why there are differences between the dialects in this study. Furthermore, the study has shown that regional Gulf Arabic dialects show some evidence of being more different phonetically than the hypothesis propsed initially in this thesis.

8.2.2 Q2: Are there differences in the speech of males and females in the Saudi Najdi and the Bahraini Bahraini Arabic dialects?

The results in Table 8.1 show that for the durational measures, there were no differences in the DDK rate between sexes as explained in §4.6.2. Furthermore, there were no sex differences in the VOT durations for words with initial voiced stops; as explained earlier (§5.9.2); this might be due to the voicing categories in the Arabic dialects examined in this study. Moreover, males had shorter VOT durations in words with initial voiceless stops as well as the voiceless stop in the voiced/voiceless contrast. Furthermore, in words with the initial plain/emphatic /t, $t^ʕ$/ males had shorter VOT durations than females. An interaction between emphasis and sex showed the same pattern for the voiceless stop /t/, where males had shorter VOT durations than females. However, for the emphatic /tˤ/, males had longer VOT durations than females and as explained earlier (§5.9.2) this shows an interplay between dialect and gender.

For the spectral measures in this study, the results unanimously showed that males had lower F0 values than females for sustained phonation data, and for vowels in words and sentences. This can attributed to males having longer vocal folds and a larger laryngeal size than females (Hollien, 1960; Kent, 1976; Hirano et al., 1981; Titze, 1989a; Fung, 1990; Williams & Eccles, 1990). Furthermore, males had lower F1-F3 values than females for the sustained phonation data and vowels in words. This also can be attributed to longer vocal tract length in males compared to females (Fant, 1973; Traunmüller, 1984, 1988). Although, both spectral measures showed sex differences between males and females, further studies are required if this pattern emerges in Arabic dialects where the Eygptiain diaelct (Kotby et al., 2010) showed simialities between sexes for F1-F3 in a number of vowels.

The initial hypothesis for sex differences was that the durational and spectral measures would show differences between males and females. The outcomes of this study, therefore, show strong support for the hypothesis made initially.

8.3 Implications

This study contributes to the literature by providing information on Arabic and more specifically on two Gulf Arabic dialects. Furthermore, it adds to the knowldge on phonological and phonetic featuers of the sedentary Riyadh Najdi Saudi dialect. Moreover, it provides normative data on a number of stimuli for a number of parameters (DDK, VOT, F0 and formant frequencies) from both male and female adult Bahraini Bahraini Arabic dialect speakers. To the knowledge of the researcher, this has not previously been investigated.

Therefore, this study adds to knowledge for male and more specifically female Bahraini Bahraini Arabic dialect. Also, the study provides information on the Najdi Saudi Arabic dialect, which has been researched previously to some extent; however, many of these studies restricted their investigations to male participants. Saudi Najdi females have not been investigated previously; therefore, this study adds to the linguistic knowledge on Saudi females as well as males using a controlled methodology that was limited to speakers of the Najdi Saudi dialect. In addition, this study adds to the linguistic knowledge on Bahraini females as well as males using a controlled methodology that was limited to speakers of the Bahraini Bahraini dialect. It showed sex differences between males and females on a number of parameters for both dialects. In addition, the outcomes from this study were established by utilising MSA and CA (i.e. the chapter from the Quran). Although, stimuli were in these forms, dialect showed some effect, therefore, replication of the study is possible in other Arabic dialects for future comparisons. The implications from this study are not limited to only the dialects under investigation, it showed that there might be further differences between Arabic dialects. It demonstrates that research on Arabic dialects might be enhanced from outlining the phonology of the dialects under investigation as well as more detailed phonetic study of the chosen Arabic dialect, thereby expanding the knowledge in a more comprehensive model of research.

The data provided by this study is useful and will aid speech and language pathologists in clinics as well as other health professionals. Furthermore, DDK rates for monosyllables and the multisyllabic sequence had not previously been established for Arabic speakers, to the knowledge of this researcher. Therefore, the data will be disseminated for use in clinics in Riyadh, Saudi Arabia and for Bahraini Arabs in Bahrain. The use of the multisyllabic sequence and the methodology adopted is recommended when patients are from different dialects of Arabic as the results showed no differences. Further confirmation is warranted in future studies on DDK rates in different dialects of Arabic.

This study provides normative data (means for all parameters and ranges for DDK and F0) for speakers of both Arabic dialects investigated in this study. Furthermore, it showed that clinicians in Saudi Arabia and more specifically Riyadh as well as Bahraini Arabs in Bahrain should use the normative data that is more specific to their respective dialects as difference were seen in this research. The results from this study showed that clinician should be aware of the patient's Arabic dialect in order to asses and design a treatment specific for that dialect. In addition, the inclusion of other stimuli tasks should be considered in clinical settings to expand the knowledge on actual speech production (e.g. sustained phonation only in voice evaluation) as will be explained in the following points. In addition, the clinical implication from the outcomes of this study will be covered.

Each chapter has presented further information on other variables, as explained in the following points:

- The information on DDK rates (Chapter 4) as described above introduces normative data for clinical settings. The study showed regardless of method of analysis for the multisyllabic sequences, dialectal differences are not found. Therefore, their applicability of use when assessing other dialects of Arabic is recommended. However, there is a need to confirm this with other dialects of Arabic and caution should be practiced.
- The information on VOT (Chapter 5) adds to the knowledge on Arabic in connection with voicing categories, place of articulation, vowel context and emphasis. The results showed dialects differences in the production of the voiceless stops. In addition, the emphatic /$t^ʕ$/ showed sex differences that are specific to the dialects investigated as described earlier. The results from this study will aid clinicians in understanding normative production for stops including the emphatic /$t^ʕ$/ for adult males and females from both Arabic dialects. Thus improving of treatment of patients with speech

difficulties with the aid of VOT as well as F1-F3. This might be promising in disorder such as cleft lip and palate where the alveolar emphatic stop were shown to be de-emphasized in cleft lip and palate children in Saudi Arabian (Al-Awaji, 2014), which might be evident in other dialects in the Arabian Gulf.

- The information on F0 (Chapter 6) furthers knowledge on Arabic in connection with vowel context, sentence type, voicing, place of articulation and emphasis. The study provides F0 including means and ranges for a number of tasks. Therefore, providing speech and language therapists with some guidance on normative F0 for male and female adult speakers from both dialects. Consequently, enabling diagnosis of abnormal voice disorders with a more objective analysis. Furthermore, in clinical settings, sustained phonation of vowels is often used for assessment and treatment of voice disorder. It is recommended that this remains the golden standard in assessment of voice for patients from different dialects of Arabic as it was not affected by dialect. Furthermore, the results showed that the chapter from the Quran as well as reading a passage might be a useful tool in assessment of different Arabic speakers. Although, their use in clinical settings in the author's opinion remains reserved as different styles of /qir'rat/ or reading in employed in the Quran as well as the reading a text were not controlled. However, the use of 1st chapter "Alfatihah" might be useful in different dialects of Arabic as well as expanding its use to different Muslim cultures as it is taught and memorized from an early age for most if not all Muslims.
- The information on formant frequencies (Chapter 7) adds to the knowledge on vowel quality and context, place of articulation and emphasis. This parameters shares similar implication as VOT.

One of the important implications of the study is the inclusion of the emphatic /tˤ/ in both dialects of Arabic. This firstly enables an understanding of normal production of one of the distinctive features of Arabic in both Arabic diaelcts as described above. From a sociolinguistic view, the results provide further support to other studies on VOT (Heselwood, 1996; Khattab et al., 2006) and formant frequencies (Khattab et al., 2006; Embarki et al., 2007) in that the results differentiate the Arabic dialects in this study as well as other Arabic dialects. The effect of emphasis on VOT showed that voicing category as well as degree of emphasis is able to distinguish between the different dialects of Arabic. In addition, the lack and/or degree of effect of emphasis on F1- F3 underline their importance on differentiating between Arabic dialects.

8.4 Limitations of the study

The sample in this study is of a healthy size, consisting of 80 speakers from both dialects of Arabic; however, a larger sample size would have meant that the results were more representative of these dialects. Due to the length of time available and the fact that only the researcher was involved in the data collection and analysis, this was not achieved. This study was restricted to adult male and female speakers of both Riyadh Najdi Saudi and Bahraini Arabs. Therefore, the results are more reflective of adult speakers of the two dialects and their employment to other dialects might be restricted. Another limitation is that the outcomes are confined to adult speakers from both dialects which are not expected to be applicable to children and older adults. It is as well a more representative of middle class for both dialects as the level of education was of graduate degrees and majority were employed in the governmental sector. Further studies are warranted to show if this is observed and can be generalized in other classes on both Arabic dialects. Furthermore, the interviews were conducted by the researcher who is a speaker of the Najdi dialect; therefore, the Bahraini dialect participants might have spoken in the white dialect (AlAwaji & Alshahwan, 2012). As the analysis was confined to an exploration between the two Arabic dialects, with the exception of DDK, cross-linguistic analysis for other parameters where applicable was not offered.

This study had a number of methodological issues as it was an exploratory study. The stimuli list was mostly in MSA; however, the results showed some dialect effects which are important in clinical setting as previously mentioned. Furthermore, the stimuli were not designed specifically for the dialects in this study, therefore limiting the representation of the dialects as well as further possible differences between the dialects. It is acknowledged that only a subset from the speech sample gathered (see Appendix 3.6), this will be addressed in more detail towards the end of the sections.

With regards to statistical analysis, the study had no random effects included in the design (Baayen et al., 2008) which might have further expanded the knowledge of the Arabic dialect investigated.

Before discussing the limitations for the parameters included in this study, some shared limitations for the word list selected in the study will be examined. Firstly, the lower vowel /a:/ was not included in a word with initial /t/, thereby, limiting the results to higher vowels /i: , u:/ for alveolar plain voiced/voiceless and the emphatic stops. Secondly, the words selected were MSA; however, the level of frequency of these words was not assessed prior to stimuli design. Thirdly, the use of the final /r/ in words as this might confound the interpretation from the effect of initial stops, although, it offers some exploration from its effect for formant frequencies. Fourthly, limiting the study to long vowels in words, while, the inclusion of short vowels and diphthongs might have expanded the knowledge on Arabic vowels. Finally, the use of isolated words rather than in connected speech which might limit the generalizability of the results.

The following are limitations for DDK with regards to stimuli and analysis:

- Limiting statistical analysis to mean DDK rates and not expanding the analysis to variability of production from both Arabic dialects. Although, minimum and maximum rates were presented.
- Expanding of analysis for accuracy and consistency in addition to mean DDK rates.
- The analysis of the full triad of multisyllabic sequences could be implemented, in agreement with Louzada et al. (2011) as well as analysis of syllable rates across

different places of articulation (Topbaş et al., 2012). Future research on methods of analysis is recommended

Limitations for VOT have been described earlier as well as limiting the analysis to monosyllables and isolated words. In addition, variability for VOT results between and within subjects was not assessed. , the study limits the analysis to only two durational measures in this study (DDK and VOT).

Limitations for F0 with respect to methods and analysis:

- It shares its restriction to statistical analysis of mean F0 only and no inclusion of statistical analysis of variability of F0 for all stimuli. Although, F0 minimum and maximum values were presented for all stimuli in the results section.
- Another limitation with regards to sentences, selected sentences for analysis were the fourth and fifth sentences in the first chapter of the Quran and the fifth sentence from the Arabic version of “The North Wind and the Sun” (Thelwall & Sa’Adeddin, 1990). An equal number of words were not analysed as the sentences from the Quran were seven words long, while the words from the Arabic version of “The North Wind and the Sun” were seventeen words long.
- Furthermore, for sentences, the study was limited to mean F0 across the whole sentence, since the study was directed to F0 between dialects. Further analysis to pitch contours might have added more understanding between the dialects.
- Spontaneous speech was not analysed for F0 as it would have been more illustrative of the Arabic dialects chosen in the study.

For formant frequencies, limitations are as followed:

- Recordings were made to WMA format in comparison to WAV which might have affected the quality for formant frequencies analysis as well as overall quality of recording (Schilling, 2013). Although, as specified in §7.4.5 described the use of outlies to control this, it remains a limitation.
- Analysis was limited to the mid-point in the vowel rather than also including onset and offset measurements.

- No normalisation techniques were used in the analysis of the formant frequencies. This would supplement the current analysis of the dialects and sex differences of the current samples.

As described earlier, the spontaneous speech (see Appendix 3.6), which might have been more representative of the dialects chosen in the study was not analysed, in addition, to automatic speech, due to the reasons specified earlier. In addition, as presented from the word list (see Appendix 3.7), initial stops with the uvular /g, q/ and glottal /ʔ/ stops, as well as a number of words with initial fricatives as well as the emphatic fricatives were not analysed.

8.5 Future research

There are two directions for future research arising from this study and the examination of its limitations: one takes a sociolinguistic perspective while the other takes a clinical perspective; the two directions are not exclusive of each other, and therefore will overlap. This section will initially describe general directions for future studies and then will move on to suggest future research on the parameters examined in this study. Before describing future direction of research, it must be emphasized that there is a need for future research on the emphatics in Arabic and its dialects from both a sociolinguistic and clinical perspective. Clinical based evidence for the emphatics is vital for a feature that characterises Arabic. In addition, from the normative data provided in this study, analysis of disordered speech in the two dialects is the next step for clinical use.

The following are future research to be considered:

- The sample size could be increased in future studies to further confirm the outcomes from this study for Riyadh Najdi Saudi Arabic and the Bahraini Arab dialect in Bahrain.

- A further study including speakers of different social statuses might be beneficial from a linguistic and clinical perspective. For example, some studies (Kahn, 1975; Khattab et al., 2006) showed the effect from social class in addition to sex differences on the acoustic correlates of emphasis. If an effect is confirmed, this would support clinicians in implementing appropriate services for patients depending on their social class and sex. Furthermore, to the knowledge of this author, this is an area of research that has not been investigated for Arabic speakers in clinical settings.
- Studies that focus on the normative production of emphatics by children might improve the understanding of their production and thus enable better treatment plans as emphatics have been shown to be strongly affected by speech disorders (e.g. cleft lip and palate disorders). The inclusion of different instruments such as Electropalatography (EPG) and x-rays might provide further information on this class of disorders as well as providing information on the production of gutturals by children and adults. However, the latter might pose some health risks.
- MSA was shown to have distinctive features in terms of formant frequencies (Embarki et al., 2007); therefore, further studies on this form of Arabic are recommended.
- Further studies are recommended in order to expand the knowledge on the dialects of Saudi Arabia and Bahrain from a phonological and phonetic/acoustic approach. This study provided a possible methodology that can be adopted as it used MSA and CA Arabic. However, future studies might be more informative by designing stimuli that are more dialectal in nature. The next logical step is to focus on two dialects: the eastern dialect in Saudi Arabia as well as the Bahrani Bahraini (Shi'a) dialect, since these two dialects are the closest in phonology to those examined in

this study. The inclusion of other Arabic dialects, and more specifically the Western Arabic dialects (e.g. Egyptian and Moroccan), should follow as these have shown to differ from Eastern Arabic dialects (Embarki et al., 2007).

- For all the parameters in this study, further studies are needed on speech and language disorders. For example, examining both VOT and formant frequencies as described earlier in relation to cleft lip and palate patients would be beneficial to treatment. For F0, voice disorders such as vocal fold nodules could be examined. Other disorders such as apraxia and dysarthria would benefit from their characteristics being profiled across all the parameters (DDK, VOT, F0 and formant frequencies). This would aid speech and language pathologists in their approach to treatment as this study provides normative data. Further statistical analysis of variability for all the parameters in this study is recommended.
- Fitch (1990) showed that in examining F0 in American English, reading was the most reliable measure of voice amongst sustained phonation, reading and continuous speech. Further analysis on all samples in this study (including spontaneous and automatic speech) is recommended. Assessment of the suprasegmental features in the Arabic dialects in this study is also recommended. Further assessment of voice qualities between dialects and male and female speakers is suggested.
- For formant frequencies, additional measurements could be carried out on different points of the vowel such as the onset and offset. In addition, using locus equations seems to be a promising area of enquiry (Embarki et al., 2007) for further analysing the differences between Arabic dialects. Additionally, normalisation of the data would offer further scope to conduct comparisons between Arabic dialects and male and female speakers.

A final reminder is that only a subset of the speech samples collected was analysed (see Appendix 3.6). Therefore, the following points are recommended. For VOT, /q/ and its realisation /g/ could be included and analysed. In addition, the inclusion of the lower vowel /a/ in stimuli is recommended for future analysis on emphatics. In addition, temporal and spectral analysis of further words with initial fricatives as well as emphatic consonants /dˤ, ðˤ, sˤ/ are also recommended (Appendix 3.7).

8.6 Final Summary

Speech and language pathologists should be aware of differences in speech production between dialects of Arabic to ensure intervention is appropriate for the client group. This study provided standardized speech data for two Gulf Arabic dialects for both sexes. In addition, it showed that depending on stimuli context, different dialectal and sex differences are present. Further analysis on other dialects of Arabic is recommended. Finally, emphatics are distinctive in spoken Arabic; therefore further analysis of this group of sounds might play a major role in characterising speech dialects.

References:

Abdelali, A. (2004). Localization in Modern Standard Arabic. *Journal of the American Society for Information Science and Technology*, 55(1), 23–28.

Abdulaziz, M. H. (1986). Factors in the Development of Modern Arabic Usage. *International Journal of the Sociology of Language*, 1986(62), 11–24.

Abou Haidar, L. (1994). Norme Linguistique et Variabilité Dialectale: Analyse Formantique Du Système Vocalique de La Langue Arabe. *Revue de Phonétique Appliquée*, 110, 1–15.

Abu-Absi, S. (1986). The Modernization of Arabic: Problems and Prospects. *Anthropological linguistics*, 337–348.

Abu-Al-Makarem, A. L. I. & Petrosino, L. (2007). Reading and Spontaneous Speaking Fundamental Frequency of Young Arabic Men for Arabic and English Languages: A Comparative Study. *Perceptual and Motor Skills*, 105(2), 572–580.

Abu-Al-Makarem, A. S. (2005). The Acoustics of Fricative Consonants in Gulf Spoken Arabic.Unpublished MSc. Thesis. Bowling Green Univeristy.

Abudalbuh, M. (2010). Effects of Gender on the Production of Emphasis in Jordanian Arabic: A Sociophonetic Study. Unpublished MSc. Thesis. Retrieved June 28, 2012, from http://kuscholarworks.ku.edu/dspace/handle/1808/6727

Ackermann, H., Hertrich, I. & Hehr, T. (1995). Oral Diadochokinesis in Neurological Dysarthrias. *Folia Phoniatrica et Logopaedica*, 47(1), 15–23.

Adank, P., Van Hout, R. & Smits, R. (2004). An Acoustic Description of the Vowels of Northern and Southern Standard Dutch. *The Journal of the Acoustical society of America*, 116(3), 1729–1738.

Adank, P., Van Hout, R. & Velde, H. V. D. (2007). An Acoustic Description of the Vowels of Northern and Southern Standard Dutch II: Regional Varieties. *Journal of the Acoustical Society of America*, 121(2), 1130–1141.

Ahmed, A. (1979). A Phonetic Study of Men and Women’s Speech with Reference to Emphasis in Cairene Arabic. Unpublished Doctoral Thesis. Univeristy of Leeds.

Al-Ani, S. H. (1970). *Arabic Phonology: An Acoustical and Physiological Investigation.* Mouten: The Hague.

AlAwaji, N. & Alshahwan, M. (2012). A Dialect Without Borders, in: *The Community Histories, Social Change and Dialect Variation workshop*. School of Languages ,University of Sheffield. Retrieved from http://www.academia.edu/6550996/A_Dialect_Without_Borders

Al-Awaji, N. N. (2014). Speech Production in Arabic Speaking Children with Operated Cleft Palate. Unpublished Doctoral Thesis. Univeristy of Sheffield.

AlDahri, S. S. & Alotaibi, Y. A. (2010). A Crosslanguage Survey of VOT Values for Stops (/d/,/t/), in: *Intelligent Computing and Intelligent Systems (ICIS), 2010 IEEE International Conference on*, (pp. 334–338).

Alghamdi, M. (2006). Voice Print": Voice Onset Time as a Model. *Arab Journal for Security Studies and Training*, 21(42), 89–118.

Alghamdi, M. M. (1998). A Spectrographic Analysis of Arabic Vowels: A Cross-Dialect Study. *Journal of King Saud University*. Retrieved March 4, 2014, from http://repository.ksu.edu.sa/jspui/handle/123456789/372

Alghamdi, M. M. A. (1990). Analysis, Synthesis and Perception of Voicing in Arabic. Unpublished PhD Thesis. University of Reading. Retrieved January 18, 2013, from http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.278156

AlJassir, H. (2001). *Riyadh City : Through Phases of Hisotry*. Riyadh,Saudi Arabia: King Abdulaziz Publishing.

AL-Juhany, U. M. (2002). Najd before the Salafi Reform Movement, Social,Political and Religions Conditions during the three Centuries Preceding the rise of the Saudi State. Retrieved July 20, 2015, from http://repository.ksu.edu.sa/jspui/handle/123456789/19042

Al-Masri, M. & Jongman, A. (2004a). Acoustic Correlates of Emphasis in Jordanian Arabic: Preliminary Results, in: *Proceedings of the 2003 Texas Linguistics Society Conference. Somerville, MA: Cascadilla Proceedings Project*, (pp. 96–106). Retrieved December 21, 2013, from http://www.neuroling.ku.edu/~kuppl/jongman/TLSemphaticsfinal.pdf

Al-Masri, M. & Jongman, A. (2004b). Acoustic Correlates of Emphasis in Jordanian Arabic: Preliminary Results, in: *Proceedings of the 2003 Texas Linguistics Society Conference. Somerville, MA: Cascadilla Proceedings Project*, (pp. 96–106). Retrieved December 13, 2013, from http://www.neuroling.ku.edu/~kuppl/jongman/TLSemphaticsfinal.pdf

Al-Masri, M. S. (2009). The Acoustic and Perceptual Correlates of Emphasis in Urban Jordanian Arabic. Unpublished PhD Dissertation. Univeristy of Kansas. Retrieved March 24, 2015,

Almbark, R. (2009). A Sociophonetic Study of Pharygealisation in Syrian Arabic: Gender and Regional Differences between Damascene and Aleppian Dialects, in: *Centre for Research in Linguistics and Language Sciences*.

Alotaibi, Y. A. & AlDahri, S. S. (2011). Investigating VOTs of Arabic Stops/b, K/with Comparisons to Other Languages, in: *Image and Signal Processing (CISP), 2011 4th International Congress on*, (pp. 2413–2417).

Alotaibi, Y. A. & Husain, A. (2009). Formant Based Analysis of Spoken Arabic Vowels, in: Fierrez, J., Ortega-Garcia, J., Esposito, A., Drygajlo, A., and Faundez-Zanuy, M. (Eds.), *Biometric ID Management and Multimodal Communication*, (pp. 162–169). Lecture Notes in Computer Science. Springer Berlin Heidelberg. Retrieved March 10, 2015, from http://link.springer.com/chapter/10.1007/978-3-642-04391-8_21

Alshahwan, M. (2008). Speaking Fundamental Frequency in Arabic and English Bilingual Saudi Speakers. Unpublished MSc. Dissertation. University of Sheffield

Al-Shatti, Al-Alwan, Al-Hajjaji, Al-Subait & Al-Shakhs. (2008). Fundamental Frequency of Saudi Arabic Speaking College Students.Unpublished BSc. Dissertation. King Saud University.

Al-Tajir, M. A. (1982). *Language and Linguistic Origins in Baḥrain*. Kegan Paul International. Retrieved July 20, 2015,

Altenberg, E. P. & Ferrand, C. T. (2006). Fundamental Frequency in Monolingual English, Bilingual English/Russian, and Bilingual English/Cantonese Young Adult Women. *Journal of Voice*, 20(1), 89–96.

Al-Wer, E. (1999). Why Do Different Variables Behave Differently? Data from Arabic, in: Suleiman, Y. (Ed.), *Language and Society in the Middle East and North Africa: Studies in Variation and Identity*, (pp. 38–57). Curzon. Retrieved December 20, 2015, from https://books.google.co.uk/books?hl=en&lr=&id=yC5mAgAAQBAJ&oi=fnd&pg=PA38&dq=jordanian+arabic+linguistic+influence&ots=vT253rPc4s&sig=mmgJdOLKF5WF-ah4_bvp5tCx1PU

Amayreh, M., Hamdan, J. & Fareh, S. (1999). Consonant Frequency in Arabic and English. *Dirasat, Soc Human Stud (special issue)*, 207–220.

Amayreh, M. M. (2003). Completion of the Consonant Inventory of Arabic. *Journal of speech, language, and hearing research : JSLHR*, 46(3), 517–29.

Amayreh, M. M. & Dyson, A. T. (1998). The Acquisition of Arabic Consonants. *J Speech Lang Hear Res*, 41(3), 642–653.

Amerman, J. D. & Parnell, M. M. (1982). Oral Motor Precision in Older Adults. *Journal of the National Student Speech Language Hearing Association*, 100, 55–66.

Amir, N., Amir, O. & Rosenhouse, J. (2014). Colloquial Arabic Vowels in Israel: A Comparative Acoustic Study of Two Dialects. *The Journal of the Acoustical Society of America*, 136(4), 1895–1907.

Andreeva, B., Demenko, G., Wolska, M., Möbius, B., Zimmerer, F., Jügler, J., et al. (2014). Comparison of Pitch Range and Pitch Variation in Slavic and Germanic Languages, in: *Speech Prosody*. Dublin,Ireland. Retrieved July 20, 2014, from http://www.coli.uni-saarland.de/~trouvain/Andreeva_et_al_2014.pdf

Andrianopoulos, M. V., Darrow, K. N. & Chen, J. (2001). Multimodal Standardization of Voice among Four Multicultural Populations: Fundamental Frequency and Spectral Characteristics. *Journal of Voice*, 15(2), 194–219.

Awan, S. N. & Stine, C. L. (2011). Voice Onset Time in Indian English-Accented Speech. *Clinical linguistics & phonetics*, 25(11–12), 998–1003.

Baayen, R. H., Davidson, D. J. & Bates, D. M. (2008). Mixed-Effects Modeling with Crossed Random Effects for Subjects and Items. *Journal of memory and language*, 59(4), 390–412.

Badawi, E. (1973). *Mustawayāt al-‘arabiyya al-mu ‘āṣira fī Miṣr :baHth ’ilaaqat al-lugha bi al-HaDaara*. Cario,Egypt: Daar Al-Ma’aarif.

Baken, R. J. & Orlikoff, R. F. (2000). *Clinical Measurement of Speech and Voice*. Singular Pub Group.

Baran, J. A., Laufer, M. Z. & Daniloff, R. (1977). Phonological Contrastivity in Conversation: A Comparative Study of Voice Onset Time. *Journal of Phonetics*. Retrieved December 2, 2013, from http://psycnet.apa.org/psycinfo/1978-29017-001

Barkat, M. (2000). Determination of Reliable Acoustic Cues for the Automatic Identification of Arabic Dialects.Unpublished Doctoral Thesis. University of Lyon. (French)

Bauer, T. (1996). Arabic Writing, in: Daniels, P. T. and Bright, W. (Eds.), *The World’s Writing Systems*, (pp. 559–564).

Bellem, A. (2008). Towards a Comparative Typology of Emphatics: Across Semitic and Into Arabic Dialect Phonology. Unpublished PhD thesis. University of London. Retrieved December 24, 2013, from http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.487300

Benjamin, B. J. (1986). Dimensions of the Older Female Voice. *Language & Communication*, 6(1), 35–45.

Bennett, S. (1983). A 3-Year Longitudinal Study of School-Aged Children's Fundamental Frequencies. *Journal of Speech, Language, and Hearing Research*, 26(1), 137–141.

Bin-Muqbil, M. S. (2006). Phonetic and Phonological Aspects of Arabic Emphatics and Gutturals.Unpublished PhD Dissertation. Univeristy of Wisconson.

Black, J. W. (1961). Relationships among Fundamental Frequency, Vocal Sound Pressure, and Rate of Speaking. *Language and Speech*, 4(4), 196–199.

Blanc, H. (1960). Stylistic Variations in Spoken Arabic, in: Ferguson, C. (Ed.), *Contributions to Arabic Linguistics*. Harvard Middle Eastern Monographs, III. Cambridge, Mass: Harvard University Press.

Blanc, H. (1964). *Communal Dialects in Baghdad*. Cambridge, Harvard Univeristy Press.

Blomquist, B. L. (1950). Diadochokinetic Movements of Nine-, Ten-, and Eleven-Year Old Children. *The Journal of speech disorders*, 15(2), 159–164.

Boersma, P. & Weenink, D. (2013). *Praat: Doing Phonetics by Computer*. Retrieved June 24, 2012, from http://www.praat.org

Breitbach-Snowdon, H. (2003). *UNS: Untersuchung neurologisch bedingter Sprech-und Stimmstörungen*. Prolog, Therapie-und Lernmittel.

Brown, W. S., Morris, R. J., Hollien, H. & Howell, E. (1991). Speaking Fundamental Frequency Characteristics as a Function of Age and Professional Singing. *Journal of Voice*, 5(4), 310–315.

Bucaille, M. (2003). *The Bible, the Qur'an, and Science: The Holy Scriptures Examined in the Light of Modern Knowledge*. Tahrike Tarsile Quran.

Bucaille, M. & Pannell, A. D. (1978). *The Bible, the Qur'an, and Science*. Seghers.

Caramazza, A. & Yeni-Komshian, G. H. (1974). Voice Onset Time in Two French Dialects. *Journal of Phonetics*, 2(3), 239–245.

Card, E. A. (1983). A Phonetic and Phonological Study of Arabic Emphasis.Unpublished Doctoral Dissertation. Cornell University.

Central Intelligence Agency. (2015). The World Factbook : Bahraini. *Central Intelligence Agencey*. Retrieved July 20, 2015, from https://www.cia.gov/library/publications/the-world-factbook/geos/ba.html

Chao, K. Y. & Chen, L. (2008). A Cross-Linguistic Study of Voice Onset Time in Stop Consonant Productions. *Computational Linguistics and Chinese Language Processing*, 13(2), 215–232.

Chen, L., Chao, K. Y., Peng, J. F. & Yang, J. C. (2008). A Cross-Language Study of Stop Aspiration: English and Mandarin Chinese, in: *Multimedia, 2008. ISM 2008. Tenth IEEE International*

Symposium on, (pp. 556–561). Retrieved January 21, 2013, from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=4741226

Chen, S. H. (2007). Sex Differences in Frequency and Intensity in Reading and Voice Range Profiles for Taiwanese Adult Speakers. *Folia Phoniatrica et Logopaedica*, 59(1), 1–9.

Cheng, H. Y., Murdoch, B. E., Goozee, J. V. & Scott, D. (2007). Physiologic Development of Tongue-Jaw Coordination from Childhood to Adulthood. *Journal of Speech, Language, and Hearing Research*, 50(2), 352.

Cheng, M.-C. (2013). Voice Onset Time of Syllable-Initial Stops in Sixian Hakka: Isolated Syllables. *Journal of National Taiwan Normal Univeristy : Linguistics & Literature*, 58(2), Taipei,Taiwan.

Chládková, K., Escudero, P. & Boersma, P. (2011). Context-Specific Acoustic Differences between Peruvian and Iberian Spanish Vowels. *The Journal of the Acoustical Society of America*, 130(1), 416–428.

Cho, T. & Ladefoged, P. (1999). Variation and Universals in VOT: Evidence from 18 Languages. *Journal of Phonetics*, 27(2), 207–229.

Cohen, W., Waters, D. & Hewlett, N. (1998). DDK Rates in the Paediatric Clinic: A Methodological Minefield. *International Journal of Language and Communication Disorders*, 33(SUPPL.), 428–433.

Cote, R. A. (2009). Choosing One Dialect for the Arabic Speaking World: A Status Planning Dilemma. *Arizona Working Papers in SLA & Teaching*, 16, 75–97.

Crary, M. A. (1993). *Developmental Motor Speech Disorders*. Singular Publishing Group San Diego, CA.

Crosswhite, K. & Antoniuo, M. (2007). Duration-Logger. Retrieved from http://markantoniou.blogspot.co.uk/2007/09/praat-christmas.html

Crystal, D. (1997). The Encyclopedia of Language. *Cambridge: Cambridge*.

Curry, E. T. (1940). The Pitch Characteristics of the Adolescent Male Voice. *Communications Monographs*, 7(1), 48–62.

Deliyski, D. D. & DeLassus Gress, C. (1997). Characteristics of Motor Speech Performance: Normative Data.

Docherty, G. J. (1992). *The Timing of Voicing in British English Obstruents*. Walter de Gruyter.

Dromey, C. & Ramig, L. O. (1998). Intentional Changes in Sound Pressure Level and RateTheir Impact on Measures of Respiration, Phonation, and Articulation. *Journal of Speech, Language, and Hearing Research*, 41(5), 1003–1018.

Duffy, R. J. (1970). Fundamental Frequency Characteristics of Adolescent Females. *Language and speech*, 13(1), 14–24.

Embarki, M. (2013). Phonetics, in: Jonathan, O. (Ed.), *The Oxford Handbook of Arabic Linguistics*, (pp. 23–44). New York: Oxford University Press.

Embarki, M., Yeou, M., Guilleminot, C. & Al Maqtari, S. (2007). An Acoustic Study of Coarticulation in Modern Standard Arabic and Dialectal Arabic: Pharyngealized vs Non-Pharyngealized Articulation. *ICPhS XVI*, 141–146.

Escudero, P., Boersma, P., Rauber, A. S. & Bion, R. A. H. (2009). A Cross-Dialect Acoustic Description of Vowels: Brazilian and European Portuguese. *Journal of the Acoustical Society of America*, 126(3), 1379–1393.

Fairbanks, G. (1960). *Voice and Articulation Drillbook*. Harper New York.

Fant, G. (1960). *Acoustic Theory of Speech Production*. The Hague : Mouton.

Fant, G. (1973). Speech Sounds and Features. Retrieved December 3, 2013, from http://psycnet.apa.org/psycinfo/1974-20912-000

Fatihi, A. R. (2001). *Aspects of Arabic Phonology*. Kalinga Publications.

Ferguson, C. (1959a). Diglossia. *Word*, 15(2), 325–340.

Ferguson, C. (1959b). The Arabic Koine. *Language*, 35(4), 616–630.

Fischer, W. & Jastrow, O. (1980). *Handbuch Der Arabischen Dialekte*. Otto Harrassowitz.

Fitch, W. T. & Giedd, J. (1999). Morphology and Development of the Human Vocal Tract: A Study Using Magnetic Resonance Imaging. *The Journal of the Acoustical Society of America*, 106(3), 1511–1522.

Flege, J. E. (1982). Phonetic Interference in Second Language Acquisition.

Fletcher, S. G. (1972). Time-by-Count Measurement of Diadochokinetic Syllable Rate. *Journal of Speech, Language and Hearing Research*, 15(4), 763.

Fletcher, S. G. (1978). Time-by-Count Test Measurement of Diadochokinetic Syllable Rate. *Austin, TX: PRO-ED*.

Flynn, N. (2011). Comparing Vowel Formant Normalisation Procedures. *York Working Papers in Linguistics (Series 2)*, 11, 1–28.

Fowler, C. A., Sramko, V., Ostry, D. J., Rowland, S. A. & Hallé, P. (2008). Cross Language Phonetic Influences on the Speech of French–English Bilinguals. *Journal of Phonetics*, 36(4), 649–663.

Fox, R. A., Jacewicz, E. & Hart, J. (2013). Pitch Pattern Variations in Three Regional Varieties of American English., in: *INTERSPEECH*, (pp. 123–127). Retrieved July 21, 2014, from http://web.shs.ohio-state.edu/Faculty/Jacewicz/Jacewicz_Publications/2013_Interspeech_Lyon_f0.PDF

Fung, Y.-C. (1990). *Biomechanics*. Springer. Retrieved July 16, 2014, from http://cds.cern.ch/record/1622592

Gadesmann, M. & Miller, N. (2008). Reliability of Speech Diadochokinetic Test Measurement. *International Journal of Language & Communication Disorders*, 43(1), 41–54.

Guimarães, I. & Abberton, E. (2005). Health and Voice Quality in Smokers: An Exploratory Investigation. *Logopedics Phoniatrics Vocology*, 30(3), 185–191.

Guimarães & Abberton. (2005). Fundamental Frequency in Speakers of Portuguese for Different Voice Samples. *Journal of voice*, 19(4), 592–606.

Haeri, N (2000) Form and Ideology: Arabic Sociolingusitics and Beyound. *Annual Review of Anthropology*,61-87.

Hagiwara, R. (1997). Dialect Variation and Formant Frequency: The American English Vowels Revisited. *The Journal of the Acoustical Society of America*, 102(1), 655–658.

Hagiwara, R. E. (2006). Vowel Production in Winnipeg. *The Canadian Journal of Linguistics/La revue canadienne de linguistique*, 51(2), 127–141.

Hamdan, A.-L., Ashkar, J., Sibai, A., Oubari, D. & Husseini, S. T. (2010). Effect of Fasting on Voice in Males. *American journal of otolaryngology*, 32(2), 124–9.

Hamdan, A.-L., Sibai, A. & Rameh, C. (2007). Effect of Fasting on Voice in Women. *Journal of voice : official journal of the Voice Foundation*, 21(4), 495–501.

Hanley, T. D. (1951). An Analysis of Vocal Frequency and Duration Characteristics of Selected Samples of Speech from Three American Dialect Regions. *Communication Monographs*, 18(1), 78–93.

Harnsberger, J. D., Shrivastav, R., Brown Jr, W. S., Rothman, H. & Hollien, H. (2008). Speaking Rate and Fundamental Frequency as Speech Cues to Perceived Age. *Journal of voice*, 22(1), 58–69.

Heath, J. (1997). Moroccan Arabic Phonology. *Phonologies of Asia and Africa (including the Caucasus)*, 1, 205–217.

Hermena, E. W., Drieghe, D., Hellmuth, S. & Liversedge, S. P. (2015). Processing of Arabic Diacritical Marks: Phonological–Syntactic Disambiguation of Homographic Verbs and Visual Crowding Effects. *Journal of Experimental Psychology: Human Perception and Performance*, 41(2), 494–507.

Herrmann, F. (2008). Praat F0 Script for Voiced Portion.

Herzallah, R. S. (1990). Aspects of Palestinian Arabic Phonology: A Non-Linear Approach.Unpublished PhD dissertation. Cornell University.

Heselwood, B. (1996). Glottal States and Emphasis in Baghdadi and Cairene Arabic: Synchronic and Diachronic Aspects. *Three topics in Arabic Phonology. Centre of Middle Eastern and Islamic Studies, Occasional Papers*, 53, 20–44.

Heselwood, B. (2007). The 'tight Approximant'variant of the Arabic 'ayn. *Journal of the International Phonetic Association*, 37(1), 1–32.

Higgins, M. B. & Saxman, J. H. (1991). A Comparison of Selected Phonatory Behaviors of Healthy Aged and Young Adults. *Journal of Speech, Language, and Hearing Research*, 34(5), 1000–1010.

Hillenbrand, J., Getty, L. A., Clark, M. J. & Wheeler, K. (1995). Acoustic Characteristics of American English Vowels. *The Journal of the Acoustical society of America*, 97(5), 3099–3111.

Hillenbrand, J. M., Clark, M. J. & Neave, T. (1997). Effects of Consonant Environment on Vowel Formant Patterns. *The Journal of the Acoustical Society of America*, 102(5), 3093–3093.

Hirano, M., Kurita, S. & Nakashima, T. (1981). The Structure of the Vocal Folds. *Vocal fold physiology*, 33–41.

Hirst, D. (2012). Analyse_tier.Praat. Retrieved from http://uk.groups.yahoo.com/neo/groups/praat-users/files/Daniel_Hirst/

Holes, C. (1983). Bahraini Dialects: Sectarian Differences and the Sedentary/nomadic Split. *Zeitschrift f\ür arabische Linguistik*, (10), 7–38.

Holes, C. (1984). Bahraini Dialects: Sectarian Differences Exemplified through Texts. *Zeitschrift f\ür arabische Linguistik*, (13), 27–67.

Holes, C. (1987). *Language Variation and Change in a Modernising Arab State: The Case of Bahrain*. Kegan Paul Intl.

Holes, C. (1990). *Gulf Arabic*. Routledge.

Holes, C. (2001). *Dialect, Culture, and Society in Eastern Arabia: Glossary*. Brill Academic Publishers. Retrieved December 23, 2015,

Holes, C. (2004). *Modern Arabic: Structures, Functions, and Varieties*. Georgetown Univ Pr.

Hollien, H. (1960). Some Laryngeal Correlates of Vocal Pitch. *Journal of Speech, Language, and Hearing Research*, 3(1), 52–58.

Hollien, H. & Malcik, E. (1962). Adolescent Voice Change in Southern Negro Males. *Speech Monographs*, 29, 53–58.

Hollien, H. & Shipp, T. (1972). Speaking Fundamental Frequency and Chronologic Age in Males. *Journal of Speech, Language and Hearing Research*, 15(1), 155.

Hoo Technologies. (2007). *WMA MP3 Converter*. Hoo Technologies. Retrieved from http://www.wma-mp3.net/index.htm

House, A. S. & Fairbanks, G. (1953). The Influence of Consonant Environment upon the Secondary Acoustical Characteristics of Vowels. *The Journal of the Acoustical Society of America*, 25(1), 105–113.

Hudson, A. I. & Holbrook, A. (1981). A Study of the Reading Fundamental Vocal Frequency of Young Black Adults. *J Speech Hear Res*, 24(2), 197–200.

Hudson, A. I. & Holbrook, A. (1982). Fundamental Frequency Characteristics of Young Black Adults Spontaneous Speaking and Oral Reading. *Journal of Speech, Language and Hearing Research*, 25(1), 25–28.

Hussain, A. A. A. (1985). An Experimental Investigation of Some Aspects of the Sound System of the Gulf Arabic Dialect with Special Reference to Duration. Unpublished PhD thesis. Univeristy of Essex. Retrieved November 28, 2013, from http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.356747

Icht, M. & Ben-David, B. M. (2014). Oral-Diadochokinesis Rates across Languages: English and Hebrew Norms. *Journal of communication disorders*, 48, 27–37.

Ingham, B. (1971). Some Characteristics of Meccan Speech. *Bulletin of the School of Oriental and African Studies*, 34(2), 273–297.

Ingham, B. (1982). North-East Arabian Dialects, London and Boston: Kegan Paul International. *Cite par Versteegh*.

Ingham, B. (1994). *Najdi Arabic: Central Arabian*. John Benjamins.

Ingham, B. (2006). Saudi Arabia: Language Situation, in: *Encyclopedia of Language & Linguistics*, (pp. 753–754). Oxford: Elsevier. Retrieved from http://www.sciencedirect.com/science/article/B7T84-4M3C3K0-268/2/beeaf54ff7971947aa91159197f6d0e0

Ismail, M. A. (2008). A Comparative Sociolinguistic Study of Gender Related Differences and Attitudes in the Use of Standard Arabic Speech Forms in the Kingdom of Saudi Arabia. Unpublished PhD thesis. King Saud Univeriesty. Retrieved June 20, 2014, from http://repository.ksu.edu.sa/jspui/handle/123456789/19320

Izadi, F., Mohseni, R., Daneshi, A. & Sandughdar, N. (2012). Determination of Fundamental Frequency and Voice Intensity in Iranian Men and Women Aged Between 18 and 45 Years. *Journal of Voice*, 26(3), 336–340.

Jesry, M. M. (1996). Some Cognitively Controlled Coarticulatory Effects in Arabic and English, with Particular Reference to Voice Onset Time. Unpublished PhD thesis. Univeristy of Essex. Retrieved December 19, 2013, from http://ethos.bl.uk/OrderDetails.do?uin=uk.bl.ethos.309771

Jessen, M. & Ringen, C. (2002). Laryngeal Features in German. *Phonology*, 19(2), 189–218.

Johnson, A. F. & Jacobson, B. H. (2011). *Medical Speech-Language Pathology: A Practitioner's Guide*. Thieme.

Johnstone, T. (1961). Some Characteristics of the Dōsiri Dialect of Arabic as Spoken in Kuwait. *Bulletin of the School of Oriental and African Studies*, 24(2), 249–297.

Johnstone, T. (1964). Further Studies on the Dōsiri Dialect of Arabic as Spoken in Kuwait. *Bulletin of the School of Oriental and African Studies, University of London*, 27(1), 77–113.

Johnstone, T. (1965). The Sound Change/j/>/y/in the Arabic Dialects of Peninsular Arabia'. *BSOAS*, 28(2), 233–41.

Jong Kong, E., Syrika, A. & Edwards, J. R. (2012). Voiced Stop Prenasalization in Two Dialects of Greek. *The Journal of the Acoustical Society of America*, 132(5), 3439–3452.

Jongman, A., Herd, W., Al-Masri, M., Sereno, J. & Combest, S. (2011). Acoustics and Perception of Emphasis in Urban Jordanian Arabic. *Journal of Phonetics*, 39(1), 85–95.

Kahn, M. (1975). Arabic Emphatics: The Evidence for Cultural Determinants of Phonetic Sex-Typing. *Phonetica*, 31(1), 38–50.

Kaye, A. S. (1990). A Linguistic Study of the Development of Scientific Vocabulary in Standard Arabic. *Zeitschrift fur arabische Linguistik/Journal of Arabic Linguistics /Journal de Linguistique Arabe*, 21, 91–96.

Kaye, A. S. (1994). Formal vs. Informal in Arabic: Diglossia, Triglossia, Tetraglossia, Etc., Polyglossia — Multiglossia Viewed as a Continuum. *Zeitschrift für Arabische Linguistik*, (27), 47–66.

Kaye, A. S. & Rosenhouse, J. (1997). Arabic Dialects and Maltese. *The Semitic Languages*, 263–311.

Keating, P. A. (1984). Phonetic and Phonological Representation of Stop Consonant Voicing. *Language*, 286–319.

Kent, R. D. (1976). Anatomical and Neuromuscular Maturation of the Speech Mechanism: Evidence from Acoustic Studies. *Journal of Speech, Language, and Hearing Research*, 19(3), 421–447.

Kent, R. D., Kent, J. F. & Rosenbek, J. C. (1987). Maximum Performance Tests of Speech Production. *Journal of Speech and Hearing Disorders*, 52(4), 367.

Kent, R. D., Read, C. & Kent, R. D. (2002). *The Acoustic Analysis of Speech*. Singular.

Kessinger, R. H. & Blumstein, S. E. (1997). Effects of Speaking Rate on Voice-Onset Time in Thai, French, and English. *Journal of Phonetics*, 25(2), 143–168.

Kessinger, R. H. & Blumstein, S. E. (1998). Effects of Speaking Rate on Voice-Onset Time and Vowel Production: Some Implications for Perception Studies. *Journal of Phonetics*, 26(2), 117–128.

Khaldūn, I. (1969). *The Muqaddimah, An Introduction to History*. Bollingen.

Khattab, G. (2002). VOT Production in English and Arabic Bilingual and Monolingual Children. *Amsterdam Studies In the Theroy and History of Linguistc Sceince Series 4*, 1–38.

Khattab, G., Al-Tamimi, F. & Heselwood, B. (2006). Acoustic and Auditory Differences in The/t/-/tˤ/opposition in Male and Female Speakers of Jordanian Arabic. *Perspectives on Arabic Linguistics. Amsterdam, Benjamins*, 131–160.

Kingston, J. & Diehl, R. L. (1994). Phonetic Knowledge. *Language*, 419–454.

Kirkham, S. (2011). The Acoustics of Coronal Stops in British Asian English. *Proceedings of the XVII International Congress of Phonetic Sciences.*, 1102–1105.

Klatt, D. H. (1975). Voice Onset Time, Frication, and Aspiration in Word-Initial Consonant Clusters. *Journal of Speech and Hearing Research*, 18(4), 686–706.

Klatt, D. H. & Stevens, K. N. (1969). Pharyngeal Consonants. *Quarterly Progress Report*, (93), 207–16.

Koenig, L. L. (2000). Laryngeal Factors in Voiceless Consonant Production in Men, Women, and 5-Year-Olds. *Journal of Speech, Language and Hearing Research*, 43(5), 1211.

Kotby, M. N., Saleh, M., Hegazi, M., Gamal, N., Abdel, S. M., Nabil, A., et al. (2010). The Arabic Vowels: Features and Possible Clinical Application in Communication Disorders. *Folia phoniatrica et logopaedica: official organ of the International Association of Logopedics and Phoniatrics (IALP)*, 63(4), 171–177.

Kreul, E. J. (1972). Neuromuscular Control Examination (NMC) for Parkinsonism: Vowel Prolongations and Diadochokinetic and Reading Rates. *Journal of Speech and Hearing Research*, 15(1), 72–83.

Krichi, M. K. & Adnan, C. (2014). The Arabic Speech Database: PADAS. *Signal Processing: An International Journal (SPIJ)*, 8(2), 10.

Krumbacher, K. (1902). *Das Problem Der Neugriechischen Schriftsprache*... KB Akademie in kommission des G. Franz'schen verlags (J. Roth).

Ladefoged, P. & Johnson, K. (2014). *A Course in Phonetics*. Wadsworth Publishing Co. Inc. Retrieved April 12, 2015,

Lain, S. (2009). Acoustic Correlates of [Voice] in Two Dialects of Venezuelan Spanish. Retrieved June 28, 2012, from http://repositories.lib.utexas.edu/handle/2152/6684

Lawler, J. (2005). Indian English. Retrieved December 6, 2013, from http://www-personal.umich.edu/~jlawler/

Lee, S., Potamianos, A. & Narayanan, S. (1999). Acoustics of Children's Speech: Developmental Changes of Temporal and Spectral Parameters. *The Journal of the Acoustical Society of America*, 105(3), 1455–1468.

Lehiste, I. & Peterson, G. E. (1961). Some Basic Considerations in the Analysis of Intonation. *The Journal of the Acoustical Society of America*, 33(4), 419–425.

Lehn, W. (1963). Emphasis in Cairo Arabic. *Language*, 29–39.

Lennes, M. (2003). Collect_formant_data_from_files.praat. Retrieved from http://www.helsinki.fi/~lennes/praat-scripts/public/collect_formant_data_from_files.praat

Lisker, L. & Abramson, A. S. (1964). Crosslanguage Study of Voicing in Initial Stops. *The Journal of the Acoustical Society of America*, 35, 1889.

Lisker, L. & Abramson, A. S. (1967). Some Effects of Context on Voice Onset Time in English Stops. *Language and Speech*, 10(1), 1–28.

Löfqvist, A. (1975). Intrinsic and Extrinsic Fo Variations in Swedish Tonal Accents. *Phonetica*, 31(3–4), 228–247.

Louzada, T., Beraldinelle, R., Berretin-Felix, G. & Brasolotto, A. G. (2011). Oral and Vocal Fold Diadochokinesis in Dysphonic Women. *Journal of Applied Oral Science*, 19(6), 567–572.

Lundeen, D. J. (1950). The Relationship Of Diadochokinesis To Various Speech Sounds. *Journal of Speech and Hearing Disorders*, 15(1), 54.

Maassen, B., Thoonen, G. & Wit, J. (1991). Toward Assessment of Articulo-Motoric Processing Capacities in Children. *Speech motor control and stuttering*, 461–469.

Mabrouk, F. A. (1981). A Linguistic Study of Gulf Phonology : An Articulatory and Acoustic Investigation of Contiguous Kuwaiti Stops and Vowels. Unpublished PhD thesis. Univeristy of Exeter. Retrieved November 28, 2013, from http://ethos.bl.uk/OrderDetails.do?did=5&uin=uk.bl.ethos.276591

Magloire, J. l & Green, K. P. (1999). A Cross-Language Comparison of Speaking Rate Effects on the Production of Voice Onset Time in English and Spanish. *Phonetica*, 56(3–4), 158–185.

Malki, K. H., Al-Habib, S. F., Hagr, A. A. & Farahat, M. M. (2009). Acoustic Analysis of Normal Saudi Adult Voices. *Saudi Medical Journal*, 30(8), 1081–1086.

Marçais, W. R. (1930). La Diglossie Arabe. *L'Enseignement Public*, (97), 401–409.

Mason, R. M., Helmick, J. W., Unger, J. W., Gattozzi, J. G. & Murphy, M. W. (1977). Speech Screening of Children in the Dental Office. *Journal of the American Dental Association (1939)*, 94(4), 708–712.

McClean, M. D. (2000). Patterns of Orofacial Movement Velocity across Variations in Speech Rate. *Journal of Speech, Language, and Hearing Research*, 43(1), 205–216.

McCrea, C. R. & Morris, R. J. (2005). The Effects of Fundamental Frequency Level on Voice Onset Time in Normal Adult Male Speakers. *Journal of Speech, Language, and Hearing Research*, 48(5), 1013–1024.

McGlone, R. E. & McGlone, J. (1972). Speaking Fundamental Frequency of Eight-Year-Old Girls. *Folia Phoniatrica et Logopaedica*, 24(4), 313–317.

Mennen, I., Schaeffler, F. & Docherty, G. (2007). Pitching It Differently : A Comparison of the Pitch Ranges of German and English Speakers. *16th International Congress of Phonetic Sciences*, 1769–1772.

Mitleb, F. (1992). Some Aspects of Arabic Duration. *Journal of the International Phonetic Association*, 22(1–2), 27–34.

Mitleb, F. (2009). Voice Onset Time of Jordanian Arabic Stops, in: 3ed International Confrence on Arabic Language Processing (CITALA'09) (pp. 133–135). Rabat,Morocco. Retrieved from http://scholar.googleusercontent.com/scholar?q=cache:xh4IG3XzuvYJ:scholar.google.com/+Voice+Onset+Time+in+Jordanian+Arabic+Apical+Stops+2009&hl=en&as_sdt=0,5

Modolo, D. J., Berretin-Felix, G., Genaro, K. F. & Brasolotto, A. G. (2011). Oral and Vocal Fold Diadochokinesis in Children. *Folia Phoniatrica et Logopaedica*, 63(1), 1–8.

Mohr, B. (1971). Intrinsic Variations in the Speech Signal. *Phonetica*, 23(2), 65–93.

Morris, R. J. (1997). Speaking Fundamental Frequency Characteristics of 8-through 10-Year-Old White-and African-American Boys. *Journal of Communication Disorders*, 30(2), 101–116.

Morris, R. J. & Brown, W. S. (1994). Age-Related Differences in Speech Variability among Women. *Journal of Communication Disorders*, 27(1), 49–64.

Morris, R. J., McCrea, C. R. & Herring, K. D. (2008). Voice Onset Time Differences between Adult Males and Females: Isolated Syllables. *Journal of Phonetics*, 36(2), 308–317.

Morrison, G. & Escudero, P. (2007). A Cross-Dialect Comparison of Peninsula-and Peruvian-Spanish Vowels, in: *Proceedings of the 16th Congress of Phonetic Scinces*. Saarbrücken,Germany. Retrieved July 23, 2014, from http://dare.uva.nl/document/95099

Muhammad, G., AlMalki, K., Mesallam, T., Farahat, M. & Alsulaiman, M. (2011). Automatic Arabic Digit Speech Recognition and Formant Analysis for Voicing Disordered People, in: *Computers & Informatics (ISCI), 2011 IEEE Symposium on*, (pp. 699–702). IEEE. Retrieved March 12, 2015, from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=5959001

Murry, T., Brown Jr., W. S. & Morris, R. J. (1995). Patterns of Fundamental Frequency for Three Types of Voice Samples. *Journal of Voice*, 9(3), 282–289.

Mysak, E. D. (1959). Pitch and Duration Characteristics of Older Males. *Journal of Speech & Hearing Research*. Retrieved July 13, 2014, from http://doi.apa.org/?uid=1960-04112-001

Natour, Y. S., Marie, B. S., Saleem, M. a & Tadros, Y. K. (2011). Formant Frequency Characteristics in Normal Arabic-Speaking Jordanians. *Journal of voice : official journal of the Voice Foundation*, 25(2), e75–84.

Natour, Y. S. & Wingate, J. M. (2009). Fundamental Frequency Characteristics of Jordanian Arabic Speakers. *Journal of voice : official journal of the Voice Foundation*, 23(5), 560–6.

Nearey, T. M. & Rochet, B. L. (1994). Effects of Place of Articulation and Vowel Context on VOT Production and Perception for French and English Stops. *Journal of the International Phonetic Association*, 24(1), 1–18.

Neel, A. T. & Palmer, P. M. (2012). Is Tongue Strength an Important Influence on Rate of Articulation in Diadochokinetic and Reading Tasks? *Journal of speech, language, and hearing research: JSLHR*, 55(1), 235–246.

Netsell, R. (1986). *A Neurobiological View of Speech Production and the Dysarthrias*. San Diego,CA: College-Hill Press.

Newman, D. (2005). Contrastive Analysis of the Segments of French and Arabic., in: Elgibali, A. (Ed.), *Investigating Arabic : current parameters in analysis and learning*, (pp. 185–220). Leiden: Brill Academic Publishers.

Newman, D. & Verhoeven, J. (2002). Frequency Analysis of Arabic Vowels in Connected Speech. *Antwerp papers in linguistics.*, 100, 77–86.

Ohala, J. J. & Eukel, B. W. (1987). Explaining the Intrinsic Pitch of Vowels. *In honor of Ilse Lehiste*, 207–215.

Omar, A. M. (1991). *A Study on Linguistic Phonology*. Cario,Egypt: Alam Al-Kutub.

Owens, J. (2006). *A Linguistic History of Arabic*. Oxford: Oxford University Press.

Oxford English Dictionary. (2010). Definition of Hadith. *Oxford Dictionaries : Language matters*. Retrieved April 29, 2010, from https://webmail.shef.ac.uk/horde/imp/view.php?thismailbox=INBOX&index=903&id=1&actionID=113&mime=ae9376c20d3644e4106ad33afdb7163b

Ozawa, Y., Shiromoto, O., Ishizaki, F. & Watamori, T. (2001). Symptomatic Differences in Decreased Alternating Motion Rates between Individuals with Spastic and with Ataxic Dysarthria: An Acoustic Analysis. *Folia phoniatrica et logopaedica: official organ of the International Association of Logopedics and Phoniatrics (IALP)*, 53(2), 67–72.

Padovani, M., Gielow, I. & Behlau, M. (2009). Phonarticulatory Diadochokinesis in Young and Elderly Individuals. *Arquivos de Neuro-Psiquiatria*, 67(1), 58–61.

Palva, H. (1991). Is There a North West Arabian Dialect Group?, in: Forstner, M. (Ed.), *Festagabe für Hans-Rudolf Singer*, (pp. 151–166). Frankfurt am Main: P. Lang.

Parkinson, D. B. (1991). Searching for Modern Fuṣḥa: Real-Life Formal Arabic. *Al-Arabiyya*, (24), 31–64.

Pegoraro-Krook, M. I. & Castro, V. C. (1994). Normative Speaking Fundamental Frequency (SFF) Characteristics of Brazilian Male Subjects. *Brazilian Journal of Medical and Biological Research*, 27(7), 1659–1661.

Peterson, G. E. & Barney, H. L. (1952). Control Methods Used in a Study of the Vowels. *The Journal of the Acoustical Society of America*, 24(2), 175–184.

Pirozzo, S., Papinczak, T. & Glasziou, P. (2003). *Whispered Voice Test for Screening for Hearing Impairment in Adults and Children: Systematic Review*. Br Med Assoc.

Portnoy, R. A. & Aronson, A. E. (1982). Diadochokinetic Syllable Rate and Regularity in Normal and in Spastic and Ataxic Dysarthric Subjects. *J Speech Hear Disord*, 47(3), 324–328.

Prathanee, B., Thanaviratananich, S. & Pongjanyakul, A. (2002). Oral Diadochokinetic Rates in Normal Thai Children. Retrieved July 25, 2012,

Prins, T. D. (1962). Motor and Auditory Abilities in Different Groups of Children with Articulatory Deviations. *Journal of speech and hearing research*, 5, 161.

Prochazka, T. (1981). The Shi'i Dialects of Bahrain and Their Relationship to the Eastern Arabian Dialect of Muharraq and the Omani Dialect of Al-Ristaq. *ZAL*, 6, 16–55.

Ptacek, P. H., Sander, E. K., Maloney, W. H. & Jackson, C. C. R. (1966). Phonatory and Related Changes with Advanced Age. *Journal of Speech and Hearing Research*, 9(3), 353–360.

Purnell, T., Idsardi, W. & Baugh, J. (1999). Perceptual and Phonetic Experiments on American English Dialect Identification. *Journal of Language and Social Psychology*, 18(1), 10–30.

Rahim, A. J. & Kasim, Z. R. (2009). A Spectrographic Study of Voice Onset Time in Arabic. *Journal of Eduaction and Science- Mosul University*, 16(36), 28–41.

Raphael, L. J., Borden, G. J. & Harris, K. S. (2007). *Speech Science Primer: Physiology, Acoustics, and Perception of Speech*. Lippincott Williams & Wilkins.

Rifaat, K. (2003). Voice Onset Time in Egyptian Arabic: A Case Where Phonological Categories Dominate, in: *Proceedings of the 15 th International Congress of Phonetic Sciences*, (pp. 791–794).

Robb, M., Gilbert, H. & Lerman, J. (2005). Influence of Gender and Environmental Setting on Voice Onset Time. *Folia Phoniatrica et Logopaedica*, 57(3), 125–133.

Rose, P. (1991). How Effective Are Long Term Mean and Standard Deviation as Normalisation Parameters for Tonal Fundamental Frequency? *Speech Communication*, 10(3), 229–247.

Rosen, K. M., Kent, R. D. & Duffy, J. R. (2005). Task-Based Profile of Vocal Intensity Decline in Parkinson Disease. *Folia Phoniatrica et Logopaedica*, 57(1), 28–37.

Rosenhouse, J. & Goral, M. (2005). Bilingualism in the Middle East and North Africa: A Focus on the Arabic-Speaking World, in: *Handbook of bilingualism: Psycholinguistic approaches*, (pp. 835–859).

Rosner, B. S., López-Bascuas, L. E., García-Albea, J. E. & Fahey, R. P. (2000). Voice-Onset Times for Castilian Spanish Initial Stops. *Journal of Phonetics*, 28(2), 217–224.

Royal, A.-M. (1985). Male-Female Pharyngealization Patterns in Cairo Arabic: A Sociolinguistic Study of Two Neighborhoods., in: *Texas Linguistic Forum*. Retrieved December 21, 2013, from http://cat.inist.fr/?aModele=afficheN&cpsidt=12073742

Russell, A., Penny, L. & Pemberton, C. (1995). Speaking Fundamental Frequency Changes over Time in Women: A Longitudinal Study. *Journal of Speech, Language and Hearing Research*, 38(1), 101.

Ryalls, J., Simon, M. & Thomason, J. (2004). Voice Onset Time Production in Older Caucasian-and African-Americans. *Journal of Multilingual Communication Disorders*, 2(1), 61–67.

Ryalls, J., Zipprer, A. & Baldauff, P. (1997). A Preliminary Investigation of the Effects of Gender and Race on Voice Onset Time. *Journal of Speech, Language and Hearing Research*, 40(3), 642.

Ryan, K. (2005). Grid-Maker. Retrieved from http://queenoflily.blogspot.co.uk/2008/11/praat-script-resources.html

Saiegh-Haddad, E. (2003). Linguistic Distance and Initial Reading Acquisition: The Case of Arabic Diglossia. *Applied Psycholinguistics*, 24(3), 431–451.

Sapienza, C. M. (1997). Aerodynamic and Acoustic Characteristics of the Adult African American Voice. *Journal of Voice*, 11(4), 410–416.

Saxman, J. H. & Burk, K. W. (1967). Speaking Fundamental Frequency Characteristics of Middle-Aged Females. *Folia Phoniatr (Basel)*, 19(3), 167–72.

Schilling, N. (2013). *Sociolinguistic Fieldwork*. Cambridge University Press.

Seddiq, Y. M. & Alotaibi, Y. A. (2012). Formant-Based Analysis of Vowels in Modern Standard Arabic—Preliminary Results, in: *Information Science, Signal Processing and their Applications (ISSPA), 2012 11th International Conference on*, (pp. 689–694). IEEE. Retrieved March 17, 2015, from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=6310641

Shanks, S. J. (1970). Effect of Aging upon Rapid Syllable Repetition. *Perceptual and motor skills*, 30(3), 687–690.

Shar, S. & Ingram, J. (2010). Pharyngealization in Assiri Arabic: An Acoustic Analysis, in: *Proceedings of the 13th Australasian International Conference on Speech Science and Technology 2010*, (pp. 5–8). Retrieved March 12, 2015, from http://assta.org/sst/SST-10/SST2010/PDF/AUTHOR/ST100026.PDF

Shoul, K. (2008). Voice Quality of Emphatics in Comparison with Non-emphatics in Morrocan Arabic. *The Journal of the Acoustical Society of America*, 123(5), 3719–3719.

Sigurd, B. (1973). Maximum Rate and Minimal Duration of Repeated Syllables. *Language and Speech*, 16(4), 373–395.

Skodda, S., Flasskamp, A. & Schlegel, U. (2010). Instability of Syllable Repetition as a Model for Impaired Motor Processing: Is Parkinson's Disease a 'rhythm Disorder'? *Journal of Neural Transmission*, 117(5), 605–612.

Smith, B. L. (1978). Effects of Place of Articulation and Vowel Environment on' Voiced' Stop Consonant Production. *Glossa*, 12(2), 163–75.

Sorenson, D. N. (1989). A Fundamental Frequency Investigation of Children Ages 6–10 Years Old. *Journal of communication disorders*, 22(2), 115–123.

St Louis, K. O. & Ruscello, D. M. (1981). The Oral Speech Mechanism Screening Examination (OSMSE). Retrieved September 11, 2012, from http://eric.ed.gov/ERICWebPortal/recordDetail?accno=ED214975

St Louis, K. O. S. & Ruscello, D. M. (1987). *Oral Speech Mechanism Screening Examination-Revised*. Pro-ed.

Stevens, K. N. & House, A. S. (1963). Perturbation of Vowel Articulations by Consonantal Context: An Acoustical Study. *Journal of Speech & Hearing Research*. Retrieved September 21, 2015, from http://psycnet.apa.org/psycinfo/1964-03485-001

Stoicheff, M. L. (1981). Speaking Fundamental Frequency Characteristics of Nonsmoking Female Adults. *Journal of Speech, Language and Hearing Research*, 24(3), 437–441.

Strange, W., Weber, A., Levy, E. S., Shafiro, V., Hisagi, M. & Nishi, K. (2007). Acoustic Variability within and across German, French, and American English Vowels: Phonetic Context Effects. *The Journal of the Acoustical Society of America*, 122(2), 1111–1129.

Swartz, B. L. (1992). Gender Difference in Voice Onset Time. *Perceptual and Motor Skills*, 75(3), 983–992.

Sweeting, P. M. & Baken, R. J. (1982). Voice Onset Time in a Normal-Aged Population. *Journal of Speech, Language and Hearing Research*, 25(1), 129.

Syrdal, A. K. (1996). Acoustic Variability in Spontaneous Conversational Speech of American English Talkers, in: *Spoken Language, 1996. ICSLP 96. Proceedings., Fourth International Conference on*, (pp. 438–441). Retrieved December 4, 2013, from http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=607148

Team, A. (2012). *Audacity*. Retrieved from http://audacity.sourceforge.net/

Thelwall, R. & Sa'Adeddin, M. A. (1990). Arabic. *Journal of the International Phonetic Association*, 20(2), 37–39.

Titze, I. R. (1988). Control of Voice Fundamental Frequency. *Journal of Singing*, (45), 18–22.

Titze, I. R. (1989a). Physiologic and Acoustic Differences between Male and Female Voices. *The Journal of the Acoustical Society of America*, 85(4), 1699–1707.

Titze, I. R. (1989b). Physiologic and Acoustic Differences between Male and Female Voices. *The Journal of the Acoustical Society of America*, 85, 1699.

Topbaş, O., Orlikoff, R. F. & St. Louis, K. O. (2012). The Effect of Syllable Repetition Rate on Vocal Characteristics. *Journal of Communication Disorders*, 45(3), 173–180.

Traunmüller, H. (1984). Articulatory and Perceptual Factors Controlling the Age- and Sex-Conditioned Variability in Formant Frequencies of Vowels. *Speech Communication*, 3(1), 49–61.

Traunmüller, H. (1988). Paralinguistic Variation and Invariance in the Characteristic Frequencies of Vowels. *Phonetica*, 45(1), 1–29.

Traunmüller, H. & Eriksson, A. (1995). The Frequency Range of the Voice Fundamental in the Speech of Male and Female Adults. *Unpublished Manuscript*. Retrieved July 21, 2014, from http://www2.ling.su.se/staff/hartmut/f0_m%26f.pdf

Tsukada, K. (2009). An Acoustic Comparison of Vowel Length Contrasts in Arabic, Japanese and Thai: Durational and Spectral Data. *Int. J. of Asian Lang. Proc.*, 19(4), 127–138.

Umeda, N. (1981). Influence of Segmental Factors on Fundamental Frequency in Fluent Speech. *The Journal of the Acoustical Society of America*, 70(2), 350–355.

United Nations Educational, Scientific and Cultural Organization (UNESCO). (2015). World Arabic Language. Retrieved October 28, 2015, from http://www.unesco.org/new/en/unesco/events/prizes-and-celebrations/celebrations/international-days/world-arabic-language-day/

Van Alphen, P. M. & Smits, R. (2004). Acoustical and Perceptual Analysis of the Voicing Distinction in Dutch Initial Plosives: The Role of Prevoicing. *Journal of Phonetics*, 32(4), 455–491.

Versteegh, K. (2001). *The Arabic Language*. Edinburgh Univ Pr.

Vicenik, C. & Sundara, M. (2013). The Role of Intonation in Language and Dialect Discrimination by Adults. *Journal of Phonetics*, 41(5), 297–306.

Volaitis, L. E. & Miller, J. L. (1992). Phonetic Prototypes: Influence of Place of Articulation and Speaking Rate on the Internal Structure of Voicing Categories. *The Journal of the Acoustical Society of America*, 92, 723.

Wahba, K. (1993). Linguistic Variation in Alexandrian Arabic: The Feature of Emphasis. Unpublished PhD thesis. Univeristy of Alexandria.

Wahba, K. M. (1996). *Linguistic Variation in Alexandrian Arabic: The Feature of Emphasis*. Cairo: American University in Cairo Press.

Wang, C.-C. & Huang, H.-T. (2004). Voice Acoustic Analysis of Normal Taiwanese Adults. *JOURNAL-CHINESE MEDICAL ASSOCIATION.*, 67(4), 179–184.

Watson, J. C. . (2002). *The Phonology and Morphology of Arabic*. Oxford: Oxford University Press.

Watson, P. J. & Hughes, D. (2006). The Relationship of Vocal Loudness Manipulation to Prosodic FO and Durational Variables in Healthy Adults. *Journal of Speech, Language, and Hearing Research*, 49(3), 636–644.

Watt, D., Fabricius, A. & Kendall, T. (2011). More on Vowels: Plotting and Normalization, in: Di Paolo, M. and Yaeger-Dror, M. (Eds.), *Sociophonetics: A student's guide*, (pp. 107–118). Routledge.

Watt, D. & Yurkova, J. (2007). Voice Onset Time and the Scottish Vowel Length Rule in Aberdeen English, in: *Proceedings of the 16th International Congress of Phonetic Sciences*, (pp. 1521–1524). Retrieved December 11, 2013, from http://www.icphs2007.de/conference/Papers/1488/1488.pdf

Wehr, H. (1979). *A Dictionary of Modern Written Arabic* (J. M. Cowan, Ed.). Otto Harrassowitz Verlag. Retrieved November 7, 2015, from https://books.google.co.uk/books?hl=en&lr=&id=WTak55pG-_IC&oi=fnd&pg=PA1&dq=Dictionary+of+Modern+Written+Arabic&ots=5SXX87QPg4&sig=2a9l8iaqwtzcLXeftwmvPA7mbxU

Weismer, G. (1979). Sensitivity of Voice-Onset Time (VOT) Measures to Certain Segmental Features in Speech Production. *Journal of Phonetics*, 7(1), 197–204.

Welby, P. (2002). Praat Checking Textgrid Script. Retrieved from http://aune.lpl.univ-aix.fr/~welby/PAGES/praat.html

Whalen, D. H., Gick, B., Kumada, M. & Honda, K. (1999). Cricothyroid Activity in High and Low Vowels: Exploring the Automaticity of Intrinsic F0. *Journal of Phonetics*, 27(2), 125–142.

Whalen, D. H. & Levitt, A. G. (1995). The Universality of Intrinsic F0 of Vowels. *Journal of Phonetics*, 23(3), 349–366.

Wheat, M. C. & Hudson, A. I. (1988). *Spontaneous Speaking Fundamental Frequency of 6-Year-Old Black Children*. ASHA.

Whiteside, S. P. (2001). Sex-Specific Fundamental and Formant Frequency Patterns in a Cross-Sectional Study. *The Journal of the Acoustical Society of America*, 110, 464.

Whiteside, S. P. & Irving, C. J. (1997). Speakers' Sex Diffrences in Voice Onset Time:: Some Preliminary Findings. *Perceptual and motor skills*, 85(2), 459–463.

Whiteside, S. P. & Irving, C. J. (1998). Speakers' Sex Diffrences in Voice Onset Time: A Study of Isolated Word Production. *Perceptual and Motor Skills*, 86(2), 651–654.

Whiteside, S. P. & Marshall, J. (2001). Developmental Trends in Voice Onset Time: Some Evidence for Sex Differences. *Phonetica*, 58(3), 196–210.

Williams, L. (1977). The Voicing Contrast in Spanish. *Journal of Phonetics*, 5(2), 169–184.

Williams, P. & Stackhouse, J. (2000). Rate, Accuracy and Consistency: Diadochokinetic Performance of Young, Normally Developing Children. *Clinical Linguistics & Phonetics*, 14(4), 267–293.

Williams, R. G. & Eccles, R. (1990). A New Clinical Measure of External Laryngeal Size Which Predicts the Fundamental Frequency of the Larynx. *Acta oto-laryngologica*, 110(1–2), 141–148.

Xue, A. & Mueller, P. . (1996). Speaking Fundamental Frequency of Elderly African-American Nursing Home Residents: Preliminary Data. *Clinical linguistics & phonetics*, 10(1), 65–70.

Yao, Y. (2009). Understanding VOT Variation in Spontaneous Speech, in: *Proceedings of the 18th International Congress of Linguists (CIL XVIII)*. Retrieved December 3, 2013, from http://www.linguistics.berkeley.edu/~yaoyao/paper/Yao_b.pdf

Yeni-Komshian, G. H., Caramazza, A. & Preston, M. S. (1977). A Study of Voicing in Lebanese Arabic. *Journal of Phonetics*, 5(1), 35–48.

Yu Hongzhi, Jin Huimin, Liao Yansha & Li Yonghong. (2010). Analysis of Reference Normal Values of Diadochokinetic Rate and U.S. China Comparison, in: (pp. V4-399-V4-402). IEEE. Retrieved April 25, 2012, from http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=5541023

Zhang, J., Huang, M., Li, M. & Liu, Q. (1999). Analysis of Results of Fundamental Frequency and Voice Parameter in Healthy Young People. *Lin chuang er bi yan hou ke za zhi = Journal of clinical otorhinolaryngology*, 13(9), 403–405.

Ziegler, W. (2002). Task-Related Factors in Oral Motor Control: Speech and Oral Diadochokinesis in Dysarthria and Apraxia of Speech. *Brain and Language*, 80(3), 556–575.

Zraick, R. I., Gentry, M. a, Smith-Olinde, L. & Gregg, B. a. (2006). The Effect of Speaking Context on Elicitation of Habitual Pitch. *Journal of voice : official journal of the Voice Foundation*, 20(4), 545–54.

Zraick, R. I., Skaggs, S. D. & Montague, J. C. (2000). The Effect of Task on Determination of Habitual Pitch. *Journal of voice : official journal of the Voice Foundation*, 14(4), 484–9.

Appendices

Appendix 3.1

Ethical approval from HCS

The University Of Sheffield.

Department of Human Communication Sciences
31 Claremont Crescent
Sheffield S10 2TA UK

Head of Department
Professor Joy Stackhouse, PhD., F.R.C.S.L.T., C.Psychol., A.F.B.Ps.S

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3rd September 2010

Dear Majid

Title: Speech characteristics of Arabic Speakers: investigating dialectal variation in two dialects.

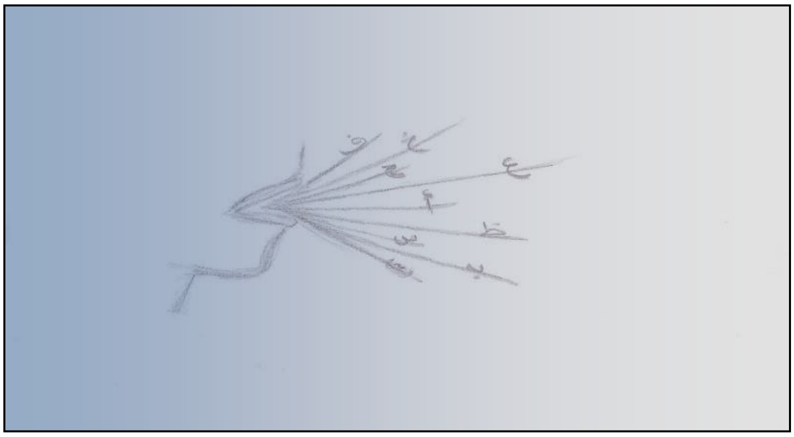
Thank you for your submission to the HCS Research Ethics Committee. The committee has reviewed your submission and supporting documents and grants you approval to commence the research.

We hope your project proceeds smoothly

Yours sincerely

pp Prof R Varley
Chair of HCS Ethics Committee

Appendix 3.2



Speech Characteristics of Arabic speakers: Dialect variations

Speech Characteristics of English and other languages have been documented.

Arabic language has different sounds. Therefore, a need to describe the speech characteristics of Arabic is much needed.

We are looking for healthy male and females, ages 20-30 years, who are <u>not</u> smokers. If you are interested in volunteering for a study that looks at the speech charicterstics of Arabic please contact me. You would be reqested to read words,passages and speak Arabic for nearly an hour. Your help will aid in esatablishing the basis of Arabic langauge for clinics.

<u>If you are interested in volunteering, please contact:</u>

Majid Alshahwan, PhD student

Department of Human Communication Sciences, University of Sheffield / King Saud University

Email: majid.slp@gmail.com

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Majid Alshahwan majid.slp@gmail

Appendix 3.3

The University Of Sheffield.

Research Project Information Sheet

Speech Characteristics of Arabic speakers: Investigating Dialectical variations in two Dialects (Najdi and Bahrani)

Mr Majid Alshahwan

Dr Sandra Whiteside

Dr Patricia Cowell

Department of Human Communication Sciences

University of Sheffield

You are being invited to participate in a research project. Before you decide whether or not to take part, it is important that you understand the purpose of this research and what is involved. Please take time to read the following information carefully, and if there is anything that is not clear or if you would like more information please ask me. Take time to decide whether or not you would like to participate. Thank you for reading this information sheet.

What are we hoping to find out?

The project aims to investigate the speech characteristics of Arabic speakers and compare it to those which have been reported in the literature. In addition, it will compare the speech characteristics of two dialects (Najdi of central region in Saudi Arabia and Bahrani from the Kingdom of Bahrain).

We aim to do this based on audio recordings of your speech, which will be subjected to auditory, acoustic and statistical analysis. We will then conduct comparisons between speakers of the two dialects in order to determine the nature of any dialectal variations. The research will also help to establish normative data for Arabic speakers of these two different dialects, which would be potentially useful in clinical applications.

Why have I been chosen?

You have been invited to participate in this project because your native language is Arabic, and because your main Arabic dialect is the Central dialect or Najdi dialect in Saudi Arabia, or the Bahrani dialect in Kingdom of Bahrain. You have also been selected as you are a healthy, non-smoker who is aged between 22-35 years old.

Do I have to take part?

No. Taking part in this research is entirely voluntary and it is your own decision. If you do not wish to take part, it will not have any implications for you at all. If you agree to take part, you can keep this information sheet and you will be asked to sign a consent form. You can still decide to withdraw from the project at any time without giving any reason.

<u>What will happen if I decide to take part?</u>

If you decide to take part, you will be involved in the data collection aspect of the project. You will be asked to attend one audio recording session, lasting approximately one hour. In addition, 15 minutes will be required to complete a questionnaire at beginning of the session. This will take place at a location that will ensure confidentiality.

The data collection will be in two parts. Firstly, you will be asked to fill in a questionnaire, eliciting some personal information such as date of birth (age), sex, language experience, occupation, and socioeconomic details, this will take approximately 15 minutes. Secondly, you will be asked to perform a series of speech tasks which will include repeating some syllables ,word and performing some short speaking (reading and interactive questions and answers) tasks. This part is estimated to last one hour. Rest shall be taken when requested by participant.

What are the potential disadvantages and risks of taking part?

There are no foreseeable disadvantages or risks of taking part in this research. Participation is entirely voluntary and it is your own decision whether or not to participate. You can withdraw from the project at any time without there being any negative consequences.

What are the potential advantages of taking part?

Whilst there are no immediate benefits to you from participating in this research, you will provide an opportunity to the student researcher to investigate the speech characteristics of Spoken Arabic, specifically, the Najdi /central and Bahrani dialects. The research will be useful in analyzing the speech pattern of Arabic speaking people for adult and will enable the establishment of normative data for speech and language therapy clinicians. In addition, it will help in determining if there are dialectical differences within the Arabic language.

Will my voice be identified in any way through taking part in the project?

The researcher, Majid Alshahwan, will keep copies of the speech recordings securely locked in his office; they will be stored digitally on a password protected computer. Only members of the research team (Majid Alshahwan and his supervisors) will have access to the recordings. If you wish to give your permission for the recordings to be used for training purposes (lectures to students within the department) or as part of research meetings, you will have opportunity to give your consent for this separately.

You will be given the right to limit the use of your recording to only this research and publication associated with this project and should be destroyed after this project had ceased.

Your recording will be given an anonymous code for the duration of this project so they are not identifiable on any written material produced by the researcher or on computer (also password protected).

The recordings will be kept for the duration of this study. When the recordings are no longer being used for research and academic purposes, they will be destroyed.

What will happen to the results of the project?

The results will form part of the researcher's PhD thesis and might be published in scientific journals or presented at research conferences. The results may also be presented to local special interest groups and organisation related to voice analysis and therapy if given consent.

What will happen if I take part in the project, or if I change my mind about this at a later date?

You are free to withdraw from the study at any point and you will not be asked to give a reason for this. If you withdraw, all copies of recordings will be destroyed at that point.

W**ho is organizing and funding the research?**

This research project is being conducted as part of a PhD project registered at the University of Sheffield (Dept of Human Communication Sciences), and is funded by King Saud University and the

Government of Saudi Arabia.

What if there is a problem or I wish to make a complaint?

If you have any concerns please discuss them with the researcher

Majid Alshahwan

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A form of complaint will be given to those interested or participating in the study, this form can either be scanned and sent or faxed to supervisors of the Researcher:

Dr Sandra Whiteside, BA, MSc, PhD

Department of Human Communication Sciences
The University of Sheffield
31 Claremont Crescent,Sheffield
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In not satisfied by the above, you can contact Head of Department of Human Communication

Professor Shelagh Brumfitt

PhD, M.Phil, DipCST, CertMRCSLT (Hons), Reg HPC, Senate Award Fellow.

Head of Department of Human Communication Sciences
31 Claremont Crescent
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Fax: +44 (0) 114 273 0547

Email: s.m.brumfitt@sheffield.ac.uk

If you are not satisfied and feel your concerns have not been dealt with satisfactorily by the people above, you would be requested to send the form to: **Registrar and Secretary of the University of Sheffield,**

Firth Court, Western Bank, Sheffield, S10 2TN.

Fax+4411422 21103

Email : **Registrar@sheffield.ac.uk**

Who has reviewed this project to ensure that it is of a suitable research standard and that it meets ethical requirements?

This project has been reviewed by the ethics committee in the Department of Human Communication at the University of Sheffield.

Thank you for reading this information sheet

Appendix 3.4

Speech characteristics of Arabic speakers: investigating dialectical variations in two dialects (Najdi and Bahrani)

Investigator: Majid Alshahwan

Questionnaire

Thank you for agreeing to participate in this study. Please try to answer, as many questions as you can that are relevant to you. However, you do not have to answer any questions if you do not wish to disclose that information.

Date: …………. Code number:
Name:……………………………………………..
Gender: M/F (please circle)
Date of Birth: …………………………………….
Occupation: ………………………………………
e-mail contact details: ……………………………
Place of residence……………………………….
Background information
1) **Health**

1. Have you had, within the last 14 days, any illness which has affected your voice?……………………………………Yes/No (please circle)

    - If Yes, please describe the symptoms…………………
    ………………………………………………………………………

2. Do you smoke?………………………………… Yes/No (please circle)

3. Have you ever been a smoker?………………Yes/No (please circle)

    - If Yes, for how long were you a smoker?…………………………

4. Do you have any voice, speech, language or hearing difficulties?..Yes/No (please circle)

    - If Yes, please provide the details…………………
    ………………………………………………………………………

5. Have you ever experienced any voice, speech, language or hearing difficulties? ………………………………………… Yes/No (please circle)

    - If Yes, please provide the details…………………
    ………………………………………………………………………

<u>2)Language:</u>

Tick or circle the most appropriate answer:

1. As an Arabic speaker, what is your native dialect?
    ( ) Bahrain dialect, which of the following?

1.Bahrani 2.Bahraini

( ) Saudi dialect, which of the following?

a. Central (Najdi) b. Northern c. Eastern d. Western e. Southern

2. Where do you currently live?..
    - How long have you lived there?..
3. Please indicate if you have lived anywhere else, and for how long.
    - Location 1………………………Length of time….……………
    - Location 2……………………… Length of time………………
    - Location 3……………………… Length of time……………..
4. What is/are the native dialect/s of your parents?

   a) Father …………………….. b) Mother ………………………..
5. What were the Arabic dialects used around you during your first 18 years?

   ………………………………………………………………………..
6. What is/are the dialect/s currently spoken at home? Please indicate which dialect is the dominant one.

   ………………………………………………………………………
7. What is/are the dialects/ languages spoken at work/college? Please indicate which dialects/languages are the dominant ones.

   ………………………………………………………………………
8. Do you speak languages other than Arabic?

   ( ) Yes ( ) No

   If yes, please specify ……………………………………………….
9. Please rate the proficiency of the languages you speak?

   1 = least proficient 6 = Most proficient

   -------------- 1 2 3 4 5 6

   -------------- 1 2 3 4 5 6

   -------------- 1 2 3 4 5 6

<u>3) Social / Educational</u>

1. Please specify the level of your education from the following?

   a. High school b. diploma c. graduate/university d. post-graduate
2. Please specify your parents' level of education?

   Father:

   a. High school b. diploma c. graduate/university d. post-graduate

   Mother:

   a. High school b. diploma c. graduate/university d. post-graduate
3. Please specify your parents' current occupation if applicable?

   Father : ………………. Mother : ………………………….

Appendix 3.5

The University Of Sheffield.

Research Project Consent Form

Speech Characteristics of Arabic speakers: Dialect variations

Dr Sandra Whiteside
Dr Patricia Cowell
Department of Human Communication Sciences
University of Sheffield

Majid Alshahwan
Speech & Language pathologist
Department of Human Communication Sciences
University of Sheffield/King Saud University

Please initial the boxes below, as appropriate:

1. I confirm that I have read and understood the information sheet for the project named above and that I have had the opportunity to ask questions about it. ☐

2. I understand that my participation is voluntary and that I am free to withdraw my consent at any time without giving a reason. ☐

3. I understand that the speech recordings and written information about me will be given a code to my data and recordings anonymous. I understand that my name will not be linked with the research materials, and I will not be identified or identifiable in the report or reports that result from the research. ☐

4. I give permission for the anonymised audio recordings collected for this study to be stored securely and confidentially for the duration of the study. ☐

5. I agree for the data collected from me to be used in for research reports and publications connected to the specific project, as well as in future research and for training purposes (lectures to students within the department). ☐

6. I agree for the data collected from me to be used only for research reports and publications connected to this specific project; I do not agree for the data to be used in future research or for training purposes and request it to be destroyed at the end of this project. ☐

7. I agree to take part in above research project. ☐

__________________ ______________ __________________

NAME OF PARTICIPANT DATE SIGNATURE

_______________________ ______________ ___________________

MAJID ALSHAHWAN DATE SIGNATURE

(To be signed and dated in the presence of the participant)

Appendix 3.6

Page 1

Speech samples were collated in the following order[13]:

1) Spontaneous speech: The spontaneous samples were answers to the following two open-ended questions:
    a. Describe your average day, from the moment you wake up till you sleep.
    b. What are your hobbies?
2) Automatic speech: Participants were asked to name the following names and numbers in succession in the following tasks:
    a. Name the days of the week.
    b. Name the months of the year.
    c. Count from 1 to 10.
3) Sustained phonation for three vowels (/a/, /i/, /u/) for more than 15 seconds.
4) Reading a Sura (chapter) from the Qur'an, specifically the first Sura that is called Alfatihah (*Opening* when translated to English; translation and transcript available in Appendix 7).
5) Reading the Arabic version of the phonetically balanced passage from *The North Wind and the Sun* (International Phonetic Association, 2004, pp. 53–54).
6) Two lists were compiled from 80 target words; these were words with initial plosives (/b/, /t/, /d/, /k/, /q/ and / ʔ/), fricatives (f/, /θ/, /ð/, /s/, /z/, /ʃ/, /x/, /ʁ /, /ħ /, /ʕ/ and /h/) and emphatic plosives (/tˤ/ and /dˀ/) and emphatic fricatives (/ðˀ/ and /sˀ/) in Arabic. An additional six words were added to the list as they were realizations of /g/ for /q/ and /ðˤ/ for /dˤ/. There were a total of 86 target words and 20 random filler words, which were assigned to the beginning and end of each list (five per list).

[13] It is noteworthy that not that all stimuli in Figure 1a and 1b have been analyzed, as only the parameters chosen for this study and their relevant stimuli will be focused on in their respective chapters.

Page 2

From the target words, 40 words were randomly selected along with 5 filler words at the beginning of the list and 5 filler words at the end. Two word lists were generated:

1. List 6a see Appendix 3.7 (a). Filler words in row 1 and 10 in the table are excluded from the word counts. Word count was for target words only resulting in 43 target words. Words that have two count (words with and without realizations).

2. List 7a see Appendix 3.7 (b).. Filler words in row 1 and 10 in the table are excluded from the word counts. Word count was for target words only resulting in 43 target words. Words that have two count (words with and without realizations).

Two further lists were generated:

i. List 6b is a repetition of the words from list 6a; however, words were arranged differently.
ii. List 7b, is a repetition of the words from list 7a; however, words were arranged differently.

7) A second repetition of reading a Sura (chapter) from the Qur'an.
8) A second repetition of the Arabic version of the phonetically balanced passage from *The North Wind and the Sun* (International Phonetic Association, 2004, pp. 53–54).
9) Diadochokinetic Rate (DDK): Production of monosyllabic and multisyllabic sounds in the following order, with demonstration from the researcher:
    1. Monosyllable /ba/
    2. Monosyllable /da/
    3. Monosyllable /ga/
    4. Multisyllable/badaga/

Appendix 3.7 (a & b)

List (a) is the first list while list (b) is below. Rows 1 and 10 are word fillers while remaining are target words. Target words used for analysis are those highlighted. Note: target words that would have realis ations are seen as two (e.g. number 5/6).

Row #	Number	Transcribed word in IPA	Meaning	Number	Transcribed word in IPA	Meaning	Number	Transcribed word in IPA	Meaning	Number	Transcribed word in IPA	Meaning	Number	Transcribed word in IPA	Meaning
Row 1	-	/bar.q/	Thunder	-	/ʔɪb.rah/	Needle	-	/ʃahad/	Female name meaning nectar	-	/ʃæl/	Witnessing	-	/bækɪr/	Tomorrow
Row 2	1	/bar/	Bar	2	/tur/	Cup for drinking water	3	/dar/	House	4	/kir/	Bellows	5/6	/qær.rah/ or /gær.rah/	Continent
Row 3	7	/fil/	Elephant	8	/sar/	Walk	9	/zir/	Beneath	10	/ʃar/	Pointed	11	/hʊræʔ/	Nonsense
Row 4	12	/ham.s/	Whisper	13	/ɤar/	Bay or grotto	14	/χur/	Inanition	15	/tˤur/	Incubate	16	/sˤur/	Depict/ city in Lebanon
Row 5	17/18	/dˤir/	Harm	19	/ðar.f/	Circumstance	20	/ʕawæli/	Maker of spears	21	/ɤali/	Priced	22	/ðɪjæb/	Wolves
Row 6	23	/θub/	Vestment	24	/ʕɪbædah/	Worship	25	/ʔaraq/	Insomnia	26	/ʕar/	Shame	27	/ɤir/	Change
Row 7	28	/ʔalam/	Pain	29/30	/dˤar/	Hurt	31	/sˤar/	Happened	32	/bur/	Wild	33	/tam/	Complete
Row 8	34	/kur/	Core	35	/θar/	Erupt	36	/sur/	Wall	37	/hab/	Blow	38	/bir/	Well
Row 9	39	/ðul/	Humiliation	40	/ɤur/	Hollow	41	/ðˤɪl/	Shadow	42	/tˤub/	Brick	43	/ðɪ:d/	Prevent
Row 10	-	/χɪbra/	Experience	-	/tælɪħ/	Finished	-	/mo:z/	Banana	-	/fahad/	Male name meaning leopard	-	/qaɹ.b/ /gaɹ./	Heart

Row #	Number	Transcribed word in IPA	Meaning	Number	Transcribed word in IPA	Meaning	Number	Transcribed word in IPA	Meaning	Number	Transcribed word in IPA	Meaning	Number	Transcribed word in IPA	Meaning
Row 1	-	/far.q/	Difference	-	/sˤælɪħ/	Male name meaning good	-	/fækɪr/	Thought	-	/sˤær/	Happened	-	/fal/	Good omen
Row 2	1	/sˤir/	Render or wax	2/3	/dˤur/	Attendance	4	/fur/	Bubbling	5	/ʕæli/	Above	6	/ɤawæli/	Expansive
Row 3	7	/ðub/	Dissolve	8	/θɪjæb/	Clothes	9	/ʕalam/	Flag	10	/ʔɪbædah/	Extinction	11	/ʕur/	Blind in one eye
Row 4	12	/ʃur/	Pointed	13	/tab/	Became repentant	14	/dur/	Role	15	/kar/	Dredger/mechanical driver	16/17	/qir/ or /gir/	Cere
Row 5	18	/far/	Fugitive	19	/θur/	Bull	20	/sir/	Walked	21	/zar/	Visit	22	/ʃirah/	Sugar syrup
Row 6	23	/ħab/	Loved or seeds	24	/ɤid/	Smoothness	25	/χir/	Good	26	/tˤi:r/	Flied	27	/ʕib/	Blotch
Row 7	28	/ðær/	Warning	29	/θar/	Revolted	30	/ʕɛr.q/	Sweat	31	/ʕid/	Celebration	32	/tir/	Wooden corner in carpentry
Row 8	33	/dir/	Covenant	34/35	/gur/ or /qur/	Cave	36	/zur/	Ghost or forged	37	/χar/	Chose	38	/ħams/	Toasted
Row 9	39	/tˤar/	Flied	40	/ɤib/	Hide	41	/ðaraf/	Shed	42	/ħɪræʔ/	Cave name	43	/ðˤɛ:d/	-
Row 10	-	/kal.b/	Dog	-	/fo:z/	Win	-	/far/	Left	-	/mærɪd/	Giant	-	/færɪd/	Alone

Appendix 3.8

The Arabic version of the phonetically balanced passage from *The North Wind and the Sun* (International Phonetic Associ ation, 2004, pp. 53–54). (Thelwall & Sa'Adeddin, 1990)

Sentence 1

The North Wind and the Sun were disputing which was the stronger

كانت ريح الشمال تتجادل والشمس في أي منهما أقوى من الأخرى

ka:nat ri:ħu ʔaʃ.ʃama:li tatadʒa:dalu waʃ.ʃam.su fi ʔaj.jin min.huma əl.ʔaq.wa min ʔal.ʔuχ.ra

Sentence 2

When a traveller came along wrapped in a warm cloak

وإذ بمسافر يطلع متلفعا بعباءة سميكة

wa ʔið bimusa:fir jatˤ.laʕu mutalaf.fiʕan biʕaba:ʔatin sami:kah

Sentence 3

They agreed that the one who first succeeded in making the traveler take his cloak off should be considered stronger than the other

فاتفقتا على اعتبار السابق في اجبار المسافر على خلع عباءته الأقوى

fat.tafaqa: ʕala ʔiʕ.tiba:r ʔas.sa:biq fi ʔidʒ.ba:r əl.musa:fir ʕala χalʕ ʕaba:ʔatih əl.ʔaq.wa

Sentence 4

Then the North Wind blew as hard as he could

عصفت ريح الشمال بأقصى ما استطاعت من قوة

ʕasˤafat ri:ħ əl.ʃama:l biʔaq.sˤa mas.tatˤa:ʕat min quw.wah

Sentence 5

But the more he blew the more closely did the traveller fold his cloak around him; and at last the North Wind gave up the attempt.

ولكن كلما ازداد العصف ازداد المسافر تدثرا بعباءته إلى ان اسقط في يد الريح فتخلت عن محاولتها .

wala:kin kul.lama ʔiz.da:d ʔal.ʕasˤf ʔiz.da:d əl.musa:fir tadaθ.θuran biʕaba:ʔatih

ʔila ʔan ʔasˤ.qatˤ fi jad ʔar.ri:ħ fataχal.lat ʕan muħa:wala:tiha

Sentence 6

Then the Sun shined out warmly, and immediately the traveller took off his cloak.

بعدئذ سطعت الشمس بدفئها فما كان من المسافر الا ان خلع عباءته على التو

baʕ.da ʔiðin satˤaʕat ʔaʃ.ʃams bidif.ʔiha fama ka:na min əl.musa:fir ʔil.la ʔan

χalaʕa ʕaba:ʔatuh ʕala ʔat.taw

Sentence 7

And so the North Wind was obliged to confess that the Sun was the stronger of the two

وهكذا اضطرت ريح الشمال إلى الاعتراف بان الشمس كانت هي الأقوى .

waha:kaða ʔidˤ.tˤar.rat riħu ʔaʃ.ʃama:li ʔila əl.ʔiʕ.tira:f biʔan.na ʔaʃ.ʃams ka:nat

hija əl.ʔaq.wa

Appendix 3.9

Translation and Arabic written form are adapted from Sahihinternational.com

Sentence 1

بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

In the name of Allah , the Entirely Merciful, the Especially Merciful.

bis.mil.lahi ar.raħ.ma:n ar.raħi:m

Sentence 2

الْحَمْدُ لِلَّهِ رَبِّ الْعَالَمِينَ

[All] praise is [due] to Allah , Lord of the worlds –

əl.ħam.du li.la:hi rab.bi əl.ʕa:lami:n

Sentence 3

الرَّحْمَٰنِ الرَّحِيمِ

The Entirely Merciful, the Especially Merciful,

ar.raħ.ma:n ar.raħi:m

Sentence 4

مَالِكِ يَوْمِ الدِّينِ

Sovereign of the Day of Recompense.

ma:liki jaw.mi d.di:n

Sentence 5

إِيَّاكَ نَعْبُدُ وَإِيَّاكَ نَسْتَعِينُ

It is You we worship and You we ask for help.

ʔij.ja:ka naʕ.budu waʔij.ja:k nas.taʕi:n

Sentence 6

اهْدِنَا الصِّرَاطَ الْمُسْتَقِيمَ

Guide us to the straight path –

ʔih.dina ʔasˤ.sˤira:tˤ ʔal.mus.tˤaqi:m

Sentence 7

صِرَاطَ الَّذِينَ أَنْعَمْتَ عَلَيْهِمْ غَيْرِ الْمَغْضُوبِ عَلَيْهِمْ وَلَا الضَّالِّينَ

The path of those upon whom You have bestowed favor, not of those who have evoked [Your] anger or of those who are astray.

sˤira:tˤ ʔal.laði:na ʔan.ʕam.ta ʕalaj.him ʁaj.ri əl.maʁ.dˤubi ʕalaj.him waladˤ.dˤa:l.li:n

Appendix 3.10

Grid makers (Ryan, 2005)

```
## Praat script by Kevin Ryan 9/05
## Parts inspired by Katherine Crosswhite and Jennifer Hay (as indicated)
## Below: user provides directory (the default below is the path for my own
desktop;
## you will probably want to change that), initial substring of filename (or
complete
## filename minus the extension), the extension (default is .wav), and one or more
tiers

form Select directory, file type, and tiers
       sentence Directory C:\Documents and Settings\Kevin\Desktop\
       sentence Filename_initial_substring_(optional)
        sentence Extension wav
        sentence Tier(s) t1 t2
endform

Create Strings as file list... list
'directory$''filename_initial_substring$'*.'extension$'
file_count = Get number of strings

## Loop through files and make grids (this section partly inspired by code by
Katherine Crosswhite)

for k from 1 to file_count
     select Strings list
     current$ = Get string... k
     Read from file... 'directory$''current$'
     short$ = selected$ ("Sound")

## Below: look for grid, if found, open it, otherwise make new one
## This section inspired by code by Jen Hay

     full$ = "'directory$''short$'.TextGrid"
     if fileReadable (full$)
       Read from file... 'full$'
       Rename... 'short$'
     else
       select Sound 'short$'
       To TextGrid... "'tier$'"
     endif

## End Jen Hay inspired block

     plus Sound 'short$'
     Edit
     pause Annotate tiers, then press continue...
     minus Sound 'short$'
     Write to text file... 'directory$''short$'.TextGrid
     select all
     minus Strings list
     Remove
endfor

select Strings list
Remove
clearinfo
echo Done. 'file_count' files annotated.
```

Appendix 3.11

Grid checker (Welby, 2002)

```
###################################################################
## check.praat
##
## pulls up TextGrid and .wav files
## use for checking (and correcting) labels
##
## Written by Pauline Welby 08-12-02
##
## works with Praat 4.3.29
##
#############################################################

form Input directory name with final slash
    comment Enter directory where soundfiles are kept:
    sentence soundDir C:\Users\Majid\Desktop\data\SM\SM3\New folder\
    comment Enter directory where TextGrid file will be saved:
    sentence textDir C:\Users\Majid\Desktop\data\SM\SM3\New folder\
    comment Enter directory where list file (if any) is kept:
    sentence listDir
    comment Check TextGrid?
    boolean check_TextGrid yes
    comment Play sound automatically?
    boolean play_sound no
    comment Save TextGrid?
    boolean save_TextGrid yes
endform


if (save_TextGrid = 0) && (check_TextGrid = 1)
 pause Changes will NOT be saved! Continue?
endif

Create Strings as file list... list 'soundDir$'\*.wav
#Read Strings from raw text file... 'listDir$'\list.txt

# loop that goes through all the specified files
numberOfFiles = Get number of strings
for ifile to numberOfFiles
   select Strings list
   fileName$ = Get string... ifile
   name$ = fileName$-".wav"

# if there are associated TextGrid files...

   if check_TextGrid = 1
      # Read in files
      Read from file... 'textDir$'\'name$'.TextGrid
      Read from file... 'soundDir$'\'name$'.wav

      # Display sound and TextGrid in edit window
```

```
      select Sound 'name$'
      plus TextGrid 'name$'
      Edit

      # automatically play Sound object
      if play_sound = 1
        select Sound 'name$'
        Play
      endif

      # prompt user to check labels
      pause Check labels

      select TextGrid 'name$'

      # save TextGrid
      if save_TextGrid = 1
        Write to text file... 'textDir$'\'name$'.TextGrid
      endif

     ## Cleaning up objects before proceeding to the next file
     Remove

   else

      # Read in sound file
      Read from file... 'soundDir$'\'name$'.wav

      # Display sound in edit window
      select Sound 'name$'
      Edit

      # automatically play Sound object
      if play_sound = 1
         select Sound 'name$'
         Play
      endif

      # prompt user to check
      pause Check

   endif

      ## Remove Sound object from objects window before proceeding to the
next file
      select Sound 'name$'
      Remove

endfor

## Remove Strings object for complete object cleaning up
select Strings list
Remove

###END OF SCRIPT###
```

Appendix 4.1

Duration analyser (Crosswhite & Antoniuo, 2007)

```
##duration logger.praat
##written by Katherine Crosswhite
##modified by Mark Antoniou

##What does this script do?
##Outputs the duration of all intervals marked in tier 1 with non-null
lables.  Durations, in milliseconds, will be written to a file called
"Durations.txt", which you will be able to find in the same directory
holding your sound files after you run the script.

##  Specify the directory containing your sound files in the next line:
form Enter directory containing TextGrids:
#Be sure not to forget the slash (Windows: backslash, OSX: forward slash)
at the end of the directory name.
      sentence Directory /Users/michaeltyler/Desktop/
endform

#Now we will do some prep work to get your log file ready.  The first thing
I usually do is make sure that I delete any pre-existing variant of the
log:
filedelete 'directory$'durations.txt

##  Now I'm going to make a variable called "header_row$", then write that
variable to the log file:
header_row$ = "Filename" + tab$ + "phoneme" + tab$ + "Duration (ms)" +
newline$
header_row$ > 'directory$'duration_log.txt

##  Now we make a list of all the text grids in the directory we're using,
and put the number of filenames into the variable "number_of_files":
Create Strings as file list...  list 'directory$'*.TextGrid
number_files = Get number of strings

# Then we set up a "for" loop that will iterate once for every file in the
list:
for j from 1 to number_files

     # Query the file-list to get the first filename from it, then read
that file in:
     select Strings list
     current_token$ = Get string... 'j'
     Read from file... 'directory$''current_token$'

     # Here we make a variable called "object_name$" that will be equal to
the filename minus the ".wav" extension
     object_name$ = selected$ ("TextGrid")

     # Now we figure out how many intervals there are in tier 1, and step
through them one at a time.
     # If an intervals label is non-null, we get its duration and write it
to the log file.
```

```
     number_of_intervals = Get number of intervals... 1
     for b from 1 to number_of_intervals
          interval_label$ = Get label of interval... 1 'b'
          if interval_label$ <> ""
               begin_vowel = Get starting point... 1 'b'
               end_vowel = Get end point... 1 'b'
               duration = (end_vowel - begin_vowel) * 1000
              fileappend                    "'directory$'duration_log.txt"
'object_name$''tab$''interval_label$''tab$''duration:3''newline$'
          endif
     endfor

     #   By this point, we have gone through all the intervals for the
current
     #  textgrid, and written all the appropriate values to our log file.
We are now ready to go on to
     #  the next file, so we close can get rid of any objects we no longer
need, and end our for loop
     select all
     minus Strings list
     Remove
endfor

# And at the end, a little bit of clean up and a message to let you know
that it's all done.
select all
Remove
clearinfo
printline All files have been processed.
printline The durations have been output to 'directory$'
```

Appendix 6.1

F0 Analysis script (Hirst, 2012)

```
#praat script
script_name$ = "analyse_tier.praat"
#author Daniel Hirst
#email daniel.hirst@lpl.univ-aix.fr
version$ = "[2009:08:07]"
date$ = date$()

#purpose Analyse a folder of Sound files
#                    and a folder of TextGrid files
#  by default the folders are called "Sounds" and "TextGrids"
#                    and are in a folder called Corpus which is in the
#                    same parent folder as this script
#          For each interval or point on selected tier
#          the script calculates
#          - duration
#           and, depending on the options selected,
#          -mean/min/max pitch, intensity, f1, f2 f3
#          the results are output to the Info window
#          and can be saved as a .txt file which can be read directly by
#          a statistics package like R

#define parameters used in the script
form analyse tier
          sentence investigator <Put your name here>
          sentence Sound_folder Corpus/Sounds
          sentence TextGrid_folder Corpus/TextGrids
          word Analysis_tier syllable
          word Sound_extension .wav
          word TextGrid_extension .TextGrid
          real Time_step 0 (= automatic)
          word Undefined_value NA
          boolean calculate_pitch yes
          boolean automatic_min_max yes
          natural min_pitch 60
          natural max_pitch 750
          boolean calculate_intensity yes
          comment For formants
          boolean calculate_formants yes
          natural Number_of_formants 5
          natural Maximum_formant 5500
          positive Window_length 0.05
          positive Pre_emphasis 50
          comment For point tier
          positive Analysis_window 0.1
endform

clearinfo
```

```
default_minimum_pitch = 60
default_maximum_pitch = 750

#Read in list of sound files
mySounds = Create Strings as file list... sounds
... 'sound_folder$'/*'sound_extension$'
nSounds = Get number of strings
item = 0

myTextGrids = Create Strings as file list... TextGrids
... 'textGrid_folder$'/*'textGrid_extension$'
nTextGrids = Get number of strings

if nSounds > 0 and nTextGrids > 0
	nSounds = Get number of strings
#print header of output file
	printline #File created by 'script_name$'
	... version 'version$'
	printline #Author: Daniel Hirst <daniel.hirst@lpl-aix.fr>
	printline #Analysis carried out by ['investigator$']
	... on 'date$' on tier ['analysis_tier$']
	printline #
	printline #Parameters:
	if calculate_pitch
		if automatic_min_max
			printline # 'tab$'pitch: Automatic min max
		else
			printline # 'tab$'pitch:
			... min='min_pitch'; max='max_pitch'
		endif
	endif
	if calculate_intensity
		printline # intensity:
	endif
	if calculate_formants
		print # 'tab$'formants: n='number_of_formants'
	... , max='maximum_formant', window='window_length',
	... pre-emphasis='pre_emphasis'
	endif
	printline #
#print column names
	print  'tab$'file 'tab$'label 'tab$'duration
	if calculate_pitch
		print  'tab$'f0_min 'tab$'f0_mean 'tab$'f0_max
	endif
	if calculate_intensity
		print  'tab$'int_min  'tab$'int_mean  'tab$'int_max
	endif
	if calculate_formants
		printline  'tab$'F1 'tab$'F2 'tab$'F3
	endif
```

```
	printline

#check if TextGrid file exists for each sound
# and call treatment
	for iSound from 1 to nSounds
		select mySounds
		sound_name$ = Get string... iSound
		textGrid_name$ = sound_name$ - sound_extension$
		... + textGrid_extension$
		sound$ = sound_folder$ + "/" + sound_name$
		textGrid$ = textGrid_folder$ + "/" + textGrid_name$
		if fileReadable(textGrid$)
			call treatment
		else
			printline # Cannot find TextGrid file
			...  ['textGrid_name$']
		endif
	endfor
else
	if nSounds = 0
		printline Folder ['sound_folder$'] doesn't contain
		... any files with extension ['sound_extension$']
	elsif nTextGrids = 0
		printline Folder ['textGrid_folder$'] doesn't contain
		... any files with extension ['textGrid_extension$']
	endif
endif

#Remove file list
select mySounds
plus myTextGrids
Remove

exit

#subroutine treatment
procedure treatment
	Read from file... 'sound$'
	mySound = selected("Sound")
	name$ = selected$("Sound")
	sound_duration = Get total duration
	Read from file... 'textGrid$'
	myTextGrid = selected("TextGrid")
	textGrid_duration = Get total duration
	if sound_duration != textGrid_duration
		plus mySound
		Scale times
		printline # TextGrid and Sound have different durations
		printline # TextGrid has been scaled to the duration of Sound
	endif
#find number of analysis tier
```

```
		select myTextGrid
		call find_analysis_tier
		if tier
#create analysis objects
				select mySound
				printline # file : 'name$'
# - pitch
				if calculate_pitch
					if automatic_min_max
						myPitch = To Pitch... time_step
						... default_minimum_pitch default_maximum_pitch
						call automatic_min_max_pitch
					else
						myPitch = To Pitch... time_step
						... min_pitch max_pitch
					endif
					printline # min_pitch 'min_pitch:0';
					... max_pitch 'max_pitch:0'
				endif
# - intensity
				if calculate_intensity
					select mySound
					myIntensity = To Intensity... min_pitch
					... time_step Yes
				endif
				if calculate_formants
					select mySound
					myFormants = To Formant (burg)... time_step
					... number_of_formants maximum_formant
					... window_length pre_emphasis
				endif
#Get time values of beginning and end of each interval
				select myTextGrid
				if isIntervalTier
					nIntervals = Get number of intervals... tier
				else
					nIntervals = Get number of points... tier
				endif
				for iInterval from 1 to nIntervals
					select myTextGrid
					if isIntervalTier
						label$ = Get label of interval... tier
						... iInterval
						start = Get starting point... tier
						... iInterval
						end = Get end point... tier iInterval
					else
						label$ = Get label of point... tier
						... iInterval
						mid = Get time of point... tier iInterval
						start = mid - analysis_window/2
```

```
                    if start< 0
                        start = 0
                    endif
                    end = mid + analysis_window/2
                    if end > sound_duration
                        end = sound_duration
                    endif
                endif
#calculate parameters for each non empty interval
                if label$ != "" and label$ != "_" and
                ... label$ != "#"
                    item = item+1
# -     duration
                    duration = 1000*(end - start)
                    call set_undefined duration
                    duration$ = value$
# -     pitch
                    if calculate_pitch
                        select myPitch
                        f0_min = Get minimum... start end
                        ... Hertz Parabolic
                        call set_undefined f0_min
                        f0_min$ = value$
                        f0_mean = Get mean... start end Hertz
                        call set_undefined f0_mean
                        f0_mean$ = value$
                        f0_max = Get maximum... start end
                        ... Hertz Parabolic
                        call set_undefined f0_max
                        f0_max$ = value$
                    endif

# -     intensity
                    if calculate_intensity
                        select myIntensity
                        intensity_min = Get minimum... start
                        ... end Parabolic
                        call set_undefined intensity_min
                        intensity_min$ = value$
                        intensity_mean = Get mean... start end
                        ... energy
                        call set_undefined intensity_mean
                        intensity_mean$ = value$
                    intensity_max = Get maximum... start
                        ... end Parabolic
                        call set_undefined intensity_max
                        intensity_max$ = value$

                    endif

# -     formants
```

```
				if calculate_formants
					select myFormants
					f1 = Get mean... 1 start end Hertz
					call set_undefined f1
					f1$ = value$
					f2 = Get mean... 2 start end Hertz
					call set_undefined f2
					f2$ = value$
					f3 = Get mean... 3 start end Hertz
					call set_undefined f3
					f3$ = value$
				endif

#print out results
				print 'item' 'tab$''name$' 'tab$''label$'
				... 'tab$''duration$'
				if calculate_pitch
					print 'tab$''f0_min$' 'tab$''f0_mean$'
					... 'tab$''f0_max$'
				endif
				if calculate_intensity
					print 'tab$''intensity_min$'
					... 'tab$''intensity_mean$'
					... 'tab$''intensity_max$'
				endif
				if calculate_formants
					print 'tab$''f1$' 'tab$''f2$'
					... 'tab$''f3$'
				endif
				printline
			endif
		endfor

#Remove objects
		if calculate_pitch
			select myPitch
			Remove
		endif
		if calculate_intensity
			select myIntensity
			Remove
		endif
		if calculate_formants
			select myFormants
			Remove
		endif
	else
#print warning if TextGrid has no analysis tier
		printline ###TextGrid ['name$'] has no tier
		... ['analysis_tier$']
	endif
```

```
#Remove Sound and TextGrid
	select mySound
	plus myTextGrid
	Remove
endproc


procedure set_undefined value
	if value = undefined
		value$ = undefined_value$
	else
		value$ = "'value:0'"
	endif
endproc

procedure automatic_min_max_pitch
	q25 = Get quantile... 0 0 0.25 Hertz
	q75 = Get quantile... 0 0 0.75 Hertz
	min_pitch = 0.75*q25
	max_pitch = 1.5*q75
	Remove
	select mySound
	myPitch = To Pitch... time_step min_pitch
	... max_pitch
endproc

procedure find_analysis_tier
	nTiers = Get number of tiers
	tier = 0
	for iTier from 1 to nTiers
		tier_name$ = Get tier name... iTier
		if tier_name$ = analysis_tier$
			tier = iTier
			isIntervalTier = Is interval tier... tier
		endif
	endfor
endproc


#Version history

#2009:08:07		declared time_step as real with default value 0 (= automatic)
#2009:05:28		first version
```

Appendix 6.2

Mean F0 sentences analysis script (Herrmann, 2008)

```
###############################################################################
# This script goes through sound and TextGrid files in a directory,        #
# all marked labels will be left untouched - all the others will be        #
# set to zero. The resulting file is then stored in the sound_output       #
# directory and will be subjected to a Pitch analysis.        #
# Frank Herrmann (June 2008)                                                #
#                                  [simplified, more user friendly version]#
##############################################################################

form F0 Analysis
	sentence participant_number: 1
	sentence input_directory C:\Users\Majid\Desktop\data\BF\BF1\New folder (2)\r-q\seperate\segmented sentences\new files\check\
	sentence output_directory C:\Users\Majid\Desktop\data\BF\BF1\New folder (2)\r-q\seperate\segmented sentences\new files\check\
	comment The name of your result file (.txt)
	sentence resultfile_name F0_results
	comment The name of your interval tier
	sentence interval_tier TI
endform

# Here, you make a listing of all the sound files in a directory.
	Create Strings as file list... list 'input_directory$'*.wav
	numberOfFiles = Get number of strings

# Define the whole resultfile directory and name
	resultfile$ = "'output_directory$''resultfile_name$'_'participant_number$'.txt"

# Check if the result file exists:
	if fileReadable (resultfile$)
		pause The result file 'resultfile$' already exists! Do you want to overwrite it?
		filedelete 'resultfile$'
	endif

# Write a row with column titles to the result file:
	titleline$ = "File'tab$'Part'tab$'F0_max'tab$'F0_min'tab$'F0_mean'tab$'F0_SD'newline$'"
	fileappend "'resultfile$'" 'titleline$'

# Go through ALL the sound files, one by one:
for ifile to numberOfFiles
	filename$ = Get string... ifile

	# A sound file is opened from the listing:
	Read from file... 'input_directory$''filename$'
	soundname$ = selected$ ("Sound", 1)

	# Open a TextGrid by the same name:
	Read from file... 'input_directory$''soundname$'.TextGrid

	# Append the previously created result file: Put in the name of the sound file
	# and the participant number
```

```
	resultline$ = "'soundname$"tab$"participant_number$"tab$'"
	fileappend "'resultfile$'" 'resultline$'

	select TextGrid 'soundname$'
	call GetTier 'interval_tier$' i_tier
	numberOfIntervals = Get number of intervals... i_tier

	# Pass through all points in the selected tier:
	for interval to numberOfIntervals
		label$ = Get label of interval... i_tier interval
		# if the label is empty, get the time indexes and set selection to zero
		if label$ = ""
			start = Get starting point... 'i_tier' interval
			end = Get end point... i_tier interval

			# set this interval to zero
			select Sound 'soundname$'
			#Set part to zero... start end at exactly these times
			Set part to zero... start end at nearest zero crossing


			# return to TextGrid
			select TextGrid 'soundname$'
		endif
	endfor

	# give this newly edited sound file a new name and save it in the output directory
	select Sound 'soundname$'
	newname$ = "'soundname$'_voiced"
	select Sound 'soundname$'
	Rename... 'newname$'
	select Sound 'newname$'
	Write to WAV file... 'output_directory$''newname$'.wav

	# Now, let's analyse the pitch of the new sound file
	select Sound 'newname$'
	To Pitch (ac)...  0 75 15 no  0.03 0.45 0.01 0.35 0.14 300
		maxf0 = Get maximum... 0 0 Hertz None
		minf0 = Get minimum... 0 0 Hertz None
		meanf0 = Get mean...  0 0 Hertz
		sdf0 = Get standard deviation... 0 0 Hertz

	# The result file is once again appended
	resultline$ = "'maxf0:2''tab$''minf0:2''tab$''meanf0:2''tab$''sdf0:2''newline$'"
	fileappend "'resultfile$'" 'resultline$'

	# Remove the TextGrid, Sound, and Pitch object from the object list
	select TextGrid 'soundname$'
	plus Sound 'newname$'
	plus Pitch 'newname$'
	Remove
	select Strings list
	# and go on with the next sound file!
endfor
select Strings list
Remove
```

```
#-----------------------------------------------------------------
# This procedure finds the number of a tier that has a given label.
procedure GetTier name$ variable$
	numberOfTiers = Get number of tiers
	itier = 1
	repeat
	tier$ = Get tier name... itier
		itier = itier + 1
	until tier$ = name$ or itier > numberOfTiers

	if tier$ <> name$
		'variable$' = 0
	else
		'variable$' = itier - 1
	endif

	if 'variable$' = 0
		exit The tier called 'name$' is missing from the file 'soundname$'!
	endif
endproc
#-----------------------------------------------------------------
```

Appendix 7.1

Formant frequencies(F1-F3) analysis script (Lennes, 2003)

```
# This script goes through sound and TextGrid files in a directory,
# opens each pair of Sound and TextGrid, calculates the formant values
# at the midpoint of each labeled interval, and saves results to a text file.
# To make some other or additional analyses, you can modify the script
# yourself... it should be reasonably well commented! ;)
#
# This script is distributed under the GNU General Public License.
# Copyright 4.7.2003 Mietta Lennes

form Analyze formant values from labeled segments in files
	comment Directory of sound files
	text sound_directory C:\Users\HCSPGR\Desktop\test\
	sentence Sound_file_extension .wav
	comment Directory of TextGrid files
	text textGrid_directory C:\Users\HCSPGR\Desktop\test\
	sentence TextGrid_file_extension .TextGrid
	comment Full path of the resulting text file:
	text resultfile C:\Users\HCSPGR\Desktop\test\formantresultsTEST.txt
	comment Which tier do you want to analyze?
	sentence Tier Formant
	comment Formant analysis parameters
	positive Time_step 0.01
	integer Maximum_number_of_formants 5
	positive Maximum_formant_(Hz) 5500_(=adult female)
	positive Window_length_(s) 0.025
	real Preemphasis_from_(Hz) 50
endform

# Here, you make a listing of all the sound files in a directory.
# The example gets file names ending with ".wav" from C:\Users\HCSPGR\Desktop\test\

Create Strings as file list... list 'sound_directory$'*'sound_file_extension$'
numberOfFiles = Get number of strings

# Check if the result file exists:
if fileReadable (resultfile$)
	pause The result file 'resultfile$' already exists! Do you want to overwrite it?
	filedelete 'resultfile$'
endif

# Write a row with column titles to the result file:
# (remember to edit this if you add or change the analyses!)

titleline$ = "Filename	Segment label	F1 (Hz)	F2 (Hz)	F3 (Hz)'newline$'"
fileappend "'resultfile$'" 'titleline$'
```

```
# Go through all the sound files, one by one:

for ifile to numberOfFiles
	filename$ = Get string... ifile
	# A sound file is opened from the listing:
	Read from file... 'sound_directory$''filename$'
	# Starting from here, you can add everything that should be
	# repeated for every sound file that was opened:
	soundname$ = selected$ ("Sound", 1)
	To Formant (burg)... time_step maximum_number_of_formants maximum_formant window_length preemphasis_from
	# Open a TextGrid by the same name:
	gridfile$ = "'textGrid_directory$''soundname$''textGrid_file_extension$'"
	if fileReadable (gridfile$)
		Read from file... 'gridfile$'
		# Find the tier number that has the label given in the form:
		call GetTier 'tier$' tier
		numberOfIntervals = Get number of intervals... tier
		# Pass through all intervals in the selected tier:
		for interval to numberOfIntervals
			label$ = Get label of interval... tier interval
			if label$ <> ""
				# if the interval has an unempty label, get its start and end:
				start = Get starting point... tier interval
				end = Get end point... tier interval
				midpoint = (start + end) / 2
				# get the formant values at that interval
				select Formant 'soundname$'
				f1 = Get value at time... 1 midpoint Hertz Linear
				f2 = Get value at time... 2 midpoint Hertz Linear
				f3 = Get value at time... 3 midpoint Hertz Linear
				# Save result to text file:
				resultline$ = "'soundname$'	'label$'	'f1'	'f2'	'f3''newline$'"
				fileappend "'resultfile$'" 'resultline$'
				select TextGrid 'soundname$'
			endif
		endfor
		# Remove the TextGrid object from the object list
		select TextGrid 'soundname$'
		Remove
	endif
	# Remove the temporary objects from the object list
	select Sound 'soundname$'
	plus Formant 'soundname$'
	Remove
	select Strings list
	# and go on with the next sound file!
endfor
```

```
Remove


#-------------
# This procedure finds the number of a tier that has a given label.

procedure GetTier name$ variable$
	numberOfTiers = Get number of tiers
	itier = 1
	repeat
		tier$ = Get tier name... itier
		itier = itier + 1
	until tier$ = name$ or itier > numberOfTiers
	if tier$ <> name$
		'variable$' = 0
	else
		'variable$' = itier - 1
	endif

	  if 'variable$' = 0
			exit The tier called 'name$' is missing from the file 'soundname$'!
	  endif

endproc
```