Phonetic and Phonological Aspects of Gemination in Libyan Arabic

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Dedication

To my mother and father,

and my husband and children …

For their love, endless support and lighting up my life.

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First and foremost, my greatest gratitude goes to Allah the Almighty (God), without His help, guidance and blessing, I would have achieved nothing.

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My parents deserve my sincere appreciation and good prayers for their great precious support, caring and guidance since my birth to this date. Thank you for always believing in me and motivating me to pursue my goals in life.

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Abstract

This thesis investigates the phonetics and phonology of geminate consonants in Libyan Arabic (LA). In addition to lexically contrastive geminates ‘true geminates’, LA has two types of phonologically derived geminate: ‘fake geminates’, which are formed as a combination of two identical consonants at the juncture of a word or a morpheme, and ‘assimilatory geminates’, which are the result of total assimilation. This study examines the effect of the phonological status of a geminate on the phonetic realization to ascertain whether underlying differences are reflected in phonetic dissimilarity. In particular, it investigates two questions: what are the acoustic and articulatory differences between singletons and lexical geminates; and are there any acoustic or articulatory differences between the three types of geminates. To answer these questions, two phonetic studies were conducted: one acoustic and one articulatory (EPG). Trisyllabic minimal or near minimal utterances containing the sonorant sounds /l, m, n, r/ were considered. Native speakers of LA were recorded reading word-lists containing medial singleton and geminate consonants preceded by short and long vowels. The acoustic study investigated both durational and non-durational parameters. The articulatory study investigated spatial and spatio-temporal (dynamic) parameters. The results provide evidence that the singleton-geminate contrasts as well as the three geminate types are phonetically distinct from each other when considering both the acoustic and articulatory correlates together. The acoustic results confirm that the primary correlate which distinguishes singletons from geminates in LA is duration. The duration of the preceding vowels gives evidence in support of temporal compensation as one of the correlates of geminates. The comparison between the three types of geminates shows that they all display similar durational and non-durational values. However, the behaviour of short and long vowels preceding assimilatory geminates is suggestive and may contribute to the phonetic distinction between these geminates and the other geminate types. The articulatory results show that the singleton and geminate consonants in LA are different in their articulatory configurations. Fake geminates are also found to be distinct both spatially and dynamically from true and assimilatory geminates, which show similar articulatory patterns. The theoretical implications of these results for the general issue of geminate behavior are discussed.

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Abbreviations

AoC	the amount of contact
BA	Berga Arabic
C	singleton consonant
CC	geminate consonant
CA	Classical Arabic
CoG	centre of gravity
EA	Eastern Arabic
EPG	Electropalatography
FA	Fezzani Arabic
F1	first formant
F2	second formant
F3	third formant
LA	Libyan Arabic
MSA	Modern Standard Arabic
PCD	peak contact duration
RMS	root mean square [amplitude]
TA	Tripolitanian Arabic
TLA	Tripolitanian Libyan Arabic
V	short vowel
VV	long vowel
WA	Western Arabic
σ	syllable
μ	mora

Chapter 1: Introduction and review of the literature

1.1 Overview of the topic

This thesis investigates the phonetics and phonology of geminate consonants in Libyan Arabic (LA). It examines the acoustic and articulatory properties of the singleton-geminate contrast and the different types of geminate consonants in Libyan Arabic using the sonorant sounds /r, l, m, n/.

In some languages, geminates (or long consonants) contrast phonologically with singletons (or short consonants), and phonetically this contrast is expressed as a difference in length or duration. That is, geminates are acoustically longer than their singleton counterparts (see e.g. Ladefoged and Maddieson, 1996 and Ham, 2001). Durational variations in geminates have been investigated for many languages (e.g. Payne (2005) for Italian; Arvaniti (1999) for Cypriot Greek; Ridouane (2007) for Berber, Ham (2001) for Bernese, Levantine Arabic, Hungarian and Madurese), and generally the duration contrast between geminate and singleton consonants has been reported to be robust. Arabic geminates have been reported to be significantly longer than their singleton counterparts as well (see e.g. Al-Ani, 1970, Ghalib, 1984, Al-Tamimi, 2004). The degree to which geminate consonants are longer than their singleton counterparts varies from language to language, however. As reported by Ladefoged and Maddieson (1996:91-92), depending on the language, geminates are on average one-and-a half to three times longer than their singleton counterparts in careful speech.

From a phonological perspective, geminates are represented either as consonants which comprise two timing units (see McCarthy, 1982) or as a single mora-projecting consonant (see Hyman, 2003). It is argued (see e.g. Ham, 2001) that each proposal has its merits. Generally, within the field of phonology, the representation of a geminate is dependent on its type and properties (for explanation and discussion see sections 1.8 and 1.9). That is, it depends on the geminate's underlying phonological status together with its surface behaviour.

Traditionally, geminates are divided into lexical (underlying 'true') geminates, 'assimilatory' geminates, formed as a result of total assimilation in consonantal sequences, and concatenated ('fake') geminates, formed as a combination of two identical consonants at the juncture of a morpheme or a word (see e.g. Davis, 2011). The contextual environment for these three traditional types is the same, since they all occur in an intervocalic position, with true geminates in within-word position and assimilatory and fake geminates in across-word-boundary position. However, word-edge geminates are also reported to exist in some languages. These are 'word-initial' geminates and 'word-final' geminates. The contextual environment for these two types is prevocalic and post-vocalic respectively. All these geminates types can be found in LA. Where word-initial and word-final geminates are argued to be underlying forms for some languages (see e.g Kraehenmann, 2011 and Al-Tamimi, Abu-abbas, and Tarawnah, 2010), fake and assimilatory geminates can only be surface forms. Assimilatory geminates, however, can behave in some languages like true geminates; in that they can show integrity and inalterability effects (see section 1.9.3 below). In the phonological literature, these different geminate types are represented differently since they result from different phonological processes and/or they have different underlying status (see sections 1.7 and 1.9).

Previous studies on Arabic gemination have either focused on true (underlying) geminates or reported results on data that consists of more than one type of geminate without making explicit the phonological status behind these different types or investigating its effect on the phonetic output (see section 1.10 for a review of the experimental studies on Arabic geminates). It is interesting to investigate whether this difference triggers any acoustic or articulatory consequences on the phonetic output. In this thesis, the different geminate types will be investigated acoustically and articulatorily in order to get a picture of what phonetic consequences the phonological status of a geminate might have.

In this introductory chapter, a background of Arabic language will be presented in section 1.2. An introduction to LA and the dialectical varieties spoken in Libya, together with an explanation of the linguistic diversity in Libya, will be addressed in section 1.3. A review of previous studies on LA will be presented in section 1.4. A basic description of Libyan Arabic phonetic inventory will be presented in section 1.5. The phenomenon of gemination in LA and the geminate types in LA will be addressed in sections 1.6 and 1.7 respectively. The phonological proposals concerning the representation of geminate consonants will be reviewed in section 1.8. The phonological representation of geminate types will be discussed in section 1.9. Then, a review of the previous experimental studies on Arabic gemination will be presented in section 1.10. Here, I argue that previous studies did not distinguish between the different types of geminates in setting up their methodologies and that a better analysis is one including all geminate types or one in which the phonological status of the geminate consonant is considered. The aim of the thesis will be presented in section 1.11. In section 1.12, the general research questions and the hypotheses proposed for this thesis will be presented. The contribution of the thesis will be presented in section 1.13. Finally, the layout of the thesis will be outlined in section 1.14.

1.2 Arabic Language (background)

Arabic is a member of the Semitic language family, which, in turn, forms part of the much larger Afro-Asiatic family (formerly known as Hamito-Semitic) (Newman, 2002). Nowadays, Arabic is spoken by about 300 million native speakers in 22 countries in an area stretching between the Atlantic Ocean and the

Arabian Gulf[1] (Habash, 2010). Figure (1.1) shows the 22 Arab countries where Arabic is the mother tongue. Arabic is also the liturgical language of over 1 billion Muslims worldwide since it is the language in which the Qur'an (the Holy Book of Islam) is revealed and written (Newman, 2002). The current standard variety of the language is the modern descendant of Classical Arabic (CA), the language of the Qur'an and the pre-Islamic as well as early post-Islamic literature, and is generally known as Modern Standard Arabic (MSA). MSA is not different from CA in the essence of its syntax, grammar, morphology and phonology. Lexically, however, MSA is much more modern (Ben-Taher, 2006 and Habash, 2010). It is worth pointing out that this modern variety does not have any mother-tongue speakers; rather, the Arabic dialects are the true native language forms.

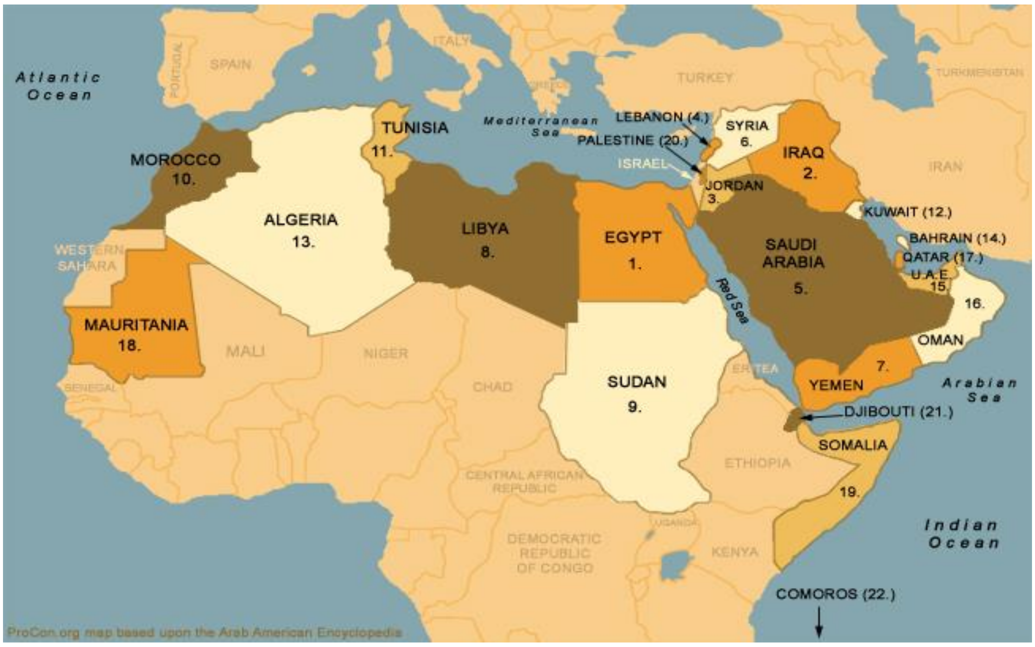

Figure 1.1: The Arab World

[Source:http://mapcollection.wordpress.com/2012/06/18/map-of-the-arab-world/]

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1 The 22 Arab countries are: Algeria, Bahrain, Comoros, Djibouti, Egypt, Iraq, Jordan, Kuwait, Lebanon, Libya, Mauritania, Morocco, Oman, Palestine, Qatar, Saudi Arabia, Somalia, Sudan, Syria, Tunisia, United Arab Emirates and Yemen. Arabic is an official language in three other countries: Chad, Eritrea and Israel.

Consequently, Arabic language can be described as “a collection of multiple variants among which one particular variant has a special status as the formal written standard of the media, culture and education across the Arab World. The other variants are informal spoken dialects that are the media of communication for daily life” (Habash, 2010:1). Arabic dialects are primarily spoken. They are restricted in use for informal daily communication. In spite of the fact that there is a rich popular dialect culture of movies, songs, TV shows and folktales, Arabic dialects are not taught in schools or even standardised.

The distance between MSA and the spoken dialects of Arabic is a prototype of diglossia, where the two forms are not perceived by Arabs as two separate languages. On the contrary, there is a special kind of coexistence between the two forms each of which serves a different set of purposes. “Although the two variants have clear domains of prevalence: formal written (MSA) versus informal spoken (dialect), there is a large gray area in between that is often filled with a mix of the two forms” (Habash, 2010:2). Some researchers argue that Arabic dialects are loosely related to Classical Arabic. Habash (2010:1-2) states that the Arabic dialects are

> “the result of the interaction between different ancient dialects of Classical Arabic and other languages that existed in, neighbored and/or colonized what is today the Arab world. … [Consequently], Arabic dialects substantially differ from MSA and each other in terms of phonology, morphology, lexical choice and syntax.”

However, others, like Owens (2015), argue that there is a direct relation between classical and spoken Arabic. The diagram in Figure 1.2 was used by him to illustrate the relation between Arabic dialects and Classical Arabic. He states that The Venn diagram intersecting the features common both to all dialects and to Classical Arabic would look something like Figure 1.2 with a large number of intersecting features in the middle. He explains that the classical views that differentiate between the two forms are not based on comparative linguistic parameters.

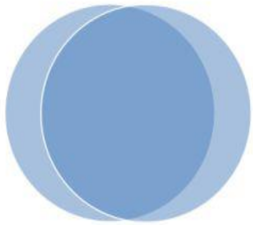


Figure 1.2: Intersection of shared features, dialects and Classical Arabic

Arabic dialects vary on many dimensions and can be divided in many different ways (Watson, 2011). These divisions do not mean that all members of each dialect group are totally homogenous linguistically (for discussion on these divisions see Alorifi, 2008 and Habash, 2010). For example, Arabic is divided into Eastern Arabic (EA) and Western Arabic (WA) varieties (where the Eastern form of Arabic can be found in Saudi Arabia, Kuwait, Qatar, Bahrain, United Arab Emirates, Oman, Yemen, Iraq, Syria, Lebanon, Palestine, Jordan, Egypt, and Sudan, and speakers of Western dialects can be found in Libya, Tunisia, Algeria, Morocco, and Mauritania). Ghazali, Hamdi and Barkat (2002:331), state that although the division of Arabic dialects into EA and WA varieties "is an oversimplification of Arabic dialectology, it is widely accepted by the linguistic community and may be supported by linguistic behaviour". In their study on speech rhythm variation in Arabic dialects, Ghazali, Hamdi and Barkat (2002) found that naive native speakers from different Arabic countries can easily determine whether the variety that they listen to belongs to the EA or the WA dialectical group. These two Arabic varieties can be further divided into six regional dialects which are, usually, identified as core dialects. These are as follows:

- The Iraqi Dialect: spoken only in Iraq.
- The Gulf Dialect: spoken around the shores of the Arabian Gulf (Persian Gulf) which includes Kuwait, Saudi Arabia, Bahrain, Qatar, United Arab Emirates, and Oman.
- Yemeni Dialect: spoken in Yemen

- The Levant Dialect: spoken by Arabs near the Mediterranean east coast, including countries such as Jordan, Syria, Lebanon, and Palestine.
- The Egyptian Dialect: covers the dialects of the Nile valley spoken in Egypt and Sudan.
- The Maghreb Dialect: refers to an Arab geographical region including Morocco, Tunisia, Algeria, and Western Libya.

Within each dialect region, as common in many other languages around the world, it is common to distinguish a number of sub-dialects based on social class, religious group (Muslim, Christian, and Jewish dialects) or sedentary (Bedouin vs. Urban dialects) (Watson, 2011).

1.3 Libyan Arabic

Libyan Arabic is a variety of Arabic spoken by about six million people who live in Libya and abroad. The official language of Libya is MSA. In Libya, CA is used by religious leaders in some formal situations, whereas MSA appears in formal spoken and written communication and sometimes in schools (Chapin, 2004). In the Arab speaking world the word 'FusHa' is used to refer to both MSA and CA. In fact, the two 'forms' are visualised and considered as one thing and naïve Arabic speakers will not be able to tell if they are any different. FusHa is considered as the only one formal form of the language. The Libyan Arabic dialect cannot be entirely separated from CA or MSA (i.e. FusHa), however. This is because many lexical items have been borrowed from these formal varieties to this dialectal variety. In fact, due to the accessibility and widespread of Quranic learning and media, which mainly and largely use FusHa, LA speakers can be considered as bilinguals who speak both the regional variety together with the standard form. This is especially the case in the new generations who are exposed to FusHa since early childhood by means of Quran teaching, children's programmes and cartoons. Young children now show competence knowledge of FusHa, the Standard form of the language. The current diglossic situation in Libya as well as in other Arabic regions badly needs an up-to-date linguistic investigation based on comparative linguistic parameters since many factors has allowed FusHa to gradually, but intrusively, move into domains that are traditionally reserved to the dialect and vice versa.

The variety of Arabic spoken in Libya can be roughly divided into three main dialects. These three major dialects are: (1) the one spoken in Tripolitania (Tarablus), in the northwest region of the country, including the capital city of Tripoli; (2) the one spoken in Cyrenaica (Berga), in the eastern region of the country, including Benghazi, the second major city in Libya; (3) the one spoken in Fezzan, in the southeast region of the country, around the city of Sebha, the major city in Fezzan region. Thus, the dialects spoken in Libya are Tripolitanian Arabic (TA), Berga Arabic (BA), and Fezzani Arabic (FA). Figure (1.3) shows these three dialectical areas.

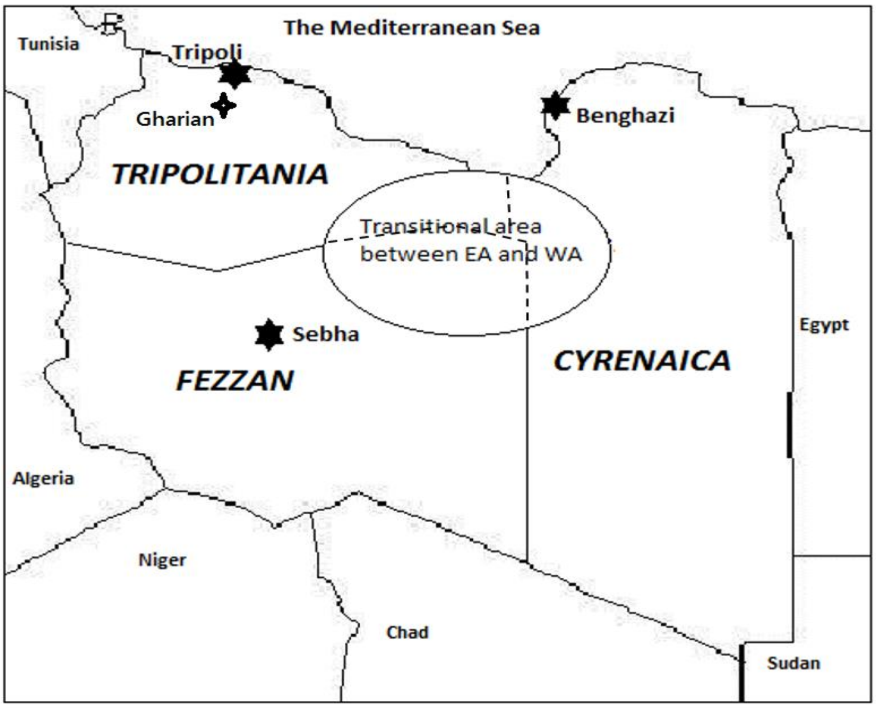


Figure 1.3: A map of Libya showing the three dialectal areas (its three provinces), its neighbouring countries and the transitional area between Eastern and Western Arabic in Libya.

The dialects of Tripolitania and Fezzan belong to the Maghrebi dialect group, which in turn is part of the WA dialect group. The dialects of Cyrenaica, on the other hand, belong to the EA dialectal group, and resemble those of Egypt and Sudan (Chapin, 2004). In addition to these three main classifications of the Arabic dialects spoken in Libya, there exist many sub-dialects in the area. These sub-dialects show variance from city to city within the same region. Alorifi (2008:5) states that Arabic dialects "do not only differ among nations, but also among regions within the same country".

As in the case of other Arabic dialects, LA is different from MSA and other Arabic dialects in terms of phonology, morphology, lexical choice and syntax (Alorifi, 2008). This could be an inevitable result of the interaction between the ancient dialects of CA and other languages that existed, neighboured or colonized Libya. These historical events form and enrich the linguistic variation of LA dialects. For instance, before and since the arrival of Arabs to Libya in the seventh century, Libya has had a great diversity of populations where it was populated simultaneously by Libycs (the Ancient Libycs were the ancestors of Amazigh), Jews, Phoenicians, Greeks, Romans, Vandals and Byzantines (see Pereira (2007) for a review of the history of the population movements in Libya and the Arabization of the country).

1.3.1 Linguistic variations and diversity in Libya

Libya is a country in the Maghreb region of North Africa, bordered by the Mediterranean Sea to the North, Egypt to the East, Sudan to the Southeast, Chad and Niger to the South, and Algeria and Tunisia to the West. Libya is the 17th largest country in the world, with an area of almost 1.8 million square kilometers. However, the population is relatively small (about 6 million) and concentrated very narrowly along the cost in the two northern regions of Tripolitania and Cyrenaica. Ninety percent of the people live in less than 10% of the area, primarily along the coast (https://www.cia.gov/library/publications/the-world-factbook/geos/ly.html). These geographical factors, together with other historical ones, have played an important role in forming the linguistic variations apparent today in Libya.

Libya has a long history of foreign control, which corresponds to many eras of linguistic diversity. During its early history, Libya was influenced by the Berber tribes, Phoenician colonies, Carthaginians, Greeks, Romans, Vandals and Byzantines. In the 7th century C.E., Libya was conquered by the Arabs and Islam was adopted as the region's primary religion (see Chapin, 2004 and Pereira, 2007). It was during this time that Arabic was introduced and gained its position as the primary language of the region. In the mid-16th century, Libya was under the rule of the Ottoman Turks and was part of the Ottoman Empire until 1911, when it was invaded by Italy and established as a colony of Italy. During World War II, Britain and France controlled and divided Libya. In 1951, Libya declared its independence.

As far as the linguistic diversity in Libya is concerned, it is clear from the brief historical review that several languages were spoken in Libya, including Amazighi (Berber), Hebrew, Arabic, Turkish, English and Italian. Although most of the populations in the region were Arab and Amazigh Muslims, who speak Arabic and Amazighi dialects, during the Ottoman rule, the language of administration was strongly influenced by Ottoman Turkish, and many Turkish words had entered the vernacular. From the last quarter of the 19th century, there was increased European culture and economic penetration of Libya, which included the establishment of Italian and French schools, where European languages were taught. Under the Italian rule, the language of administration and state schools became Italian. Many indigenous people became fluent in that language. After the British occupation of large parts of Libya, English became the language of the regime (see e.g. Simon, 1989 and Chapin, 2004).

The other factor that has contributed to the linguistic diversity in Libya is a geographical one. Geography was the principal determinant of the separate historical development of Libya’s three traditional regions – Tarablus

(Tripolitania), Berga (Cyrenaica), and Fezzan (Chapin, 2004). The first province, Tripolitania, includes Tripoli and the surrounding cities. It is located in the north-west region of Libya. The second province, Cyrenaica, is located in the Eastern part of Libya. The third province, Fezzan, is located in the south-west region of Libya. These three provinces are cut off from each other by formidable deserts. Consequently, each retained its separate identity. At the heart of Tripolitania, is the largest city and capital, Tripoli, which is home to 1.7 million of Libya's 6.4 million people. Tripolitania shares a common history with the Maghreb, of which it was a part geographically and culturally. In contrast, Cyrenaica historically was oriented towards Egypt and Mashriq (East). Fezzan was less involved with either the Mashriq or the Maghreb, but “maintained close relations with the sub-Saharan Africa as well as the coast” (Chapin, 2004:20).

It is clear that the three main dialectal areas in Libya correspond geographically to the three main provinces (see Figure 1.3). Thus, Tripolitanian Arabic (TA), Berga Arabic (BA), and Fezzani Arabic (FA) became the main dialectal areas in Libya. Since, as stated earlier, TA and FA belong to the WA group and BA belong to the EA group, it can be claimed that the transition between EA and WA dialects lies in Libya between TA and BA. Figure (1.3) shows the transitional area between Eastern and Western Arabic.

Additionally, and adding to the complexity of the linguistic structure of Libyan Arabic, some varieties of Amazighi/Berber are still spoken in some regions in Libya today, with hundreds of years of mixing with Arabs, such as, Nafusi, Ghadamis, Sawknah, Awjilah, and Tamasheq. Nafusi (also known as 'Tamazight') is spoken in some cities in Jabal Nafusa ‘Nafusa mountain’, southeast Tripoli such as Yafran and Nalut, in the coastal area around the city of Zuara, west Tripoli, and close to the Libyan-Tunisian border, known as Jerbi. Pre-school children in these areas are monolingual in Nafusi. Tamahaq (or Tamachek) is spoken by Touareg in the south Hoggar Mountain area around Tamanrasset and south into Niger, and also in west Libyan Oases around Ghat. Awjilah is spoken by Berbers in Eastern Cyrenaica. Ghadamis is spoken in a small oasis near the Algeria-Tunisia border. Sawknah is nearly extinct (Gordon, 2005). However, “all but small minority of the Libyan people are native Arabic – speakers and thus consider themselves to be Arabs" (Chapin, 2004:94).

As mentioned above in section 1.3, Libyan Arabic dialects are clearly very connected to MSA and CA. This situation, over decades, have been enhanced by learning the Quran Tajwīd (reading and memorizing it) which is very widespread in Libya. Tajwīd is a scholarly codification of the sound of the revelation as it was revealed to the Prophet Muhammad and he subsequently rehearsed it with the Angel Gabriel. It was codified in the 8th century C.E (Nelson, 2009). In practice, this is mainly mastering the phonetics and phonology of reciting the language of the Holy Quran. It deals with accent, phonetics, rhythm and tempo of Quranic recitation. Children usually start learning the science and art of Quranic Tajwīd at the pre-school age. This practice is optional but very common especially in large cities. This early exposure and learning of the language of the Quran adds to the linguistic features of the dialects spoken in Libya. Currently, there are one million Hāfidhs (people who memorize and master Tajwīd for the whole Quran) registered in Libya (see Al Jazeera Documentary, 2016 and Al Jazeera net, 2009). This is about fifth of the population in the country. In addition to this number of Huffādh, a very large number of the population have learned the science of Tajwīd and acquired its required skills at some point in their life when learning smaller parts of the Quran, but not necessarily mastering the whole book. Libyan Huffādh almost always come first in Quranic memorizing and Tajwīd mastering competitions in the Islamic world (Al Jazeera net, 2009). These results show the high level of competence of the Quranic language by Libyan speakers. This interaction between the Quranic Language of Classical Arabic and the dialects of Libya contributes to the linguistic characteristics of the Arabic spoken in Libya.

Currently, Arabic is the official language of Libya. However, Italian and English are widely understood in the major cities. Italian is widely understood by the older generation, whereas English occupies an increasingly important place as the second language of the country. Although, the government of Libya in 1970s adopted a significant policy of Arabization abandoning the use of Latin Alphabet and, in 1984, and for about a decade, foreign languages were no longer thought in

Libya, English now is taught from primary school onwards. In universities, scientific, technical and medical courses are conducted in English, and, in large part taught by foreigners employing foreign languages.

The main focus of this study is Tripolitanian Libyan Arabic (TLA). It is spoken in the northwest region of the country, mainly in the capital Tripoli and the surrounding cities. Tripoli is the home of 1.7 million people. This is about 29% of Libyan's population, which is about 6 million. Tripoli is the destination of migrants from other cities in Libya and from neighbouring countries. When listening carefully to different speakers in Tripoli, different dialects can be recognized. These include dialects from east, west and south of Libya, together with Arab and African dialects. However, in the surrounding areas or cities (within Tripolitania) this phenomenon is less recognized, since the majority of inhabitants are Libyans who are originally resident in these cities.

To conclude, Libya has witnessed many linguistic changes over the centuries. The introduction of Islam and Arabization of the country is one of the big milestones in Libyan history. However, a number of geographical and historical factors influenced what are today LA dialects. These dialects are the result of the interaction between different classical Arabic dialects and other languages that existed in, neighboured and/or colonized Libya. LA dialects substantially differ from MSA, other Arabic dialects, and each other. Today, speakers of Libyan Arabic speak their own variety of LA. Depending on the region, this can be TA, BA, FA or any of the sub-dialects (it is common to distinguish Bedouin from sedentary sub-dialects (see Pereira, 2011), though these dialects are not considered proper for official occasions. They are also exposed to, and can use, MSA. CA is also used by religious leaders and Imams.

1.3.2 The language variety under investigation

In order to control for any dialectal variation, this study focuses mainly on TLA as it tends to be spoken by sedentary Libyans born and raised in the main cities in the Tripolitanian region. The subject employed in the articulatory study is from the capital Tripoli where he was born and lived until he obtained his first degree. The subjects employed in the acoustic study are from Gharian, a city in the region of Tripolitania, 80 km south west of Tripoli (see map in Figure 1.3). Gharian is the largest city in the Nafusa Mountain (Al-jabel Al-gharbi), one of the highest mountains in Libya, with a population of about 300,000 people. This is the author's dialect. Therefore, the investigation will benefit from a native speaker intuition. This is an urban dialect which is very similar to the one spoken in the capital Tripoli and others found in the same region (Tripolitania), which makes it possible for the results of the current study to be representative of the wider region of Tripolitania and consequently of interest to a wider audience.

A considerable number of people from other cities of the region live in Gharian. Moreover, a large number of people from Gharian city commute to the capital Tripoli for different purposes such as studying and working. Additionally, TLA is the dominant dialect on TV shows and radio programmes in Libya. This interaction of the dialects of the Tripolitanian region which has been going on for decades results in the fact that the accent of the Gharian speakers can be considered as representative of the wider region. This is of advantage for the generalizability of the findings of this study.

1.4 Previous studies on LA

A number of studies have been conducted that deal with Libyan Arabic. Non-native authors carried out the earliest research into languages in Libya. These include Panetta (1943) *L'arabo Parlato a Bengasi* 'The Arabic spoken in Bengazi'. This is a collection of texts with the aim of introducing the dialect spoken in Bengazi to the Italian colonizers. In the 1950s and 1960s, research on the dialect spoken in Berga (Cyrenaica) was carried by Mitchell (1952; 1957; 1960).

In the late 1970s, native LA researchers started to investigate the grammar, phonetics and phonology of the language. Elfitoury's (1976) doctoral thesis adopts a structural approach to describe the grammar of the dialect spoken in Tripoli. Swed's (1977) dissertation, based on the framework of generative linguistics, sheds light on the development of the Arabic verb in three Arabic dialects: Tripoli dialect (Libya), Cairene dialect (Egypt) and Baghdadi dialect (Iraq). Using a similar framework, Aurayieth's (1982) doctoral dissertation investigates the phonology of the verb focusing on Eastern Libyan Arabic. Laradi's thesis (1983) investigates the phenomenon of pharyngealization in Tripoli dialect.

Owens' book (1984) *A short reference grammar of Eastern Libyan Arabic* is a general non-technical introduction to Eastern Libyan Arabic, using basic data and informal terminology to present the phonology, morphology and syntax of the dialect spoken in Bengazi.

Abumdas (1985) and Elgadi (1986) employed a generative approach to provide a synchronic analysis of the phonology and morphology of LA as spoken in Zliten and Tripoli respectively. Harrama's (1993) thesis is an electic synchronic analysis of the morphology of the LA dialect spoken in Al-Jabal Al-Gharbi. Al-Ageli's study (1996) deals with the syllabic and metrical structure in the dialect of Tripoli in light of Optimality Theory.

Recent studies on LA employed experimental phonetic techniques to investigate the language. These include the work of Ahmed (2008) which investigates the production and perception of LA vowels. Ahmed's thesis provide an acoustic and articulatory description of the LA vowel system and compares between the phonetic features of LA vowels and those of other Arabic dialects. Kriba's thesis (2010) focuses on pharyngealization in LA using locus equations to investigate the distinction between plain and emphatic consonants. Elramli (2012) adopts a constraint-based approach to investigate assimilation in the phonology of LA as spoken in Misrata. Maitiq (2013) investigates the magnitude of anticipatory pharyngealization in LA. Shitaw (2014) investigated the articulatory timing and the timing of voicing of single stops and two-stop consonant clusters in TLA. Finally, Gummed (2015) provided an acoustic and articulatory analysis of consonant sequences across word boundaries in TLA.

This review of the literature on the studies that were mainly concerned with LA show that these studies were mainly doctoral theses conducted by Libyan students. It should be highlighted here that most of the studies concerned are of the comparative type, comparing the dialect to other languages, mainly English, for pedagogical purposes. This involves outlining the difficulties that Libyan learners face when learning English. Other studies are highly theoretical, dealing with LA dialects using the generative theory framework. Moreover, the small number of studies reported on LA are mainly based on auditory analysis of the dialect. Therefore, considerable disagreement is found among these researchers about some of the sounds used and their characteristics. Recent work on LA shows the employment of experimental phonetic techniques to investigate the language. To date, geminate consonants in LA have not been investigated either phonetically or phonologically for any of the Libyan dialects.

1.5 Basic description of TLA

References to TLA are few in the literature. Therefore, as a native speaker of TLA, I am using my intuition and linguistic knowledge to describe the linguistic features (which are relevant to this study) of geminate consonants in this regional dialect. For discussion on the reliability of using intuition as linguistic data by native speakers of non-standard dialects, see Henry (2005).

Before proceeding with the overview of the topic and the relevant literature on the subject, a brief overview of the Libyan Arabic variety spoken in the region of Tripolitania, with its phonetic inventory, will provide necessary background for the discussion that will follow.

1.5.1 Consonants

The consonantal inventory of TLA is almost the same as that of MSA with some additions and/or modifications. A full phonetic inventory is shown in Table (1.1).

	Bilabial	Labio-dental	Dental	Dental-alveolar	Alveolar	Post-alveolar	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosives	b			t d tˤ dˤ				k g	q		ʔ
Nasals	m			n							
Rhotics					r						
Fricatives		f (v)	(θ) (ð) (ðˤ)	s z sˤ		ʃ ʒ			χ ʁ	ħ ʕ	h
Approximants	w (labial-velar)						j				
Lateral approximants				l							

Table 1.1: TLA consonant inventory.

Although TLA speakers use /v/, it occurs in loan words only. /θ/, /ð/ and /ðˁ/ are restricted to MSA and CA lexical items and some Bedouin sub-dialects spoken in Libya. Words containing these sounds in MSA are produced with [t], [d] and [dˁ] respectively in TLA. /q/ is found to MSA and CA lexical items used in the dialect such as [quɾʔaːn] 'Qur'an' and [qaɾaːɾ] 'decision'. Many other lexical items containing /q/ in MSA are produced with /g/ in TLA. /g/ is restricted to LA and CA, but not MSA. The rest of the consonants exist in both LA and MSA.

The consonant inventory of TLA includes a number of emphatic coronals that are phonemically distinct from their 'plain' counterparts. The term emphatic refers to a secondary posterior constriction of the velopharyngeal region of the vocal tract, which is absent in the plain counterpart. This effect gives an auditory impression of darkness or heaviness that is called in Arabic linguistic tradition *tafxīm with istiʕlaa* 'intensification' (see e.g Al-Nwisri, 2000).

In addition to the primary emphatic consonants /tˁ/, /dˁ/ and /sˁ/, TLA has two secondary emphatics: [lˁ] and [rˁ]. The set of primary emphatic consonants is uncontroversial, because of the existence of various lexical items attesting its underlying status and its lexical distinctive function. [lˁ] and [rˁ], on the other hand, are not fundamentally emphatics and the emphatic version is only an allophonic variant of the sound. The /r/ being emphatic is conditioned by the context in which this sound occurs. For example, this sound loses its emphasis when preceded by the high long vowel /i:/ or the mid long vowel /e:/. The emphatic form of the /l/ in TLA appear in the name of 'Allah' [ʔalˁ:a:h] 'God' when preceded by /a/ or /u/, however, the non-emphatic form of the sound is used when it is preceded by /i/ as in [bil:a:h] '(I swear) by Allah'. The same applies to both CA and MSA, where this does not apply to any another word in the language. This condition was mentioned in early Arab and Muslim linguistic books on reciting the Holy Qur'an (see e.g Al-Nwisri, 2000). /z/, also, can have an emphatic version in TLA when it is contiguous to /tˁ/ and/or back vowels, as in [zˁmɑtˁ] 'he swallowed' and [zˁoːzˁ] 'two'. Interestingly, this propagation of the emphatic feature that affects the alveolar fricative /z/ has not been reported in CA or MSA.

This phenomenon is commonly referred to as ‘emphasis spread’ in work on Arabic (see e.g. Maiteq, 2013).

1.5.2 Vowels

In addition to the three short vowels /i/, /a/, or /u/ and their corresponding long ones /i:/, /a:/, or /u:/ that constitute the vowel inventory in MSA, there are other vowels that are only found in TLA (and some other Arabic dialects). These are the short and long low back vowels /ɑ/ and /ɑ:/, the long mid front vowel /e:/ and the long mid back vowel /o:/. The ten TLA vowels are illustrated in Table (1.2).

<table>
<tr><td></td><td>Front</td><td>Central</td><td>Back</td></tr>
<tr><td>High</td><td>/i/ /i:/</td><td></td><td>/u/ /u:/</td></tr>
<tr><td>Mid</td><td>/e:/</td><td></td><td>/o:/</td></tr>
<tr><td>Low</td><td colspan="2">/a/ /a:/</td><td>/ɑ/ /ɑ:/</td></tr>
</table>

Table 1.2: TLA Vowels[2]

/ɑ/ and /ɑ:/ are considered as allophonic variations of (in complementary distribution with) /a/ and /a:/ in MSA, where they are restricted to emphatic consonant environments as in [ta:b] 'he repented' and [tˤɑ:b] 'it was cooked'. However, the two realizations show phonemic distinction in TLA as in: [da:r] ‘he did’ [dɑ:r] ‘room’. [a] and [a:] are in free variation with [æ] and [æ:] respectively in TLA.

All TLA vowels show length contrast except for /e:/ and /o:/. The corresponding vowels for these two long mid vowels in CA and MSA are originally the diphthongs /ai/ and /au/ respectively. Many Arabic dialects nowadays have

[2] Some of these LA vowels may have allophonic variation in some environments, but it is beyond the scope of this thesis to address this issue in depth.

monophthongal realizations for these two diphthongs instead (see e.g. Youssef, 2013). Consider the examples in (1).

(1)	**MSA**	**TLA**	**Gloss**
	/bait/	/be:t/	house
	/bain/	/be:n/	between
	/laun/	/lo:n/	colour
	/kaun/	/ko:n/	universe

1.6 Gemination in TLA

Although many phonetic and phonological aspects of Arabic dialects have been investigated by researchers (e.g. Watson, 2002), little attention has been given to the investigation of the phonetics and phonology of Libyan Arabic dialects. As a result, I have relied on my own linguistic knowledge as a native speaker of TLA.

All consonant phonemes in TLA (Table 1.1) have geminate counterparts which can occur both word-medially and word-finally with the exception of the glottal stop /ʔ/ 'hamza' which can only be geminated word-medially. The same applies for the consonant phonemes in MSA, where any Arabic consonant can occur as a geminate in word-medial or word-final position, and the glottal stop /ʔ/ represents the only exception in that it can be geminated only word medially (see e.g. Al-Rajihi 1984). Geminate consonants in the Arabic writing system are presented with one letter only, and a diacritic, called '*ʃadda*' (ّ), is placed over it. This sign is an un-looped Arabic ʃ-sound derived from the word /ʃad:a/ 'catch firmly'. This sign is important to avoid confusion with corresponding words having single consonants since geminate and singleton consonants are contrastive in Arabic (see e.g. Nasr, 1960). Like MSA, contrasts between single forms and geminate forms are phonemic in TLA. Compare the examples in Table 1.3.

As mentioned in section 1.5.2 above, vowel length is also phonemic in TLA. Both short and long vowels can occur before geminate consonants in TLA. In fact, any of the ten vowels can precede or follow geminates in TLA. The vowel element that precedes or follows the geminate in MSA can be any of the three short vowels /i/, /a/, or /u/ or their corresponding long ones /i:/, /a:/, or /u:/.

Singletons		Geminates	
/ba:lah/	'his mood'	/ba:l:ah/	'he made it wet'
/fara:ʃa/	'butterfly'	/far:a:ʃa/	'stallholders'
/sama:ka/	'thickness'	/sam:a:ka/	'fishermen'
/xama:t/	'raw materials'	/xam:a:t/	'spoiled (food)'

Table 1.3: Examples illustrating contrastive geminate and singleton consonants in word-medial position in TLA.

Geminate consonants in TLA as well as in MSA are contrastive. There are mono-morphemic words that contrast single and geminate consonants, as in [sa:rah] 'female's name' vs. [sa:r:ah] 'pleasing' and [fala:ħ] 'success' vs. [fal:a:ħ] 'farmer'. The semantic meaning of these lexically contrastive forms is not connected and not necessarily related to a single trilateral root abstract meaning. In addition, gemination can also be associated with a number of morphological contexts. Along with cases of morphologically conditioned gemination, there are cases of phonologically conditioned gemination. The target of morphological and phonological gemination differ: morphologically conditioned gemination involves geminating the medial consonant of a trilateral root, whereas phonologically conditioned gemination involves geminating the final consonant of the root.

Morphologically conditioned geminates occurs in both the verbal and nominal morphology. That is, gemination can arise due to morphological gemination processes such as formation of causative verbs and of instrumental nouns as in [ktab] 'wrote' → [kattib] 'cause to write' and [ʕaṣir] 'to squeeze' → [ʕaṣ:ara] '*squeezer*' respectively. These forms can also be found in MSA. This geminate occurs medially in the trilateral root in the case of both nominal and verbal morphology.

There is another form of word-medial intervocalic morphologically derived geminates in TLA that can be found in diminutive nouns that denote smallness or endearment/affection, as in: [xa:lid] ‘Khalid [male name]’ → [xal:u:d] or [xlu:da] and [amal] ‘Amel [female name]’ → [am:u:la]. These diminutive derived forms are also common in other Arabic dialects (see e.g Al-Mashabqa, 2015). Another case of medial gemination, also morphologically conditioned, occur in the broken plural of some nouns as in [tˤa:lib] ‘student’ → [tˤul:a:b] ‘students’ and the nouns of profession as in [xab:a:z] ‘*baker*’. Unlike the lexically non-derived contrastive forms in LA (and MSA), the morphologically derived geminates are usually semantically related to the non-geminate forms.

Phonologically conditioned gemination, on the other hand, can arise due to the concatenation of identical consonants and from certain assimilations as in /sir#ra:mi/ [sir:a:mi] ‘the secret of Rami’ and /qul#rab:i/ ‘say my God’ → [qur:ab:i] respectively (see section 1.7 below for more discussion).

1.7 Geminate types in TLA

Consonant gemination in Libyan Arabic is very frequent and plays an important role in the grammar of the language. LA has lexical contrastive singleton and geminate consonants in all positions. In addition, it has two types of post-lexical phonologically derived geminates: concatenated geminates and assimilated geminates.

1.7.1 True geminates

A true geminate is “an inherent part of a morpheme” (Spencer, 1996:25). In TLA, true geminates occur word-medially in intervocalic position forming a basic part of the internal structure of the word. This type of gemination, which is the one usually referred to when talking about geminate consonants in Arabic, functions to distinguish one word from another, and contrasts can be made between the geminate consonants and their corresponding single ones. Consider the examples in Table 1.3 above for true geminates in TLA.

As in many other languages, true geminates in Arabic show two aspects of 'integrity': first, they prevent insertion of intervening segments (epenthesis); second, they "escape rules whose application would modify one half of the geminate while leaving the other unchanged" (Kenstowicz, 1994:410). In the literature, these two features that characterize the behaviour of geminates are called 'inseparability' and 'inalterability' respectively.

1.7.2 Fake geminates

Fake geminates occur across a morpheme boundary. That is, a fake geminate is formed by combining two morphemes/words (see e.g. Ladefoged and Maddieson, 1996 and Gussmann, 2002) so that two identical segments happen to be next to each other, i.e. concatenated. As in true geminates, this type occurs in intervocalic position in Arabic as in /man#nuriid/ [man:uri:d] 'those who we want' and /sir#ra:mi/ [sir:a:mi] 'the secret of Rami'. This type of geminate is found in both TLA and MSA in the same environment/context.

1.7.3 Assimilatory geminates

In TLA, as well as in MSA, in certain phonological contexts, gemination is considered a natural outcome of assimilation (see e.g. Ghalib, 1984). This very often applies to the /l/ of the definite article in Arabic /ʔal/ (which is normally prefixed to nouns) when one of the coronal consonants /t, tˤ, d, dˤ, ð, ðˤ, s, sˤ, z, θ, ʃ, n, l, r/ follows it. The /l/ is assimilated to the subsequent consonant, which is in turn pronounced as a geminate as in [tamr] 'dates' → [ʔat:amr] 'the dates'. Interestingly, the alveolar lateral /l/ will not assimilate to these sounds outside the definite article context, with the exception of /r/. This behaviour suggests that this geminate may not be an assimilatory one since it is conditioned by morphosyntactic context. Heselwood and Watson (2015) argue that this is a true geminate, not assimilatory. However, their argument may be questionable as these are not lexically contrastive geminates as in the case of true geminates. In addition, this geminate does not form an inherent part of the morpheme or a basic part of the internal structure of the word.

The other context in which assimilatory geminates often occur in TLA, as well as in MSA, is across word boundary where the final consonant of one word is assimilated to the initial consonant of the following word resulting in one geminate consonant (see e.g. Bakalla, 1983), as in /min#man/ ‘from whom’ → [mim:an] and /qul#rab:i/ ‘say my God’ → [qur:ab:i]. It worth noting here, that there is an incomplete paradigm with /n/; unlike /qul#rab:i/ where the /l/ assimilates to the following /r/, /qul#nabi/ ‘say prophet’ does not show assimilation. In /man#laki/ ‘who is yours’ → [mal:aki], on the other hand, the /n/ assimilates to the following /l/. It is obvious that these examples show regressive assimilation (i.e. the final consonant of the first word is assimilated to the first consonant of the second word), which is more frequent in Arabic than progressive assimilation (i.e. the first sound affects the second one) (Ghalib, 1984). This type of geminate is found in both TLA and MSA in the same contexts

1.7.4 Word-initial geminates

As indicated in section 1.7.3 above, the /l/ of the definite article in Arabic [ʔal] is assimilated to the following coronal consonant, which is in turn pronounced as a geminate as in [tamr] ‘dates’ → [ʔat:amr] ‘the dates’. In TLA, however, the glottal stop of the definite article [ʔil] (together with the following vowel) is omitted, sometimes, resulting in a prevocalic word-initial geminate. So, [tamr] ‘dates’ → [t:amr] ‘the dates’ or [tamr] ‘dates’ → [ʔit:amr] ‘the dates’. The two resulting forms are found within and across speakers.

The other form of initial geminates in TLA is found in forms like [n:a:di] ‘I call’ and [n:a:ʒi] ‘I am conversing’. The alveolar nasal stop of the prefix [n] ‘I (do)’ is happened to be next to the alveolar nasal at the beginning of the words [na:di] ‘call’ and [na:ʒi] ‘converse’ resulting in an initial geminate nasal. The MSA equivalents for the examples mentioned above are [ʔuna:di] and [ʔuna:ʒi] respectively with the prefix pronoun [ʔu] ‘I (do)’. These forms seem to be contrastive in TLA, where it is easy to find minimal contrastive pairs. Consider the examples in (2) below:

(2)	**Single**	**Gloss 1**	**Gloss 2**	**Geminate**	**Gloss**
	[na:di]	‘club’	‘call’	[n:a:di]	‘I call (for someone)
	[na:ʒi]	‘Nagi’(name)	‘converse’	[n:a:ʒi]	‘I am conversing’

When the TLA verb starts with a consonant other than the alveolar nasal [n], as in [ndar:is] ‘I teach’ and [nzaj:in] ‘I decorate’, the resulting forms do not have initial geminates. However, if the word that follows the prefix starts with the alveolar rhotic [r] or the alveolar lateral [l], the prefix [n] is assimilated to the following [r] or [l], resulting in an initial geminate, as in [r:ak:ib] ‘I assemble’ and [l:abis] ‘I dress (sb) up’.

1.7.5 Word-final geminates

Word-final geminates are found in the so-called ‘double verbs’ in Arabic. In TLA, only the geminate ‘derived’ form can be found, whereas MSA shows a well-known alternation between a ‘canonical’ form (such as [sanan] ‘he sharpened’) and a ‘derived’ form ([san:] ‘he sharpened’) with a final geminate (see e.g. Gafos, 2003 and Rose, 2000). This final geminate is derived when there are two identical consonant sounds that are the onsets of two adjacent syllables other than the initial within the same word according to the rule in (3).

(3) $$C\,V.\,C_i\,\underset{\varnothing}{\underset{|}{V}}\,C_i \longrightarrow CVC_i.C_i \text{ (or } CVC_{i:}\text{)}$$

The nucleus vowel of the second syllable is omitted to allow gemination to occur. However, this geminate segment can be degeminated by suffixation in MSA.

When the verbal suffix -t 'I', for example, is attached to the word [san:], the omitted vowel [a] recovers to degeminate the nasal consonant resulting in the word [sanant] ‘I sharpened’.

In TLA, however, these word-final geminates are not degeminated by suffixation. When the suffix -t 'I' is attached to the word [san:] in TLA, the long vowel /e:/ is inserted between the geminate consonant and the suffix resulting in the word [san:e:t] ‘I sharpened’. The /e:/ infix in the case of geminate verbs come before consonantal inflectional suffixes. This is also found in most modern Arabic dialects (see e.g. Gibson, 2009).

In addition to the word-final geminates that are found in the ‘double verbs’, in TLA, word-final geminates can be the result of a deletion process where disyllabic nouns and verbs in MSA change to monosyllabic words in TLA by omitting the nucleus vowel of the first syllable of the MSA word resulting in a monosyllabic word with initial consonant cluster and a final geminate. The final extrametrical consonant of the MSA form is geminated in TLA, and it is not extrametrical in TLA. For example, the MSA words [ħaʒar] ‘stone’ and [ħafar] ‘(he) dig’ are [ħʒar:] and [ħfar:] respectively in TLA according to the rule in (4). This kind of geminate seems to be non-contrastive in TLA. These word-final geminates that are the result of deletion cannot be found in MSA.

$$\text{(4)}\qquad C\underset{\substack{|\\ \varnothing}}{V}.\ CV.\ \langle C\rangle \quad\longrightarrow\quad CCVC\!:$$

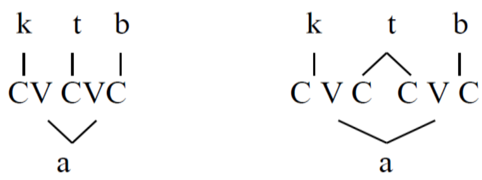
However, there are recent claims that word-final geminates can be contrastive in Arabic (see e.g Al-Tamimi, Abu-abbas, and Tarawnah, 2010). In TLA, word-final geminates seem to be contrastive when considering minimal pairs such as /ma:l/ ‘money’ vs. /ma:l:/ ‘(he is) bored’, /ʕa:m/ ‘year’ vs. /ʕa:m:/ ‘public’ and /ʃa:d/ ‘(he is) catching' vs. /ʃa:d:/ 'odd/abnormal'. The issue of whether word-final geminates are distinctive or not is beyond the scope of this study, however.

1.8 The phonological representation of geminates

In the first half of the twentieth century, there was a debate on whether geminate consonants should be analyzed as long segments or a series of two short identical segments (see Ghalib, 1984 and Ham, 2001 for more discussion on these positions). Moving on to early generative work, Chomsky and Halle (1968) propose the binary feature [±long] to distinguish singleton and geminate consonants. However, this proposal did not solve the debate. On the contrary, it reflects an ambiguity problem in that it allows for two possible characteristics of geminates, one as a single segment characterized by the feature [+long], and one as a sequence of two segments each characterized by the feature [-long]. The fact that geminates behave differently cross-linguistically (in that geminates show integrity in some languages such as Arabic where a geminate consonant cannot be split by epenthesis, whereas a consonant cluster may undergo this process, whereas in other languages such as Biblical Hebrew geminates and clusters pattern together) is dealt with in this proposal in terms of a rule which changes a single-segment representation of a geminate to a double-segment representation and vice versa. However, this rule seems to be inadequate in that "neither representation could be identified as basic, even within the same language" (Ham, 2001:8).

By extending the principles of autosegmental phonology, McCarthy (1982) makes an important contribution to eliminate the ambiguity problem. He divides discrete feature matrices into three distinct tiers: a consonantal root tier, a vowel melody tier, and a CV skeletal tier made up of timing slots. Under this analysis, a geminate consonant is represented as a single root node linked to two timing slots in the skeletal tier, whereas a singleton consonant is associated to the skeletal tier in a one-to-one relationship. An instance of this analysis is in (5). The fact that geminate consonants are doubly-linked to the skeleton represents that these segments are treated here as being single entities (root nodes) and complex structures (skeletal sequences).

(5)

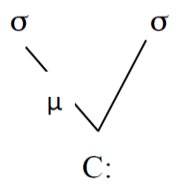


‘he wrote’ ‘he dictates’

Many subsequent modifications have been developed around the skeletal proposal such as adopting the C and V slots to differentiate between the functional positions within the syllable (Clements and Keyser 1983) and the replacement of C and V slots with Xs which represent neutral units on a timing tier (Leven, 1985, cited in Kenstowicz, 1994 and Ham, 2001). Nevertheless, Ham (2001) points out that since in McCarthy’s (1982) proposal root nodes are on the melodic tier, which are inherently characterized by the feature [±consonantal], replacing the C and V timing slots on the skeletal tier, the X-slot proposal is rendered redundant.

Another representation of the singleton-geminate contrast was provided by the advent of the moraic theory (see Hyman, 2003, for discussion on Hayes’s (1989) proposal on moraic theory, see Majdi and Winston, 1993, Al-Ageli, 1995, and Ewen and Van der Hulst, 2001). Under this proposal, root nodes are directly linked to either syllables or moras, which are themselves units of the prosodic structure. According to this view, geminates are distinguished from singletons by their being moraic underlyingly (i.e. inherently weight-bearing consonants). Since moraic theory distinguishes between weight and syllable position on the one hand, and weight and length on the other, it explains why not all timing slots have equal prosodic status such that onset consonants never contribute to syllable weight or trigger compensatory lengthening. Such observations could only be accounted for in terms of conditioning in earlier C-V and X slot theories under which length is computed by counting the timing positions. Under moraic representation, a word-medial geminate consonant is shared between two syllables serving as both weight-bearing coda and weightless onset (i.e., the coda of the first syllable and the onset of the second) as in (6).

(6)



Singletons, on the other hand, are non-weight bearing units. However, they might be assigned weight by position.

1.9 The phonological representation of geminate types

As stated in sections 1.6 and 1.7 above, all geminate types can be found in TLA. These are true geminates, fake geminates, assimilatory geminates, word-initial geminates and word-final geminates. See Table 1.4 for examples of these geminate types in TLA. The phonological representations of these geminate types vary according to the underlying phonological status (and the surface behaviour) of each geminate. In LA, true geminates are lexical (underlying) contrastive. Fake and assimilatory geminates are post-lexical (derived) that can only appear on the surface level. Word-initial and word-final geminates can arguably have different statuses to true, fake and/or assimilatory geminates in that they can show characteristics of one or more of these types. However, they will not be considered in the current study for a number of reasons (see section 1.11). In this section, only the geminate types that are relevant to this study (true, fake and assimilatory) will be discussed as follows:

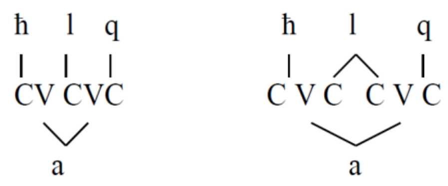
	Utterance	Gloss	Phonological Status
	[liri:ma]	‘for Rima’	Singleton
	/bir:i:ma]	‘valve’	True geminate
/sir#ri:ma/ →	[sir:i:ma]	‘the secret of Rima’	Fake geminate
/min#ri:ma/ →	[miri:ma]	‘who is Rima’	Assimilatory G. [n→r]
	[bar:]	‘wild life’	Word-final geminate
	[r:a:ʒi]	‘I am waiting’	Word-initial geminate

Table 1.4: Examples illustrating the singleton and the different geminate types in Libyan Arabic.

1.9.1 True geminates

As indicated in section 1.7.1, true geminates form an inherent part of a morpheme and function to distinguish one word from another. They occur word-medially in an intervocalic position. Under the CV proposal, a true geminate is represented as a single root node linked to two timing slots in the skeletal tier, whereas a singleton consonant is associated to the skeletal tier in a one-to-one relationship. Consider the example in (7). The fact that the geminate consonant [l:] is doubly-linked to the skeleton represents that this segment is treated as being a single entity.

(7)



‘he shaved’ ‘he flew’

Within moraic theory, a word-medial true geminate consonant is shared between two syllables serving as both a weight-bearing coda and a weightless onset. Consider the example in (8) for a pair of words that are differentiated on the grounds that one contains a medial geminate consonant and the other contains its singleton counterpart. It is clear that the singleton consonant is a non-weight bearing unit.

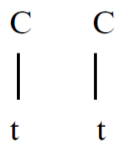
(8)

‘(he) shaved’ ‘(he) flew’

1.9.2 Fake geminates

As explained earlier (see section 1.7.2), fake geminates occur across a morpheme boundary, so that two identical consonant segments happen to be next to each other in an intervocalic position. These fake geminates are non-contrastive in Arabic. It is assumed (see Ham, 2001:106, Spencer, 1996:79, and Gussmann, 2002:27) that such pseudo-long consonants should be represented as a sequence of two identical segments each linked to its own timing slot under the CV frame, as in (9).

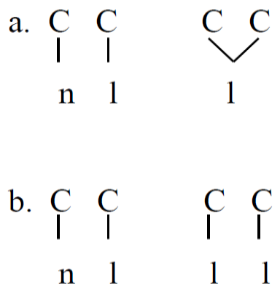
(9)



1.9.3 Assimilatory Geminates

Assimilatory geminates are the result of assimilation process where the final consonant of the first word is assimilated to the initial consonant of the following one (see section 1.7.3 above). This means that this geminate type occurs in an intervocalic position (in Arabic) across a morpheme or word boundary. Hayes (1986:409) (cited in Ham, 2001 and Majdi and Winston, 1993) points out that geminates that are the output of total assimilation can be represented in two ways, as a ‘true geminate’ (10a) or ‘fake geminate’ (10b), depending on two possible diagnostics. The first of these is whether or not these assimilatory geminates can be split by epenthesis (i.e. whether they show integrity effects, see section 1.7.1 above), and the second is whether or not one half of this type of geminate is subject to phonological processes that can affect singleton consonants in the same environment (i.e. whether they show inalterability effects, see section 1.7.1 above). Relying on my linguistic knowledge, and as a native speaker of Arabic, I would say that assimilatory geminates form a tight bond that resists disruption by both epenthesis and phonological rules.

(10)



1.10 Experimental studies on Arabic gemination

The review of the experimental studies in the literature will be based primarily on studies conducted on Arabic language (in general) due to the shortage of studies on TLA (see section 1.4), and, also, due to the fact that the different Arabic dialects share some features with each other, considering their common origin and taking into account the fact that the same standard variety is used officially in all of the countries from where these dialects come. Additional published data on other geminating languages will also be discussed at various crucial junctures.

Obrecht (1965) conducted three experiments employing synthetic stimuli to investigate duration as a cue factor in discriminating singleton and geminate consonants in Arabic using minimal pairs that contain three phonetic categories: ‘stops’, /b/ versus /b:/, ‘nasals’, /n/ versus /n:/ and ‘spirants’ /s/ versus /s:/. Stops and nasal contrasts are used in word-medial position, whereas spirant contrasts are used in word initial position. All the geminate consonants in the stimuli were true geminates. The subjects who participated in this study were native Arab speakers from different Arab countries. The perceptual boundary between both [b] and [b:] and [s] and [s:] was between 140 and 160 ms, while for the [n] to [n:] continuum, the boundary lay between 90 and 110 ms.

In his acoustical and physiological study, Al-Ani (1970) investigated Standard Arabic as used in Iraq relying on spectrographic analysis and x-ray films. Unfortunately, a number of methodological problems as well as the inconsistency in the terminology weigh down Al-Ani’s (1979) study, and make it difficult to interpret his results. Apparently, the data consists of exclusively words (or syllables) produced in isolation. Additionally, the length of tokens is undetermined. To show the geminate and singleton contrast in Arabic, only four words arranged in two minimal pairs have been reported in this study. Al-Ani (1979) reports that word-medial geminate nasals are found to have the duration of 275-330 ms, while their singleton counterparts are found to have the duration of 110-140 ms. He reports that the duration of /n/ is longer than that of /m/ in both contexts. However, the duration of each particular nasal is not provided. He reports that the duration of the medial singleton trill is found to be 40-50 ms. No information was provided for a geminate trill in this study, however. The duration of the word-medial singleton /l/ is found to be 60-75 ms in his study, whereas its geminate counterpart showed the duration of 300-375 ms. He further reports that the duration of short vowels (when they are not produced in isolation) is from 100-150 ms, whereas the duration of long vowels is from 225-350 ms. No information is provided about the context in which the measured vowels occur.

In his investigation of the significance of gemination in Iraqi Arabic, Ghalib (1984) conducts a series of experimental studies (acoustic, perceptual, aerodynamic and articulatory). He investigates the differences between singleton and geminate consonants that occur initially (in a prevocalic position) and medially (in an intervocalic position) in words pronounced in isolation and in words pronounced in a carrier sentence. The stimuli were almost the same in all of his studies. The words used in these studies were all bisyllabic and the target singleton and geminate consonants were the voiceless fricative /s/ and the voiced stop /d/. All the intervocalic geminate consonants used in this study are true geminates. However, the initial geminates in this study were assimilatory geminates that are the output of assimilating the alveolar lateral [l] of the definite article [ʔal] to the initial consonant of the following word. Although Ghalib (1984) indicates in his survey on gemination in Arabic linguistics that geminates can be the result of an assimilation process in Arabic, he did not mention whether the assimilatory status of these geminates in his stimuli has any effect on the results obtained or whether their acoustic, perceptual, articulatory or aerodynamic characteristics are different from those of true geminates.

Generally, the results of Ghalib's (1984) acoustic study shows that geminate consonants are significantly longer than their singleton counterparts (both word-initially and word-medially) whether they are spoken in isolation or in a carrier sentence. The results of his perceptual investigation of phoneme boundary between the singleton and geminate consonants in word-medial position confirmed the findings of the acoustic experiment. Using two synthetic speech experiments, he found "a perceptual salience of differences in duration between single and geminate consonants" Ghalib (1984:296). The results of his two palatographic studies (using both Direct palatograph and Electropalatograph (EPG)) suggest that the production of a geminate consonant is accompanied by firmer lingual-palatal contact than that of a singleton consonant, with the area of contact for geminate consonants being considerably greater than that for singleton consonants. Also, the results show a different build-up in the contacts between singletons and geminates. Ghalib (1984) argues that this 'firmer contact' between the articulatory organs is a reflection of the longer duration of geminates which, he argues, are consequently associated with greater mechanical pressure. He found that the production of geminate consonants in Iraqi Arabic does not involve a rearticulation of the same consonant. But, rather, it is produced as one long individual consonant. His aerodynamic study reveals that geminates are generally accompanied by higher intraoral pressure (Po) than their singleton counterparts. Also, the results show significant differences in the oral airflow (Uo) and in minimum cross-sectional area (Ac min.) between geminate and singleton consonants in both fast and slow speech rates. These results are considered by him to be suggestive of a higher articulatory effort for geminate consonants. This conclusion is consistent with the description of geminate consonants as ‘strong’ or ‘tense’ by some researchers (see e.g. Ridouane, 2010). In general, Ghalib (1984:531) concludes that duration is “a major factor in the linguistic functioning of gemination”.

Ham (2001) investigates the timing properties of geminate consonants using stops in four languages; Bernese, Levantine Arabic, Hungarian and Madurese, so as to answer the question of whether the phonological representation of geminates need be uniform across word position and across languages. The word list for Levantine Arabic contains word-medial intervocalic (singleton and geminate) (voiced and voiceless) stop consonants and word-final post-vocalic (singleton and geminate) (voiced and voiceless) stop consonants. All word-medial geminate and singleton stops occur in disyllabic words whereas those words that contain final geminates were monosyllabic. All the geminates in word medial position were true geminates. The results show that the closure phase of geminate stops is about 90% longer than that in singleton consonants both word medially and word finally.

Al-Tamimi (2004) carried out a spectrographic investigation of the temporal relation between the singleton and geminate sonorants /m, n, l/ in an intervocalic position in Jordanian Arabic. Twelve minimal or near-minimal pairs were used in this study. However, the list contains two meaningless words. In addition, the geminate consonant of one of the words in the list was the result of a regressive assimilation (that is, assimilatory geminate). The results of this study confirm previous findings that geminate consonants in Arabic are significantly longer than their singleton counterparts, with the mean duration of the geminate [n] ranging from 143-168 ms, the geminate [m] ranging from 153-177 ms and the geminate [l] ranging from 157-178 ms. The durations of the singleton counterparts of these consonants were from 47-61 ms for [n], 62-77 for [m], and 56-95 ms for [l] depending on whether these consonants (both geminates and singletons) are preceded by short or long vowels respectively.

In her acoustic and auditory analysis of medial geminate and singleton consonants in read and spontaneous speech in Lebanese Arabic, Khattab (2007) reports that the duration of geminate consonants (stops, nasals and liquids) in read speech are, generally, comparable to what has been found for Jordanian Arabic. However, “the duration of geminate consonants in spontaneous speech are closer to those of the singleton targets in the word lists” (Khattab, 2007:156). The durational results of Khattab (2007), along with the results of Al-Tamimi’s (2004) acoustic investigation, indicates that the five-time difference between singleton and geminate liquids reported by Al-Ani (1970) seem to be artificially large. In another study on Lebanese Arabic, Khattab and Al-Tamimi (2008) use fricatives, nasals, liquids and approximants to investigate the temporal relations between singleton and geminate consonants for each of the consonant categories separately. The results show that the shortest singleton consonants are taps followed by laterals, nasal, approximants and then fricatives. In the geminate context, the order is more or less the same. All the words used to investigate gemination in Lebanese contain true geminates.

Al-Tamimi, Abu-Abbas and Tarawnah (2010) carried out an experimental study to investigate word-final geminates in Jordanian Arabic using tokens with final singleton and geminate /m, n, d/. The acoustic results show that the ratio of singleton to geminate duration is 1:1.5 in favour of the geminate consonant. The videofluoroscopic results reveal that final geminates in Jordanian Arabic are “produced with a combination of articulatory gestures that makes them more tense when compared to singletons” (Al-Tamimi, Abu-Abbas and Tarawnah, 2010:118). They argue that the tension in articulating the geminates “enhances perceptuality boundaries and maintains phonemicity” (Al-Tamimi, Abu-Abbas and Tarawnah, 2010:111). Their spectrographic and videofluoroscopic analysis reveal that final geminates are permissible in Jordanian Arabic. They argue that the distinctiveness of word-final geminates is associated with temporal compensation of the preceding vowels and the muscular tension accompanying their production.

Additionally, the relation between word-medial singleton and geminate consonants and the preceding vowels have served as the focus of a number of experimental investigations as well. “The prolongation of the consonant is thought to involve an unconscious process of correlation between the presence of gemination and the vowel that precedes it” (Al-Tamimi, 2004:39). This process serves to maintain the rhythmic structure of a word by balancing the durational change of some phonetic segments in that an intervocalic consonant borrows duration from the preceding vowel so as to enhance the perceptual contrasts between the geminate and singleton consonants. However, the strategy of this “temporal compensation” is a disputed issue and researchers seem at variance whether the type of the following consonant (singleton vs. geminate) essentially influences the duration of vowels (for more discussion on the different views on temporal compensation see Ghalib, 1984 and Al-Tamimi, 2004).

Al-Tamimi’s (2004) study on Jordanian Arabic reveals that there is a strong correlation between the duration of the vowel and the following single/geminate consonant. He states that this correlation is not affected by the place or manner of articulation of the consonant. The mean duration of vowels before single consonants is longer than it is before geminate consonants. Al-Tamimi, Abu-Abbas and Tarawnah (2010) also found evidence of temporal compensation with the preceding vowel in Jordanian Arabic. In another study on Jordanian Arabic, Al-Mashaqba (2015) reported that geminate consonants have influence on the adjacent vowels. He found that the vowels preceding and following geminates are shorter than their counterparts neighbouring singletons. These findings contrast with the findings for Iraqi Arabic obtained by Ghalib’s (1984) study, which shows that vowels preceding single consonants are not significantly different from those preceding geminates. In another study on Iraqi Arabic, Hassan (2003), no evidence was found in support of temporal compensation. The durational differences in this study have been found negligible and phonologically redundant. Additionally, Khattab and Al-Tamimi (2008) find no evidence for temporal compensation between medial consonants and preceding vowels in Lebanese Arabic. Instead, their findings suggest that there is a type of temporal compensation which is “related to the manner of articulation and is independent of the phonological length of the medial consonant or its preceding vowel" Khattab and Al-Tamimi (2008:8). However, the results of Khattab's (2007) study indicate that medial consonants and preceding vowels show proportional rather than absolute temporal compensation. In another study on Lebanese Arabic, Khattab and Al-Tamimi (2014), found evidence of absolute temporal compensation in the case of preceding long vowels.

While traditionally the emphasis has mainly been on durational cues to geminates, some studies have suggested that other non-temporal characteristics contribute to the singleton-geminate distinction and sought evidence of other acoustic correlates of gemination. For example, Ghalib (1984) found a flatter shape of the tongue in geminate articulation. Local and Simpson (1988) found evidence for palatalized configuration for geminate sonorants in Malayalam that is not present in their singleton counterparts. In another study on Malayalam, Local and Simpson (1999) found differences in the quality of the sonorant geminates as opposed to their singleton counterparts, while geminates appear to affect the duration and quality of preceding segments as well. Payne (2005) also found that geminate laterals, in Italian, are produced with palatalized configuration. In another study on Italian, Payne (2006) found evidence for apical contact for singletons as opposed to laminal contact for geminates, and a flatter shape of the tongue in geminate articulation. Ridouane (2007) found that the stops in Tashlhiyt Berber are more lenited in singleton contexts. He also found that the geminate stop release is produced with higher root mean square (RMS) amplitude than that of the singletons. Some researchers argue that some of these non-temporal cues are suggestive of a tense/lax distinction between singleton and geminate consonants alongside durational contrasts (see e.g Al-Tamimi and Khattab, 2011 and Ridouane, 2007). Although these non-temporal cues are found to be salient for some languages, the results of these studies are not consistent cross-linguistically. For instance, Arvaniti and Tserdanelis (2000) report evidence from several types of measurements that non-durational cues to gemination do not exist in Cypriot Greek. It will be interesting to investigate whether gemination in TLA is manifested by any non-temporal parameters.

Moreover, some studies showed that, in languages that allow word-initial voiceless geminate stops, even though the geminate contrast is neutralized perceptually and acoustically (in cases where no significant secondary cues to gemination exist), articulatorily, the distinction still holds in languages such as Tashlhiyt Berber (Ridouane, 2007) and Swiss German (Kraehenmann and Lahiri 2007, 2008). It is shown in these articulatory studies that word-initial geminates were systematically longer in their articulation than their singleton counterparts. Another finding of these studies was that stops were longer in phrase-initial position than in phrase-medial, which was interpreted as prosodic lengthening and strengthening in cases whereby it involved more linguopalatal contact. Payne (2006) also reported that gemination in Italian involved longer consonant duration as well as greater linguopalatal contact and the use of different regions of articulators. Based on these findings, Payne (2006) analysed gemination in Italian as a fortitional (i.e. strengthening) process. The concept of ‘articulatory strengthening’ at prosodic-domain edges was first introduced by Fougeron and Keating (1997). They considered this strengthening to mean more extreme articulation, that is, spatial variation. They have presented several possible mechanisms of domain initial strengthening. A number of subsequent studies have investigated domain-initial strengthening effects, in a number of languages, by examining differences in acoustic and articulatory properties of singleton consonants across different prosodic positions (see e.g. Keating, 2003; Cho and Keating, 2001; Onaka, 2003). Generally, the results of these studies support Fougeron and Keating’s (1997) proposal that articulatory strengthening involves temporal and spatial enhancement strategies, such as larger and/or longer gestures, which may be attributed to greater impact of the tongue against the hard palate in consonant formation. The results also reinforce their findings that linguopalatal contact is strongly related to consonant duration. While the fortitional strengthening characterising the geminate contrast observed by Payne (2006) can be considered a phonological process, the articulatory strengthening governed by prosodic factors (such as position in the word or phrase, stress and intonational focus) can be considered a phonetic process, which is expected to be operative across languages. Thus, lengthening and strengthening effects of the gemination contrast are expected to manifest acoustically and articulatorily in TLA also. These phonetic effects may interact with possible strengthening effects that may accompany the phonological contrast/status of singletons and the three geminate types.

While consonant gemination in Libyan Arabic is very frequent and plays an important role in the grammar of the language, to date, I have been unable to find studies that investigated the singleton-geminate contrast or the role played by the preceding vowel in this dialect. Moreover, as it is obvious from the literature, no previous study has investigated the acoustic or articulatory properties of the different geminate types in any of the Arabic dialects (or even in Standard Arabic). Previous studies on Arabic gemination have either focused on true (underlying) geminates or reported results on data that consists of more than one type of geminates without making explicit the phonological status behind these different types or investigating its effect on the phonetic output. It is interesting to investigate whether the different phonological status triggers any acoustic or articulatory consequences on the phonetic output.

Some studies (see Pycha, 2010 for Hungarian and Ridouane, 2010 for Tashlhyit Berber) have examined the phonetic correlates of different types of geminates and found that the type of a geminate can condition its phonetic correlates. Also, some studies (see Nolan 1992 and Local 2003) that have investigated assimilation patterns in English and other languages show that place assimilation patterns are not always complete, and leave subtle phonetic traces. It has been found that, for example, the /t/ of '*late calls*' usually does not become a /k/, but rather becomes a doubly articulated stop, with both a velar and an alveolar closure, which varies in its strength. These studies suggest that the phonological patterns/processes have phonetic correlates. This raises the question as to whether the phonological status of the geminate types in TLA has any phonetic correlates such as different duration patterns or different articulatory configurations.

Moreover, in the Arabic and Islamic tradition there is a distinction between underlying and surface geminates. As an expert Quranic Tajwīd teacher, the current author can easily infer these facts from the rules of Qur'anic Tajwīd, which is one of the most prominent sciences of the Qur'an (see section 1.3.1). These rules govern the parameters of sound production in reciting the Holy Qur'an (such as temper and duration, place and manner of articulation, rhythm and articulation of syllables). In Arabic Tajwīd tradition, the term *muḍa''af* /mudˤaʕʕaf/ 'doubled' or *mushaddad* 'strengthened' is used to refer to the lexical true geminates whereas the term *mudgham* [mudʁam] 'assimilated' is used to refer to the post-lexical fake and assimilatory geminates. The use of different terminology to refer to lexical and derived geminates reflects knowledge of different phonological status of these geminate types, and possible differences on the phonetic surface level. Moreover, *Idġām al-mithlain* 'assimilation of (two) identicals (sounds)' is the term used to refer to the process that produces fake geminates and *Idġām al-mutagaribain* 'assimilation of (two) similar (sounds)' is used to refer to the process that results in assimilatory geminates. This is a very clear and precise way of describing the nature of fake and assimilatory geminate types while at the same time grouping them under one cover term of assimilation or Idġām indicating probably that they behave similarly in some domains while making clear that they result from different processes. According to *Idġām* rules in Tajwīd (see e.g. Al-Jazari, 833H, Al-Ghūl, 2002, Surty, 2005 and Al-Nwisri, 2000) *Idġām al-mithlain,* which result in what is called fake gemination in this work, applies to all of Arabic consonants when they are concatenated across word boundaries. However, *Idġām al-mutagaribain,* which results in what is called assimilatory gemination in this work, applies to the alveolar nasal [n] when it is followed by certain sounds. The alveolar nasal [n] should assimilate to the following sound if it was /j/, /r/, /m/, /l/, /w/, or /n/ across-word boundary resulting in a geminate consonant. The assimilation should be without *Ghunna* [ʁun:a] 'nasalization' in the case of /l/ and /r/, but with *Ghunna* 'nasalisation' in the case of /j/. /m/, /w/, and /n/. It is clear that the distinction between true, fake and assimilatory geminates in Arabic language has been noticed and explained centuries ago. It is interesting to investigate whether these different phonological statuses of geminates trigger any acoustic or articulatory consequences on the phonetic level.

1.11 Aim of the thesis and expectations

Indeed, there is a dearth of phonetic and phonological studies on Libyan Arabic. The goal of the present thesis is to contribute as much as possible to the limited knowledge about the phonetics and phonology of Libyan Arabic geminate patterns by investigating their acoustic and articulatory correlates from the point of view of the relationship between phonology and phonetics using the approximant consonants /r, l, m, n/.

In this thesis, the four sonorant sounds /l, m, n, r/ were selected to investigate the phenomenon of gemination in TLA in particular, because all the types of geminates (to be investigated in this study) can be presented in this subset of consonants in a way that enables the researcher to find minimal/matching phrases for comparison purposes. That is, and as discussed in section 1.10, all consonant sounds in Arabic can show gemination of any type (see section 1.7 for geminate types in TLA) with the exception of *Idġām al-mutagaribain* or assimilatory geminates across word boundary which can only appear in this subset of sounds. Therefore, this subset of sounds have been chosen to enable accurate comparisons.

The geminate types that will be employed in this thesis are true geminates, fake geminates and assimilatory geminates. This subset of geminate types was chosen for the same reasons mentioned above and because they allow comparing singletons to both lexical and derived geminates (fake and assimilatory) in TLA. Initial and final geminates were excluded for a number of reasons. First, it is still controversial whether they are lexically contrastive or derived forms. Therefore, their phonological status is still not very clear and needs a separate in-depth investigation not only in the case of LA alone, but also in all other Arabic dialects as well as the standard form of the language, which is beyond the scope of this study. Second, although all geminate types can arguably occur in an intervocalic position (in connected speech for initial and final geminates), both fake and assimilatory geminates are phonologically derived and occur only across a word boundary, whereas initial and final geminates occur only across a morpheme boundary and are morpho-syntactically conditioned. Finally, although initial and final geminates have been discussed in the Arabic literature, they have not been included in or considered as part of *Idġām* rules. It will be useful to only consider geminate types that are uncontroversial and that allow for accurate comparisons of the phonological status and the contextual environment.

The aims of this study are twofold: (1) to investigate the phonetic correlates of the singleton-geminate contrast in Libyan Arabic; (2) to find out whether the phonological status of a geminate has any phonetic output, and whether these phonetic correlates are salient so that they impose the need for them to be present in the phonological representation.

Since fake and assimilatory are derived geminate forms, it is expected that they show phonetic realization that is distinct from true geminates. It is expected that they pattern together showing similarity in some of the phonetic correlates. However, and since they are the result of different phonological processes, they are expected to differ from each other as well. It is expected that assimilation in TLA is categorical and, therefore, obligatory in the language. This assumption is based on the expected influence of the Quranic language (in which assimilation is obligatory) on the Libyan dialects. Therefore, assimilatory geminate might show phonetic correlates that are similar to those of true geminates, but different from the fake ones.

Besides the purely phonetic correlates of the phonological status of a geminate, the results of this thesis are expected to have some implications regarding more general theoretical issues, such as the phonetic implications of the phonological representation of the different geminate types.

1.12 General Research Questions and Hypotheses

This thesis investigates the phenomena of gemination in Libyan Arabic. There are mainly two research questions (specific research questions and hypotheses for each study will be presented separately in the introduction of each one):

1. What are the phonetic correlates of the singleton-geminate contrast in TLA?

2. Does the phonological status of a geminate (true vs. fake vs. assimilatory) influence the phonetic output (acoustically and articulatory)? If yes, what are the theoretical implications of these different phonetic realizations?

In order to answer these questions, the following two general hypotheses have been suggested:

(H1) Geminate consonants in Libyan Arabic are acoustically and articulatorily different from their singleton counterparts

(H2) ‘True’, ‘fake’ and ‘assimilatory’ geminates are different in their acoustic and articulatory properties.

1.13 The contribution of the thesis

To the best of the present researcher’s knowledge, this study constitutes the first attempt to provide a phonetic and phonological account of gemination in TLA using experimental techniques, and combining acoustic and articulatory methods. The inclusion of two types of phonetic analysis methods will help to achieve a better understanding of the topic by giving complementary explanations of the phenomena and providing better understanding of all aspects of speech involved in gemination in this dialect.

The results of these analyses will be compared either to findings from other Arabic dialects (to find out the similarities and differences in gemination patterns among Arabic dialects) or to relative findings from other languages with geminates. The results of this study may be used by researchers who work on LA dialects, or those working on other Arabic varieties, for different purposes such as cross-dialectal and cross-linguistic comparisons. They also may contribute to the linguistic knowledge of gemination and can be used by researchers who are interested in the phenomenon of gemination in general.

Investigating the singleton-geminate contrast and the different geminate types is an important and interesting topic for many reasons. First, it will try to account for the acoustic and articulatory parameters of geminates from the point of view of the interaction between phonology and phonetics. This account will be based on data from TLA which is a typical geminating language in showing a two-way surface contrast in duration on the one hand, and in having different geminate types on the other hand. The other contribution is that no previous studies have investigated the singleton-geminate contrast in Libyan Arabic.

Furthermore, the thesis is intended to touch upon more general theoretical issues relating to phonetics and phonology, such as the syllabification and representation of the singleton and the three geminate types and the interaction between phonetics and phonology.

To that end, one acoustic and one articulatory study will be conducted to provide a thorough account of gemination in TLA. The structure of the thesis will be presented in the following section.

1.14 Outline of the thesis

The thesis consists of four chapters, two of which are experimental.

The first chapter will present a theoretical literature of the linguistic significance of geminates in Arabic with an overview of the geminate types in standard Arabic and TLA. In addition, it will provide an overview of the proposals for the phonological representation of geminates in the literature. It will also review previous work in Arabic geminates.

Chapter two investigates the acoustic temporal and non-temporal relations between the singleton and geminate sounds /l, m, n, r/ on the one hand, and the different geminate types (true, fake and assimilatory) on the other so as to investigate whether the different phonological status of these consonants have a phonetic output.

Chapter three will present the articulatory investigation of the singleton-geminate contrast and examines the articulatory differences between the three geminate types using electropalatography (EPG), with the aim of enhancing the evidence from the acoustic experiment and providing input on areas that cannot be measured acoustically.

Chapter four will summarize the findings of the two experimental studies and address their theoretical implications. Then, it will conclude the topic and provide suggestions for future research.

Chapter 2: Acoustic study

2.1 Introduction and purpose of the study

The focus of this chapter is to investigate the acoustic correlates of the singleton-geminate contrast and the three geminate types in TLA using sonorant consonants, and to compare the results with those of previous studies.

While, traditionally, durational cues to gemination have formed the main emphasis in investigating the singleton-geminate contrast and, generally, these studies in various languages have shown that duration is the most robust correlate of gemination (see Khattab and Al-Tamimi, 2008 and Arvaniti, 1999, among others), some studies have suggested that other correlates of geminates exist, and argued that these characteristics contribute to the perceptual effect of gemination. These include a palatalized configuration for geminate sonorants (Local and Simpson, 1988) and geminate laterals (Payne, 2005), more lenited stops in singleton contexts (Ridouane, 2007), higher root mean square (RMS) amplitude for geminate stop release (Ridouane, 2007), apical contact for singletons as opposed to laminal contact for geminates (Payne, 2006), a flatter shape of the tongue in geminate articulation (Payne, 2006 and Ghalib, 1984), and differences in the quality of the sonorant geminates as opposed to their singleton counterparts, while geminates appear to affect the duration and quality of preceding segments as well (Local and Simpson, 1999). The effect of gemination has also been found to extend to the surrounding vowels and sometimes across the whole word. For example, the vowels preceding singletons have been found to be longer and more centralized than those before geminate consonants (Local and Simpson, 1988 and

Al-Tamimi, 2004) and the vowels following geminates have been reported to show higher amplitude than those following singletons (Doty, Idemaru and Guion, 2007). Some researchers argue that some of these cues are suggestive of a tense/lax distinction between singleton and geminate consonants alongside durational contrasts (see e.g Al-Tamimi and Khattab, 2011 and Ridouane, 2007).

Although these non-temporal cues are found to be salient for some languages, the results of these studies are not consistent across languages. For instance, Arvaniti and Tserdanelis (2000) report evidence from several types of measurements that non-durational cues to gemination do not exist in Cypriot Greek.

A review of the literature reveals that these non-durational differences have not been previously examined for the three geminate types even in the languages where these correlates are found to be salient as mentioned above. This study contributes to the literature on gemination (and the literature on Arabic language) by providing a detailed examination of both the durational and non-durational acoustic correlates of the singleton-geminate contrast and the three geminate types using approximant sounds in TLA. There are few phonetic studies on Arabic gemination (see section 1.10 above). While most of these studies have focused on the durational cues of the singleton-geminate contrast, this study looks at a variety of non-durational correlates as well as durational ones.

In this acoustic study, durational and non-durational parameters of gemination will be investigated. These include the duration of the singletons and the three types of geminates, the durations of the preceding vowels, Root Mean Square (RMS) amplitude differences between the singleton-geminate contrast and between the three geminate types, and F1, F2 and F3 for the target consonants (at mid-point) (to test for the presence of gestural differences (i.e. palatalization effects) between geminates and non-geminates and between the three geminate types).

2.2 Research Questions and Hypotheses

This study investigates the acoustic (temporal and non-temporal) properties of the singleton and the three geminate types in TLA. The study addresses three research questions:

1. Do intervocalic geminates in TLA show the same significant durational differences from their singleton counterparts as those reported to exist in other Arabic varieties?
2. Are there acoustic correlates to gemination other than the duration of the geminate consonant itself?
3. Does the phonological status of a geminate (true vs. fake vs. assimilatory) influence the acoustic output?

On the basis of previous findings, the following hypotheses have been suggested:

(H1) Geminate consonants in TLA are significantly longer than their singleton counterparts.

(H2) There is a strong correlation between the duration of a geminate consonant and that of the preceding vowel in TLA. That is, geminate consonants in TLA shorten the preceding vowels.

(H3) The singleton-geminate contrast in TLA is enhanced by other acoustic (non-durational) parameters.

(H4) The different geminate types are different in their acoustic (durational and non- durational) properties.

2.3 Methodology

In this section, the methods and procedures of investigating the research questions are presented.

2.3.1 Design

2.3.1.1 Subjects

Dornyei (2007: 96) points out that "the strength of the conclusions we can draw from the results obtained from a selected small group depends on how accurately the particular sample represents the population". In this study, the acoustic properties of gemination in TLA will be investigated. Therefore, the subjects who are suitable for this study had to meet the following criteria:

1. Native speakers of TLA
2. Monolinguals during childhood
3. Parents do not speak languages other than Arabic
4. No history of speech or hearing difficulties
5. Do not know the aim of the research
6. All speak the same regional dialect

The subjects selected for this study meet these criteria. They were four native speakers of TLA, three males and one female. They ranged in age, at the time of recording, from 30 to 38 years and had no obvious speech or hearing defects. The subjects were from the city of Gharian, approximately 80 kilometers south of Tripoli. They had lived there almost all their lives, and had been educated there until they got their first degrees. They speak a typical TLA dialect. They were all postgraduate students who speak English as a second language and live in West Yorkshire during the time of recording. They have been in the UK for less than two years. Two of them started learning English by the age of 16; the other two started learning English in 2001 and 2009. English is the only foreign language that they speak. Their parents speak Arabic only. The subjects were not told the exact purpose of the research for which their recording would be used. They were told that the recordings will be used in a study on their Arabic regional dialect, however. At the time of recording they were studying in disciplines other than linguistics and phonetics (sport, mechanical engineering and food science), with the exception of the female subject who is studying linguistics at the University of Leeds. However, she was not told the purpose of the study until after recording.

The subjects signed a consent form and were ensured that their personal information remains confidential and that the data will be presented with complete anonymity. They were told that they could withdraw from participation in this project at any time and that they could decide not to allow me use the data. However, they agreed to take part in the recording and were happy for me to use the data.

2.3.1.2 Stimuli

The stimuli were designed to test the dependent variables of duration (for consonants and preceding vowels), RMS amplitude difference (between singleton and geminate), and F1, F2 and F3, for the independent variable of phonological status of the consonant (three different types of geminate and the singleton). Position of the consonant in the utterance, syllable structure of the carrier word, and intonation were controlled for. To ensure that the target sounds are included in the speech production of the subjects, a list of tokens was compiled by the researcher so as to ensure equal proportions of the sounds under study.

2.3.2 Compilation of word list

Ladefoged (2003) points out that nonsense words should be avoided in preparing lists and that when the list of words contains true sounds of the language to be studied and words that speakers feel comfortable with, the speakers will produce the tokens in a natural way and the results will be valid. In this study, the author, who is a native speaker of TLA, assembled a word list containing only real words and phrases which are commonly used by the speakers of this language.

The list consists of 30 utterances (words or short phrases) divided into eight sets. Each two sets contain one of the sonorant sounds /r, l, m, n/ both as singletons and geminates. Each set contains four utterances: one utterance (word) with a singleton consonant, one (word) with a true geminate, one (phrase) with a fake geminate, and one (phrase) with an assimilatory geminate, except for the two sets for the alveolar nasal /n/, which consist of three utterances each due to the lack of the assimilatory geminate in these sets. The number of contexts in which the singleton and the different geminate types occur is the same across the stimuli. The utterances within each set are either identical or near-identical apart from the consonant of interest. Ladefoged (2003:5) states that using minimal or near-minimal contrasting sets of words confirms that the sounds to be studied are not "affected by the context". In all the utterances that contain the assimilatory geminates, the geminate consonant is the result of assimilating the alveolar nasal /n/ in the coda of the last syllable of the first word to the consonant in the onset of the first syllable of the second word (i.e. /l, m, r/). The alveolar nasal /n/ is one of the most frequently assimilated sounds in the contexts of /l/, /m/, and /r/ especially while reciting the Holy Qur'an (see Bakalla 1983 for more explanation on the treatment of nasal elements by early Arab and Muslim phoneticians).

The singleton and geminate consonants always occur in the middle of the word/utterance in an intervocalic position, except in 4 tokens that contain the singleton consonants /r/, /m/, and /n/ where the singleton consonants occur in word initial position due to the lack of matching minimal or near-minimal tokens. Word-medial consonants in TLA can be preceded by either short or long vowels, therefore, short and long vowels are included in the utterances in equal numbers before both the singleton and geminate consonants (and before the different consonant types). The tokens are balanced for differences in consonant quantity and the phonological status of the consonants. Since voicing has been shown to influence duration significantly (see e.g. Ham, 2001 and Ladefoged, 2003), it has been balanced as well. Likewise, the previous and following vowels were balanced for both quality and quantity within and across sets, since vowel quality also influences duration (see Ham, 2001). Syllable structure is another factor that may affect vowel duration in that vowels in open syllables tend to be longer than those in closed syllables (see e.g. Ham, 2001 and Ladefoged, 2003). The list is balanced on this account as well. See Table 2.1 for lists of the utterances in two sets of the stimuli (A full word list of the stimuli with their glosses is available in Appendix 1).

One of the two sets compiled for /l/				
	/ˈxa:**l**i:/	‘my uncle’	CV:<u>**C**</u>V:	Singleton
	/ˈdˤa:**l:**i:n/	‘lost (people)’	CV:<u>**C:**</u>V:C	True geminate
/xa:l#li:na/ →	[ˈxa:**l:**i:na]	‘Lina’s uncle’	CV:<u>**C:**</u>V:CV	Fake geminate
/xa:n#li:na/ →	[ˈxa:**l:**i:na]	‘(he)betrayed Lina’	CV:<u>**C:**</u>V:CV	Assimilatory geminate [n→l]
One of the two sets compiled for /r/				
	/ˈma**r**a:mi/	‘goalkeepers’	CV<u>**C**</u>V: CV	Singleton
	/ˈba**r:**a:ni/	‘stranger’	CV<u>**C:**</u>V:CV	True geminate
/sir#ra:m/ →	[ˈsi**r:**a:mi]	‘the secret of Rami’	CV<u>**C:**</u>V:CV	Fake geminate
/min#ra:mi/ →	[ˈmi**r:**a:mi]	‘who is Rami?’	CV<u>**C:**</u>V:CV	Assimilatory geminate [n→r]

Table 2.1: Two sets of the utterances used in the acoustic study.

As Table 2.1 shows, the four utterances in each set match in the syllable structure and the position of the singleton and geminate consonants within the utterance (with almost all of them in an intervocalic position), with all the geminates in either word middle across-syllable (true geminate) or utterance middle across-words across-syllable (fake and assimilatory geminates).

Additionally, "it has been observed that word size systematically influences segmental timing, such that duration decreases more or less uniformly as syllable count increases" (see Ham,2001: 30). In this study, all the singleton and geminate consonants occur in tri-syllabic utterances (i.e. the utterance size is uniform within and across the sets). It should be pointed out that due to lack of minimal or near minimal tokens, four utterances in the list are disyllabic. However, they match with the other utterances in the quality and quantity of the following vowels and consonants and the syllable structure. Therefore, the duration of the single consonants and the different kinds of geminates in this study can be directly compared since the size and position-in-utterance is consistent across the list.

The position of the stress is reported to influence vowel duration in that stressed vowels are longer than unstressed ones (see Ham, 2001). Ladefoged (2003) states that in compiling lists the position of stress should be considered if it is significant in the language, as in the case of English. Arabic was strongly classified with English as a 'stress-timed' language (see e.g. De Jong and Zawaydeh, 1999; and Watson, 2007, 2011 for discussion). Although English and Arabic are both stressed-timed languages, they show marked differences with regard to the place and function of stress. There is a fair amount of phonological literature concerning the placement of stress in various Arabic dialects (see e.g. Al-Mozaini, 1981; Al-Mozaini, Bley-Uroman, and McCarthy, 1985; Brame, 1974; Kenstowicz, 1986, 1983; Kenstowicz and Abdul-Karim, 1980). The phonological literature typically describes Arabic stress as predictably falling on a particular location in the word, depending on the internal structure of the syllables making up the word. The pattern of stress location varies considerably in colloquial and modern renditions of Classical Arabic (see e.g. De Jong and Zawaydeh, 1999, and Watson, 2011). Some researchers propose rules to allocate the position of stress in a number of

Arabic dialectal variations (see e.g. McCarthy, 1982:53-68, Watson, 2002:79-121, Al-Ageli, 1995). Word stress is not distinctive in Arabic, that is, it does not serve to distinguish meanings, although the morphological structure of words often affects stress (Kager, 2009). Some researchers argue that it can be contrastive in some cases. This may only be restricted to some Bedouin Arabic dialects, however (see Rosenhouse, 2009). Nevertheless, phonetically, stress is of marginal significance in Arabic and "there is even no decisive evidence to its significant location in individual words" (Ghalib, 1984:9). Recent studies show that duration is not a correlate of stress in Arabic (Bouchhioua, 2009). In her investigation of the role of duration in signalling stress and accent in southern British English, Tunisian Arabic, and English as produced by Tunisian speakers, Bouchhioua (2008) found that "unlike English, where duration is a robust correlate of both stress and accent, Tunisian Arabic has shown a lack of durational involvement in lexical stress". This fact did not affect the production of English lexical stress by Tunisian speakers who produced significant durational contrasts between stressed and unstressed constituents. Moreover, speakers of Amman and Cairo Arabic dialects are found to lack vowel reduction in L2 English unstressed syllables (Almbark, Bouchhioua, and Hellmuth, 2014), which was considered as a clear pattern of L1 transfer in the phonetic realisation of stress. Since studies on both EA and WA dialects show that stress does not affect duration in Arabic, it is not probably a confounding factor in this study. However, and since the acoustic correlates of stress in TLA have not been experimentally explored, the algorithm proposed by Al-Ageli (1995) for TLA stress is used to locate the position of stress in the stimuli. Applying this algorithm show that all the target singleton and geminate consonants in the stimuli occur in a pre-stressed position (see Appendix 1).

Lastly, it should be pointed out that all the utterances in the list were embedded in a carrier sentence which was selected so as to be contextually natural and which placed the target utterances in phrase-medial position. The carrier sentence used in this study is [ga:l aħmid ________ ta:ni] "Ahmed said ________ again". The idea behind using the carrier phrase is that it gives consistency of every feature in that the speakers say each utterance in the same manner and it "ensures that each word occurs in the same rhythmic position, which is important as the position in an utterance can affect the stress pattern and length" (Ladefoged, 2003:8). In addition, the use of the carrier phrase renders the sound segment more natural (Ghalib, 1984).

One final point is that the rate of speech (i.e. "the time to achieve articulatory targets" Sole, 1992:30) that speakers may exploit to fit different conversational situations is also reported to be a source of variation in the duration of consonant and vowel segments (see Ghalib, 1984 and Ham, 2001). Guidance was given to the speakers prior to the recording sessions so as to speak in a normal conversational speaking rate, and once each recording is complete, it was checked for the rate of speech by the researcher who is a native speaker of TLA.

2.3.3 Data collection procedure

Each one of the four subjects was asked to read a list composed of 108 utterances (30 utterances x 3 repetitions + 6 filler words x 3 repetitions). The tokens were randomized and the 6 filler words (x 3 repetitions), that do not contain singleton-geminate contrasts and their syllable structure is completely different from the tested utterances, were inserted after each 5 utterances (i.e. to avoid list effect in any of the target utterances). The recordings were made in the recording studio in the Department of Linguistics and Phonetics at the University of Leeds. The software (Gold Wave) available in the computer system of the recording studio was used to record the tokens simultaneously as produced by the subjects in mono, 44.1 kHz sampling rate. The distance between the speakers and the microphone was about 35 cm. Each subject read the first half of the list (54 utterances) then a break was taken. After that, the second half was recorded.

Although the words in the list were typewritten using the MSA orthography, the spelling and diacritics, where needed, followed the informal TLA pronunciation in order to avoid any influence on the speakers by the way in which MSA is pronounced. The subjects were asked to familiarize themselves with the list before recording so that they produce the utterances as naturally as possible. After that, they were asked to read the first 36 utterances (these contain the basic 30-word list) once to the researcher to check whether they understood the right target dialectal words or not. The subjects were instructed to pronounce the utterances in an informal style as if they were speaking their regional dialect with a normal conversational rate.

It should be pointed out that in producing one of the utterances with the assimilatory geminate /m/, two of the subjects show a within-speaker variance in that they were not consistent in assimilating the alveolar nasal /n/ to the following bilabial nasal /m/ in all three repetitions. Apparently, they can do both variations. Additionally, they did assimilate the /n/ to the following /m/ in all three repetitions in the other utterance in the set. Since they produced both variations (assimilatory and non-assimilatory) naturally, they were asked to re-produce these tokens producing the assimilatory version.

Another point to be highlighted here is that some researchers (e.g. Coolican, 1999) consider that the mood of the participant or the environmental conditions can affect the subject's behaviour and lead to false results. To help the subjects relax and feel comfortable, we chatted before, in the middle of, and after the recording sessions on many different subjects. As indicated by many researchers (Ladefoged, 2003) this act is an efficient way to enhance validity and reliability. The subjects appeared to be relaxed and happy to do the task. They were in a normal mood during the recording of the data. I can judge that there were not any factors about the environment of recording that affected their style of speaking.

2.3.4 Data analysis and measurements

A total corpus of 360 utterances (30 utterances x 3 repetitions x 4 speakers) were extracted from the list each into a separate wavfile for auditory and acoustic analysis. Durational measurements (in millisecond) of the singleton consonants, the different geminate types and the preceding and following vowels were made using PRAAT software package version 5.1.17 (Boersma and Weenink 2009). The data were labelled semi-automatically using Praat annotation text grids relying on both the spectrogram and the corresponding waveform. The durational measurements were obtained using a script and checked by hand (example in Figure 2.1). Additional measurements where obtained automatically using specifically designed scripts[3]. The acoustic measurements conducted in this study include the following:

- The duration of the singletons and (the three types of) geminates.
- The durations of the preceding vowels.
- RMS amplitude differences between the singleton-geminate contrast and between the three geminate types.
- F1, F2 and F3 for the target consonants (at mid-point) (to test for the presence of gestural differences (i.e. palatalization effects and/or strengthening) between geminates and singletons and between the three geminate types).

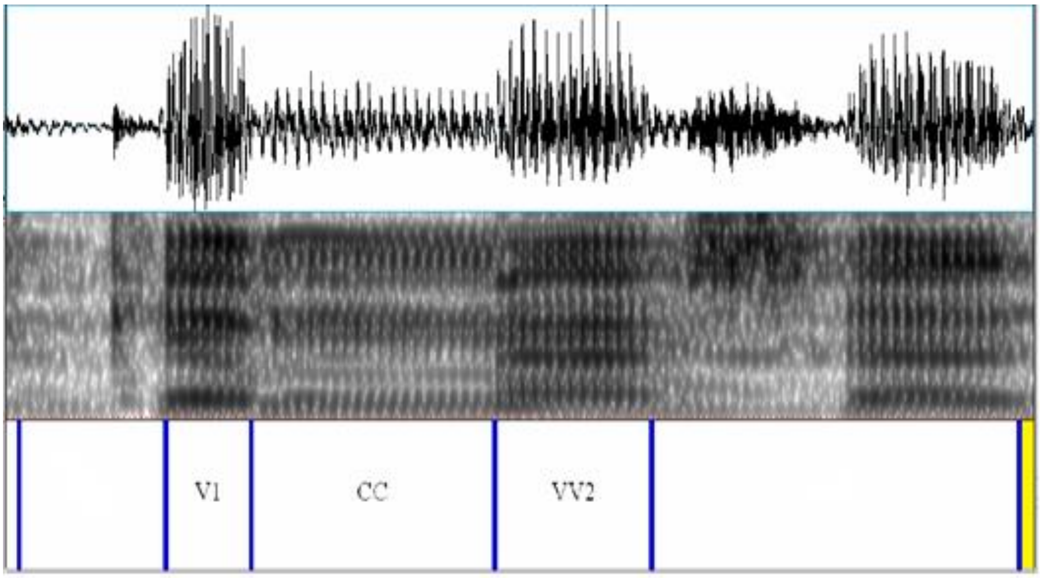


Figure 2.1: An illustration of data labelling showing the word /kam:a:ʃa/ 'pliers' as produced by one of the male speakers.

[3] The RMS script and the formant measurements script were kindly designed by Dr Leendert Plug.

The validity of the conclusions that can be drawn from an experiment that uses segmentation as part of its methodology is dependent on the reliability of segmentation criteria (Turk, Nakai and Sugahara, 2006). Moreover, Ladefoged (2003:103) states that if measuring the durations of segments to be reliable, researchers should "choose consistent measurement points, and report the duration of each sound in the same way". In this study, an oral constriction criterion is used to segment all the target speech sounds. In this method, the onset and release of oral consonantal constriction is used to identify the sound boundaries. This criterion is preferable in segmenting sound durations since it "can be used comparably for many different classes of speech sounds" (Turk, Nakai and Sugahara, 2006: 2). Criteria for measurements were as follows:

1. The duration of the singleton and geminate nasal sounds was measured from the beginning of the oral closure to the point of release coinciding with the occurrence of sudden reduction in the acoustic energy in the spectrogram with upper frequencies not so evident and a brief dip in the amplitude waveform (see Figure 2.2 and Figure 2.3).
2. The duration of the singleton and geminate rhotic sounds was measured from the beginning of the oral closure to the point of release represented by a brief gap appears in the acoustic signal (tap) or movement of the third formant through the frequency scale (approximant) (see Figure 2.4 and Figure 2.5).
3. The geminate rhotic was realised as a trill by some speakers. The duration of these trills was measured from the beginning of the oral closure to the point of release coinciding with the appearance of brief gaps in the acoustic signal (see Figure 2.6).
4. The duration of the lateral approximant was measured from the onset of the oral closure to the point of release associated with spectral discontinuity at constriction onset and release with evident upper frequencies (see Figure 2.7).
5. The duration of the preceding vowels was measured from the onset to offset of the second formant F2 (see Figure 2.8).

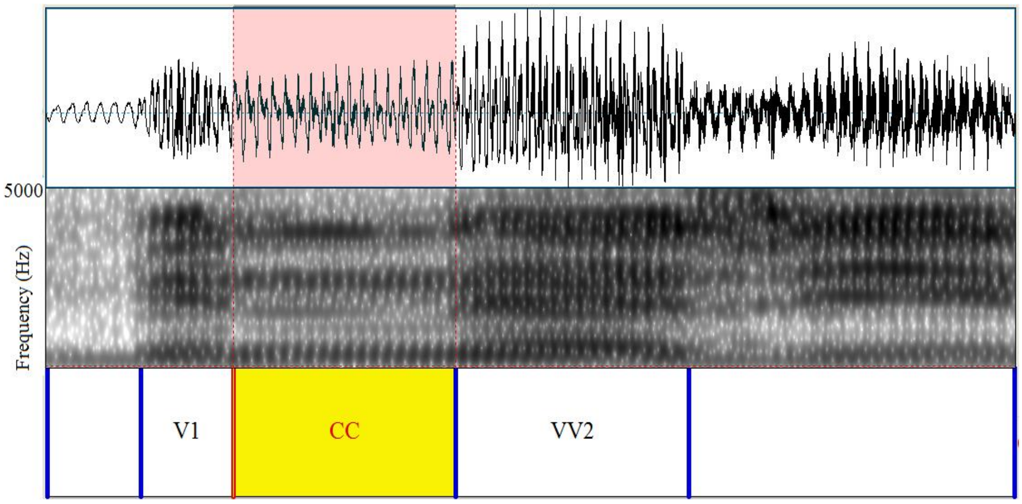


Figure 2.2: Waveform and spectrogram of /n/ in /bin:a:ʒi/.

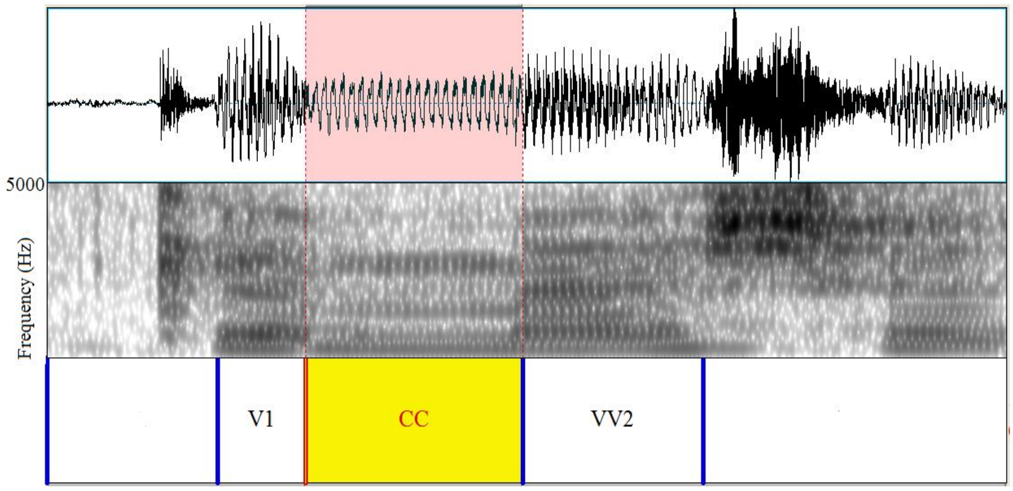


Figure 2.3: Waveform and spectrogram of /m/ in /kam:a:ʃa/.

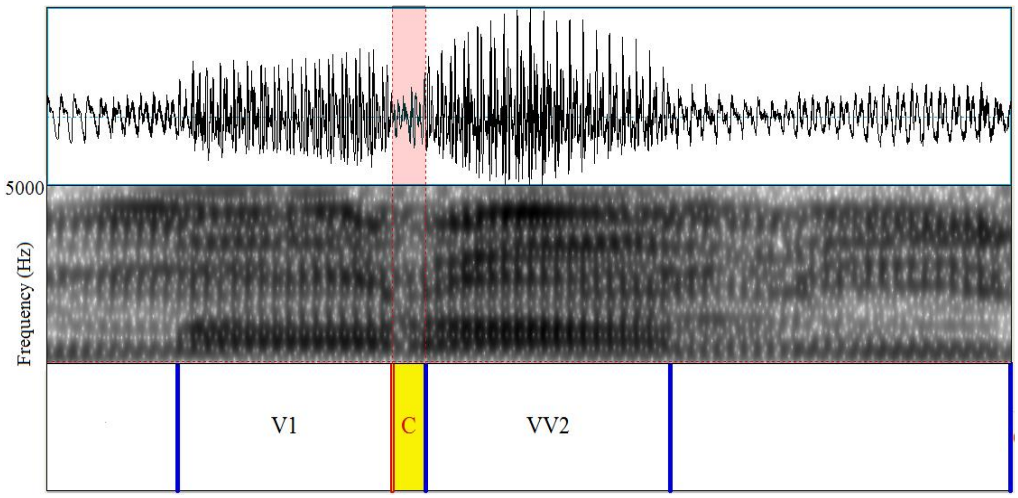


Figure 2.4: Waveform and spectrogram of /r/ as a tap in /mara:mi/.

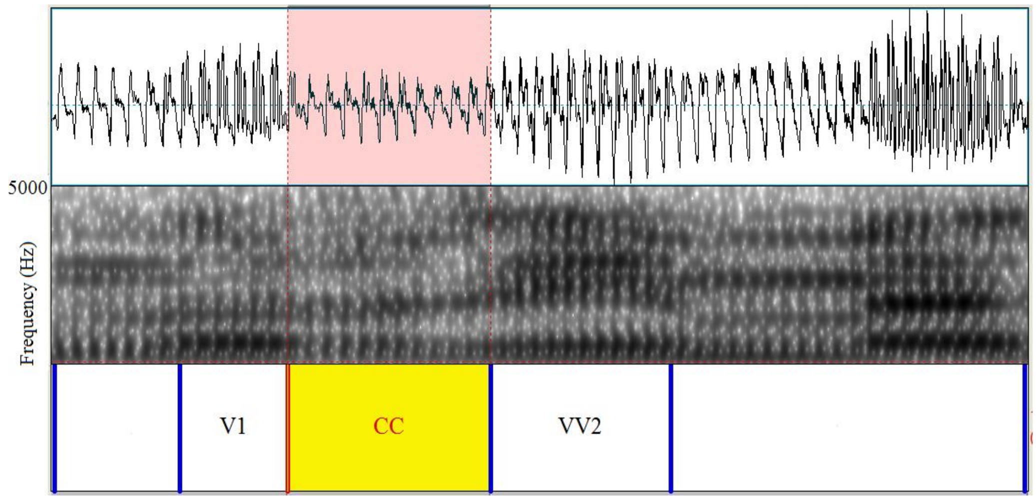


Figure 2.5: Waveform and spectrogram of /r/ as an approximant in /mir:i:ma/.

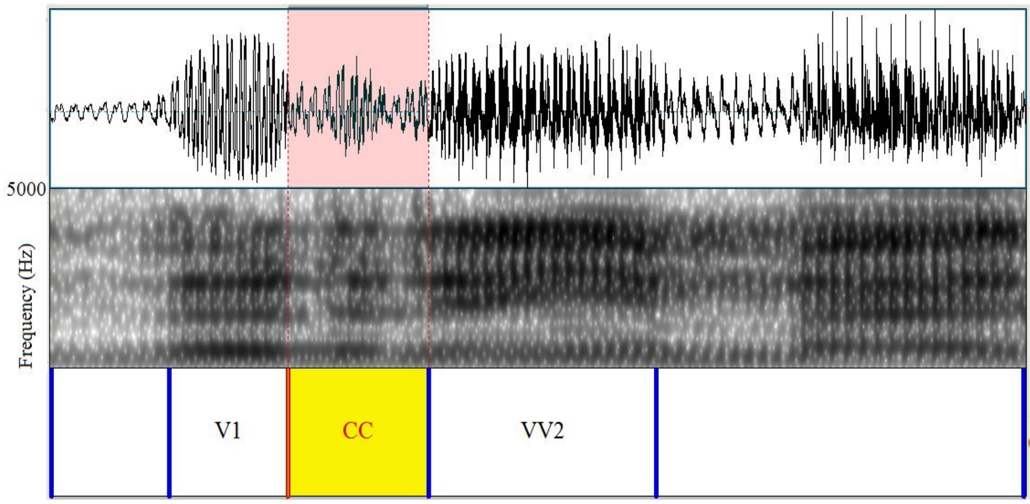


Figure 2.6: Waveform and spectrogram of /r/ as a trill in /bir:i:ma/.

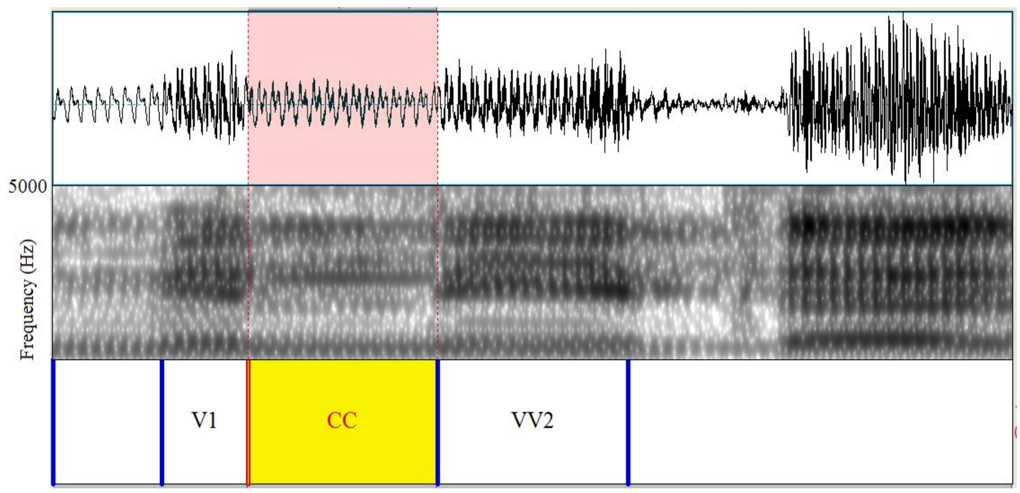


Figure 2.7: Waveform and spectrogram of /l/ in /mil:i:ta/.

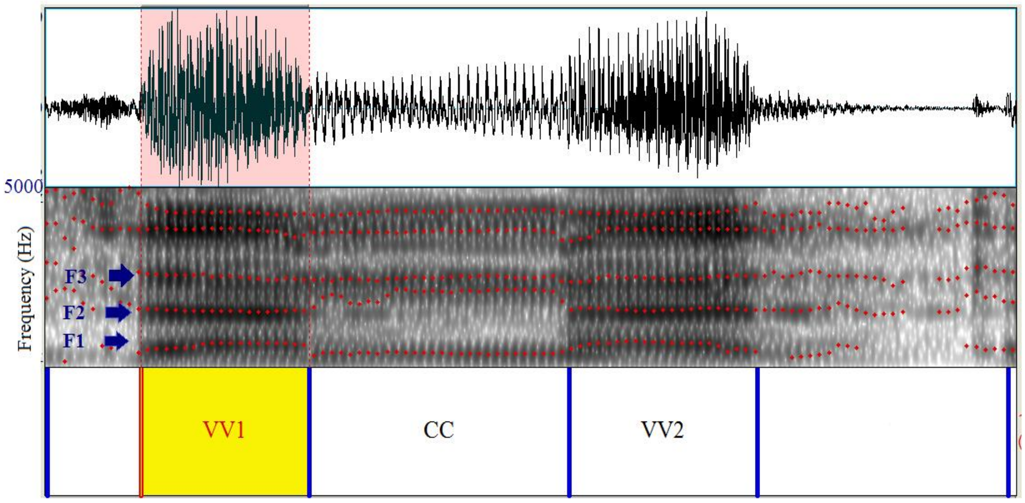


Figure 2.8: Waveform and spectrogram of /sa:m:a:t/ showing the onset and offset of F2 for the preceding vowel

2.3.5 Variables

There are three kinds of variables relevant to this study, independent, dependent and controlled variables. An independent variable is the variable that is manipulated by the researcher and which is assumed to have a direct effect on the dependent variable. A dependent variable, on the other hand, is the variable that is supposed to be directly affected by changes in the independent variable (see e.g. Rasinger, 2008 and Coolican, 1999). In this study, the independent variables are the phonological status of the target consonants (singleton vs. true geminates vs. fake geminates vs. assimilatory geminates). The dependent variables are the measured variables (i.e. the measurements of these different consonantal kinds (and that of the preceding and following vowels). The other variables that are relevant in this study are all the variables in the universe other than the dependent and independent variables and which could affect the dependent variable. In this study, these relevant (extraneous) variables are properly dealt with (neutralized) and held constant in some sense (controlled). Herzog (1996: 30) states that "because it is held constant, a controlled variable cannot change values systematically along with another variable… . Thus, …the variable cannot be involved in a relationship and is therefore ruled out as a cause in the experiment". The variables that have been controlled and ruled out in this study are listed below:

1. The rhythm of speech
2. The position of the singleton and geminate consonants within the utterances
3. The syllable structure of the tested tokens
4. The size of the tested utterances
5. The quality and quantity of the preceding and following vowels
6. The quantity of the singleton and geminate consonants
7. The mood of the participants
8. The rate of speech

2.4 Results

This section reports on the results of the acoustic investigation of the durational correlates of gemination, section 2.4.1, and the non-durational correlates of gemination, section 2.4.2, in TLA. All the results of the statistical analysis were obtained by using the SPSS package version 22 available on the computer cluster desktop at the University of Leeds. An independent Analysis of Variance (ANOVA) and an independent T-test are considered in the statistical analysis of the results in this study since the dependent variable is continuous and normally distributed with one or more independent variables that are categorical with two or more levels.

The results are based on a series of independent analysis of variance (ANOVAs) and independent T-tests. In all the tests, the fixed factor was phonological status of the target consonants ((singletons vs. true geminates) vs. fake geminates vs. assimilatory geminates) and the random factors were the sound category (/l/, /r/, /m/ and /n/) and speaker (x4). LSD comparisons were performed to determine differences between levels within factors. The dependent variables are four, namely (1) duration of the target consonants, (2) duration of the preceding vowels, (3) RMS amplitude of the target consonants, and (4) F1, F2 and F3 at mid-point of the target consonants.

2.4.1 Durational correlates

2.4.1.1 Singleton-geminate contrast

A factorial analysis of variance (ANOVA) reveals that the durational differences between singletons and (true lexical) geminates is significant ($F(1,3)=91.837$, $p<0.001$), sound category is significant ($F(3,8)=4.009$, $p<0.05$), and speaker is not significant ($F(3,6)=0.072$, $p=0.973$). The interaction between the singleton-geminate contrast and sound category is not significant ($F(3,9)=1.313$, $p=0.329$). The interaction between the singleton-geminate contrast and speaker is significant ($F(3,9)=7.706$, $p<0.05$). However, The interaction between the three factors is not significant ($F(9,16)=1.164$, $p=0.322$). See Figure 2.9 for mean duration and standard deviation of singleton and geminate consonants. This reflects that duration plays a significant role in the phonemic contrast between singleton and geminate consonants in TLA with the ratio of C to CC being 1 to 2.42.

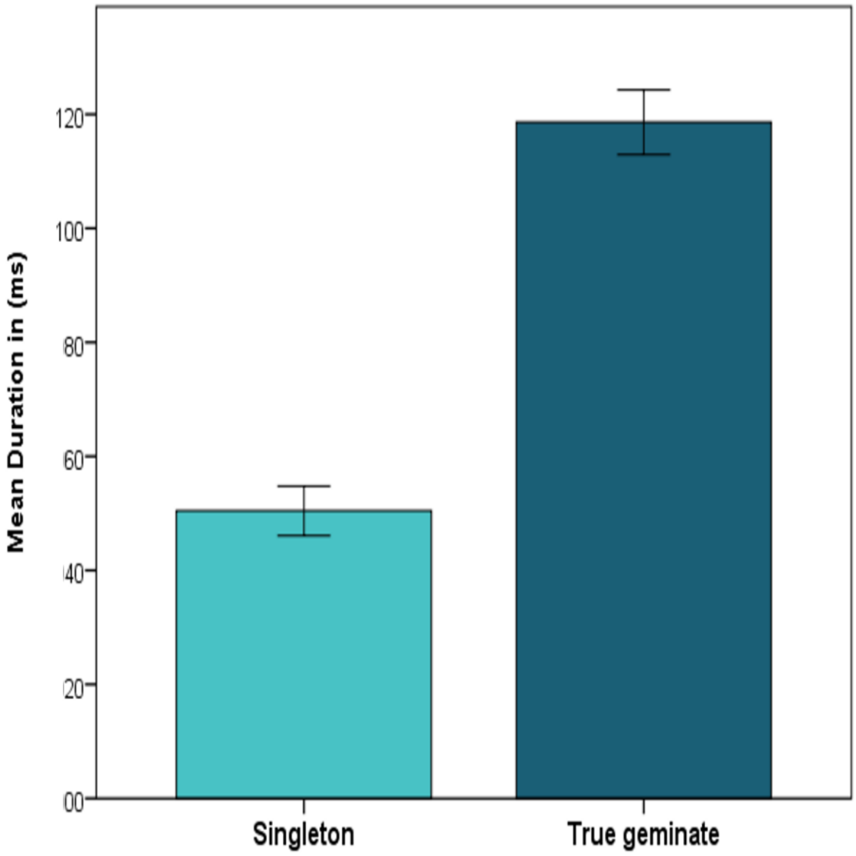


Figure 2.9: Mean duration and standard deviation of singleton and geminate consonants.

Figure 2.10 shows durational results for each of the four sounds in C and CC contexts. It is clear that there is a consistency in the durational behaviour of these sounds in the context of C and CC. As Figure 2.10 shows, in both C and CC contexts the shortest consonants are rhotics followed by the alveolar nasals and the laterals (which show similar durational patterns), with the bilabial nasal being the longest. It has been noticed from the data that the alveolar rhotics show manner variation within and across speakers. The singleton /r/ is realised as a tap or approximant. The geminate /r/ is realised as approximant, trill or weak fricative.

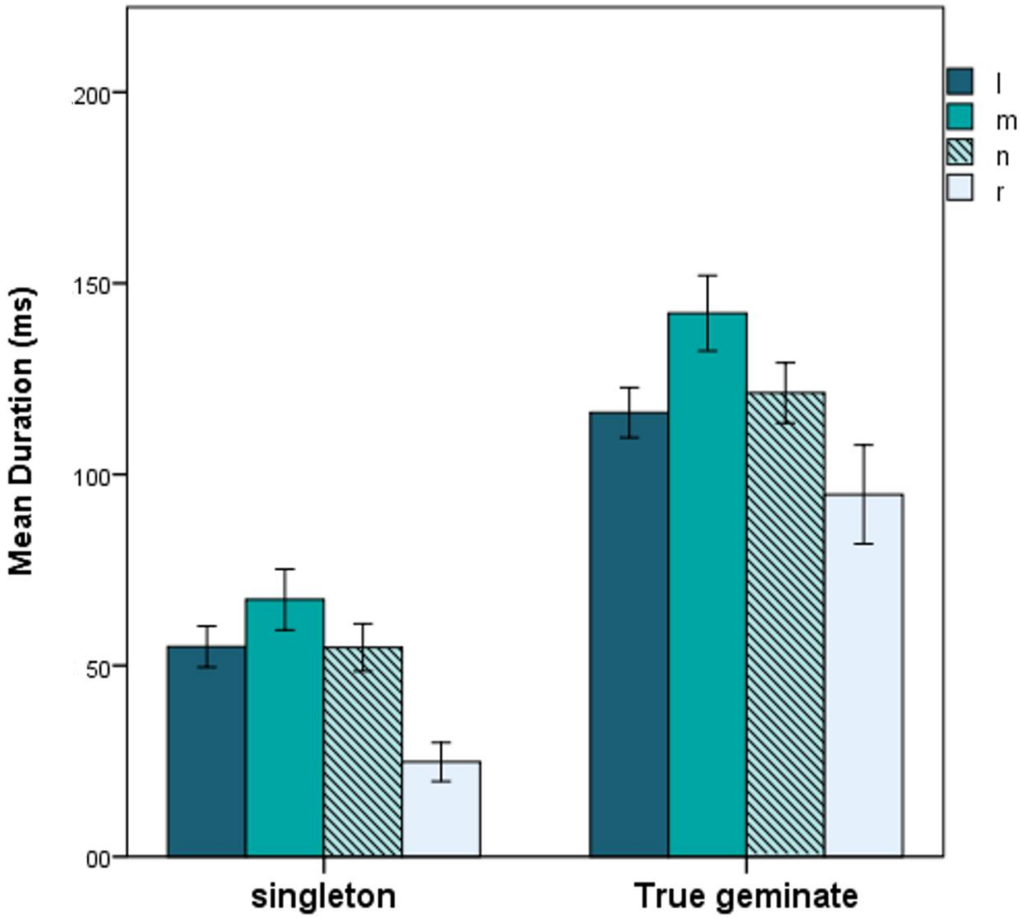


Figure 2.10: Mean duration (in ms) and standard deviation of each of the consonant categories in singleton and geminate targets.

2.4.1.2 Geminate type

An ANOVA testing the durational differences between singletons and each geminate type show that the phonological status is significant ($F(3,11)=62.496$, $p<0.001$), the sound category is significant ($F(3,12)=6.887$, $p<0.05$), and the speaker is not significant ($F(3,13)=0.668$, $p=0.586$). The three-way interaction of phonological status x sound x speaker is not significant ($F(24,30)=1.350$, $p=0.130$). This result shows that the durational differences between singleton consonants and each geminate type separately also achieves significance with no effect of speaker reflecting consistency in the durational contrast between singletons and each geminate type for all speakers.

Figure 2.11 and Table 2.2 show the durational results, the standard deviation and the number of tokens for the singleton and the three geminate types. It is clear from Figure 2.11 that the distributions for C and CC in the case of fake geminates show minor overlap, whereas in the case of true and assimilatory geminates the distributions for C and CC are overlapping. Table 2.2 shows that fake geminates are about 2.5 times as long as their singleton counterparts whereas true geminates and assimilatory geminates are about 2.3 and 2.4 times as long as their singleton counterparts respectively.

	Phonological Status			
	Singleton	True geminate	Fake geminate	Assimilatory geminate
Mean	**50.4**	**118.6**	**126.7**	**121.7**
SD	21.4	28	18.7	27.9
Total N	96	96	96	72
Ratio of C to CC		**1 : 2.35**	**1 : 2.51**	**1: 2.41**

Table 2.2: Mean duration (in ms), standard deviation and the number of tokens for singleton consonants and the three geminate types and the ratio of C to CC.

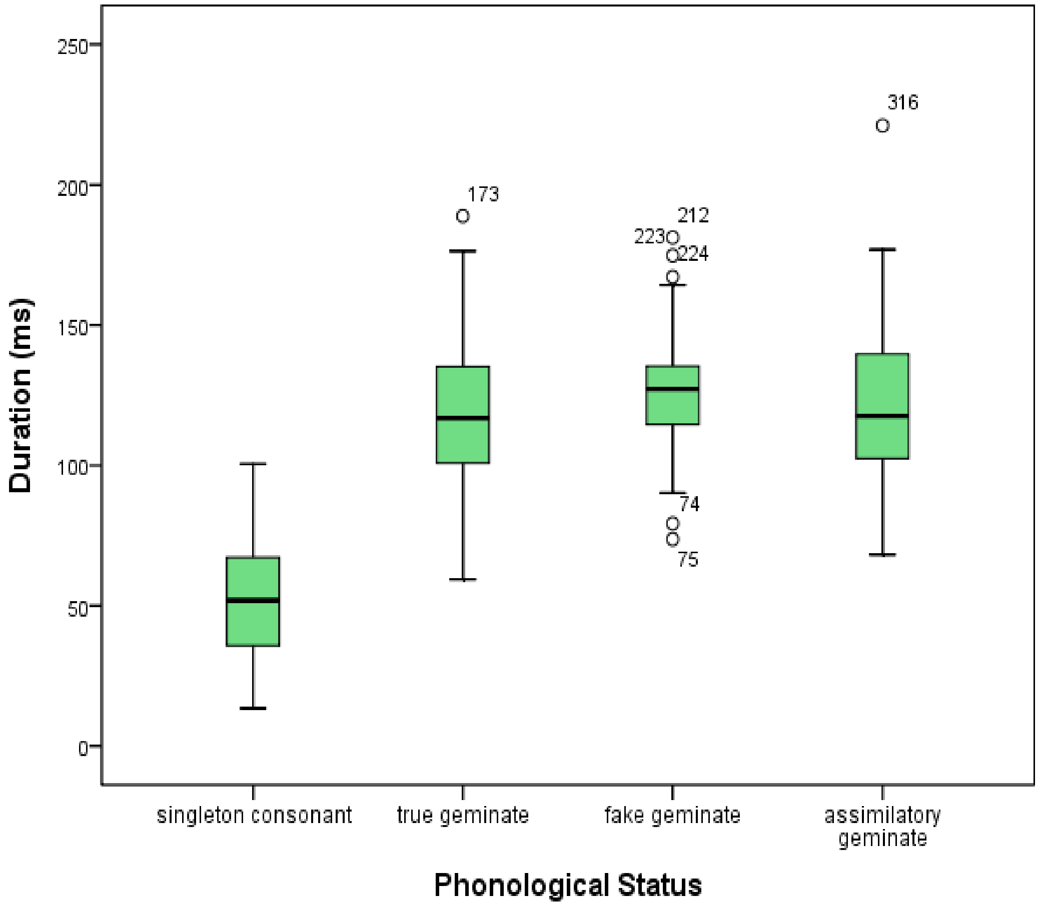


Figure 2.11: Durational results of singletons, true geminates, fake geminates and assimilatory geminates.

Figure 2.12 shows durational results for each of the four sounds in the singleton and three geminate types contexts. It is clear that there is a consistency in the durational behaviour of these sounds in the context of C and CC regardless of geminate type. In both C and CC contexts the shortest consonants are rhotics (with the exception of fake geminates /r/ that show similar duration to the alveolar nasal and alveolar lateral) followed by both the alveolar nasal and the alveolar lateral (which show similar durational patterns), with the bilabial nasal being the longest. Figure 2.12 shows that all geminate types for each sound are significantly longer than their singleton counterparts.

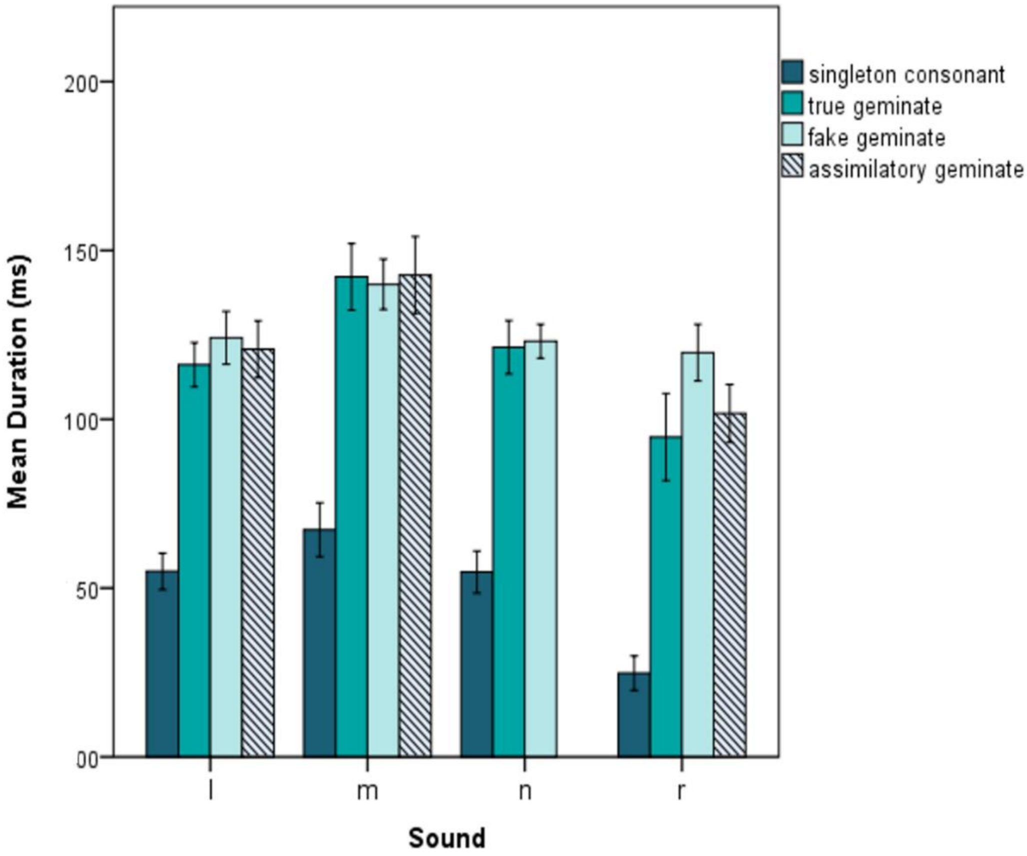


Figure 2.12: Mean duration (in ms) and standard deviation of each of the consonant categories in singletons and the three geminate types.

ANOVA shows no significant durational differences between the three geminate types (F(2,4)=1.294, p=0.353), the sound category is significant (F(3,10)=5.352, p=<0.05), and the speaker is not significant (F(3,8)=1.884, p=0.203). The interaction between the geminate type and sound category is not significant (F(5,15)=2.700, p=0.062). The interaction between the geminate type and speaker is not significant (F(6,15)=1.272, p=0.327), which suggests that the speakers' durational patterns of the three geminate types are similar. The three-way interaction of geminate type x sound x speaker is also not significant (F(15,22)=1.397, p=0.150). Post-hoc tests reveal that the durational difference between true geminates and fake geminates (see Figure 2.11) approaches significance (p=0.051). The difference between true and assimilatory geminates is not significant (p=0.754). The difference between fake and assimilatory geminates is not significant as well (p=0.393).

Figure 2.13 presents the durational means of the four sounds /l, m, n, r/ in the three geminate contexts. It is clear that the significant sound effect reported in the previous ANOVA relates to the behaviour of the alveolar rhotic /r/, which shows longer duration as a fake geminate compared to its duration as a true or assimilatory geminate (see also Figure 2.12 above). Apparently, it is the behaviour of this sound that contributed to the Post hoc results making the durational differences between true geminates and fake geminates approaching significance.

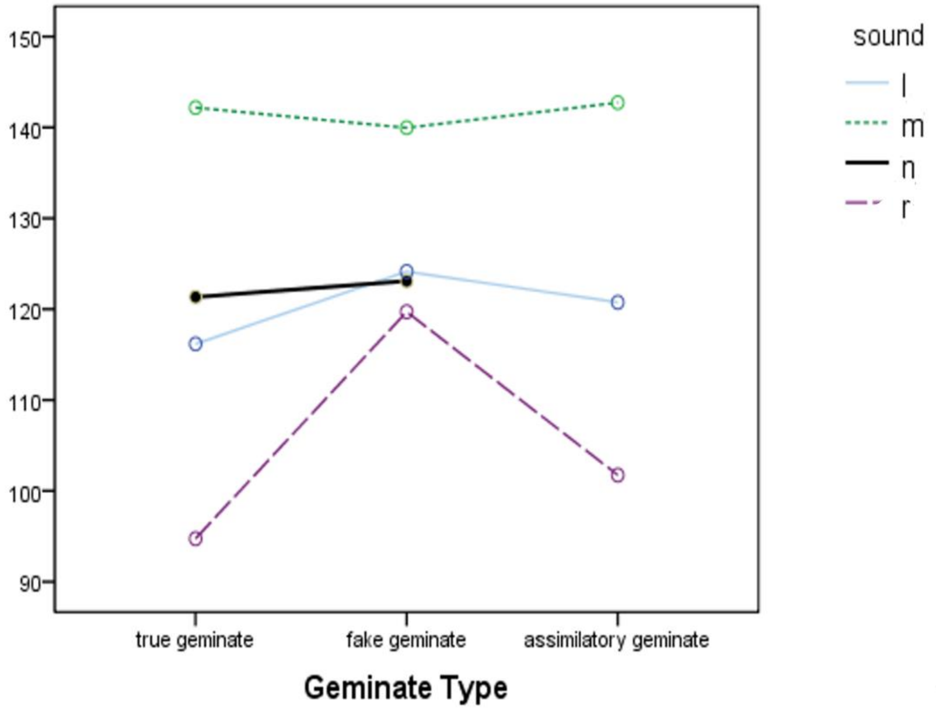


Figure 2.13: Significant interaction between the sound category and the geminate type.

To verify and confirm this observation, an AVONA was repeated for each sound type separately. For the alveolar lateral /l/, no significant durational differences between the three geminate types could be found (F(2,6)=1.135, p=0.382). The speaker factor seem to have effect (F(3,6)=6.963, p=0.022). However, no interaction between geminate type and speaker could be found ($F(6,6)=1.506$, $p=0.192$). Post hoc LSD test also failed to show any significant differences between the three geminate types of this sound as well. When testing the bilabial nasal /m/, the three geminate types also fail to achieve significant differences ($F(2,6)=0.122$, $p=0.887$). The speaker has no effect and the interaction between the geminate type and speaker is not significant ($F(6,6)=0.930$, $p=0.480$). Post hoc comparisons failed to show any significant differences between the geminate types of /m/ as well. An ANOVA testing the durational differences between the geminate types of the alveolar nasal /n/ shows that the geminate type is not significant ($F(1,3)=0.049$, $p=0.839$), the speaker is not significant ($F(3,3)=0.326$, $p=0.809$), and the interaction between them is significant ($F(3,40)=3.645$, $p<0.05$). As regarding the three geminate types of the alveolar rhotic /r/, they achieve significant durational differences ($F(2,6)=9.027$, $p<0.05$). The speaker factor also show significant effect ($F(3,6)=15.539$, $p<0.05$). The interaction between them is not significant ($F(6,60)=1.560$, $p=0.175$). Post hoc LSD test show that fake rhotic geminates are significantly longer than both true geminates ($p<0.001$) and assimilatory geminates ($p<0.001$). True and assimilatory geminate rhotics show similar durations ($p=0.155$), however.

To sum up, it is confirmed by statistical testing that /l/, /m/ and /n/ behave alike and that /r/ behaves quite differently. In other words, /l/, /m/ and /n/ show similar durational patterns for the three geminate types. The alveolar rhotic /r/, however, shows durational differences between fake geminates on the one hand and true and assimilatory geminates on the other.

As mentioned above (section 2.4.1.1), the alveolar rhotic sounds are found to exhibit different manners of articulation within and across speakers for both the singleton and geminate consonants. This manner variation is also present in fake and assimilatory geminates. This leads to the possibility that /r/ is different temporally because it shows manner variation of a type that the other sounds do not show. Therefore, alveolar rhotic manners of articulation and the distribution of these manners across singleton and geminate types have been checked. Table 2.3

shows the distribution of these manners across the singletons and the three geminate types.

	Tap	Trill	Approximant	(Weak) fricative
Singleton	13 (54%)		11 (45%)	
True geminate		11(45%)	4 (16.6%)	9 (37.5%)
Fake geminate		9 (37.5%)	4 (16.6%)	11 (45%)
Assimilatory geminate		9 (37.5%)	6 (25%)	9 (37.5%)

Table 2.3: The percentage of the realizations of /r/ across the singletons and the three geminate types.

As can be seen from Table 2.3, there is variation in the realisation of the geminate rhotics. In general, the geminate /r/ is realised as a trill, an approximant or a weak fricative. All the speakers show variation in their realization of the singleton and geminate rhotics. Some of the variations are found to be in repetitions of the same token. There is not very obvious division for rhotics by geminate type. To sum up, these realisations do not seem to be categorically different geminate allophones.

2.4.1.3 Preceding vowel

Figures 2.14 and 2.15 show absolute and proportional means and standard deviations for vowel and consonant durations in medial VC, VCC, VVC, and VVCC contexts. Table 2.4 lists the means and standard deviations for the above targets and the ratio of C to CC in short and long vowel contexts. Table 2.5 shows the ratio of V to VV in the context of short and long C. As can be seen from Figure 2.14 below, there is a significant difference between the absolute durational results of the preceding short vowel in the context of singleton and geminate consonants, that is, gemination significantly shortens preceding short vowels ($t = 10.157$, $p<0.001$). On the contrary, the durational values for long vowels preceding singleton consonants are not significantly different from those preceding geminate consonants (t = -0.445, p=.659). However, by examining the proportional durations (Fig. 2.15) as a function of the VC sequence, it is clear that the long vowel in the VVCC sequence contributes a smaller proportion of the overall duration compared with the long vowel in the VVC sequence. This suggests over all proportional rather than absolute temporal compensation between preceding long vowels and geminate consonants.

Context	**VC**		**VCC**		**VVC**		**VVCC**	
Segment	**V**	**C**	**V**	**CC**	**VV**	**C**	**VV**	**CC**
Mean	87.6	38.3	50.9	116.1	101.2	67.1	103.6	136.3
SD	30	21.8	14	23	22.1	17.7	26.3	24.2
Ratio of C to CC	**1 : 3.03**				**1 : 2.03**			

Table 2.4: Mean duration (in ms) and standard deviation for vowels and consonants in medial VC, VCC, VVC, and VVCC contexts, and ratio of C to CC in short and long vowel contexts.

Looking at consonant duration first, geminate consonants are predictably longer than singleton consonants regardless of the quantity of the preceding vowel. The ratio of C to CC (Table 2.4) is around 1 to 3 when preceded by a short vowel and 1 to 2 when preceded by a long vowel. This seems to be due to V duration being significantly shorter before geminate consonants than before singleton ones and VV duration being not significantly different in these two contexts. This is reflected in the ratio of V to VV presented in Table 2.5 where the ratio of V to VV is 1 to 1.15 in the context of C and about 1 to 2 in the context of CC.

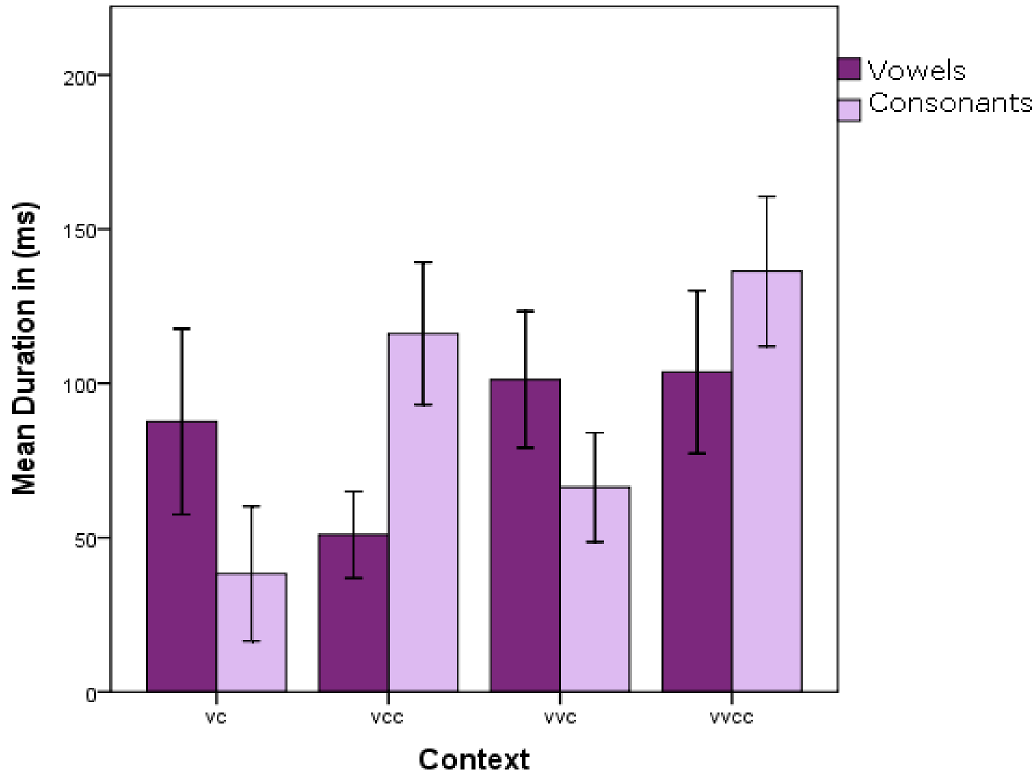


Figure 2.14: Absolute mean duration (in ms) and standard deviation of the preceding short and long vowels in the context of singleton and geminate consonants.

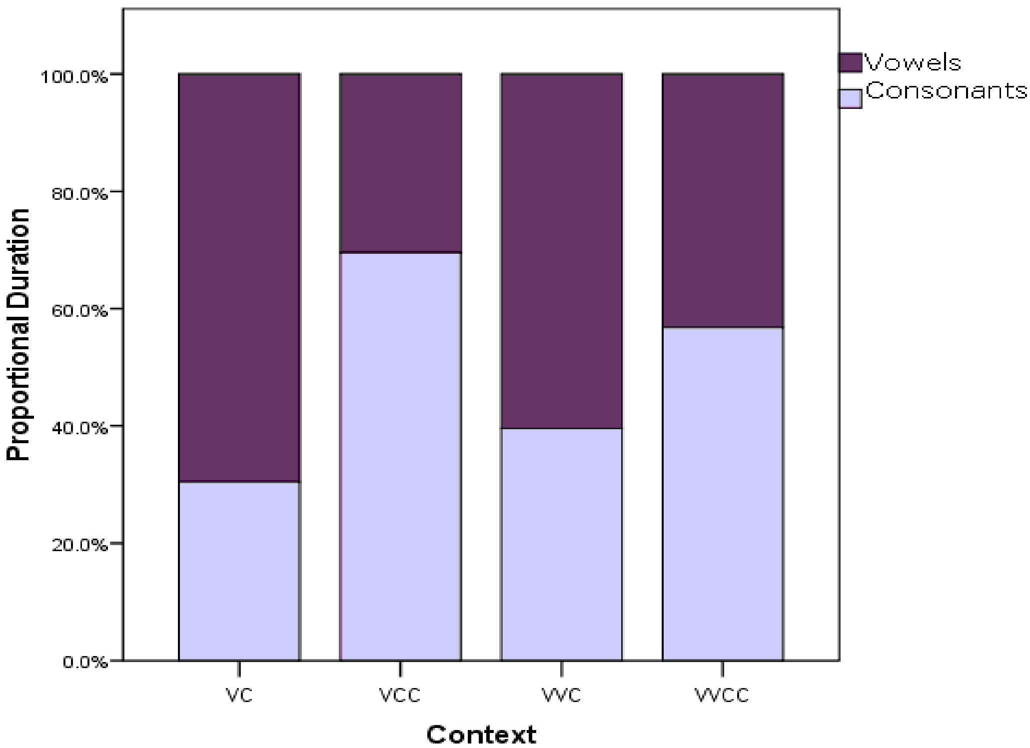


Figure 2.15: Mean proportional duration of the preceding short and long vowels in the context of singleton and geminate consonants.

Ratio of V to VV		
Consonant context	C contexts	CC contexts
Ratio of V to VV	1: 1.15	1 :2.03

Table 2.5: Ratio of V to VV in singleton and geminate contexts.

As far as the geminate type in Arabic is concerned, an ANOVA with the preceding vowel length (short and long) as a fixed factor and the phonological status (singleton consonant, true geminate, fake geminate, and assimilatory geminate) as a random factor shows that the preceding vowel length is significant (F=14.735, p<0.05), the phonological status is not significant (F=0.447, p=0.737), and the interaction between them is significant (F=22.111, p<0.001). This relates to the fact that short vowels preceding singleton consonants and assimilatory geminates are longer than those preceding both true and fake geminates (see Figure 2.16) and that long vowels preceding singleton consonants and assimilatory geminates are shorter than those preceding both true and fake geminates. ANOVA shows that the durational differences of VV in the context of the three geminate types are significant (F=5.804, p=0.004). Post Hoc tests show that long vowels preceding assimilatory geminates are significantly shorter than those preceding both true geminates (p=0.008) and fake geminates (p<0.05). Although long vowels preceding assimilatory geminates are shorter than those preceding singleton consonants, this durational difference is not significant in ANOVA (F=1.601, p=0.211). Regarding the behaviour of short vowels, ANOVA shows that the durational differences of short vowels in the C and CC contexts are significant (F=40.319, p<0.001). Interestingly, Post Hoc tests show that short vowels preceding assimilatory geminates are significantly shorter than those preceding true geminates (p<0.05) and fake geminate (p<0.001). The duration of short vowels before true geminates is not significantly different from short vowels before fake geminates (p=0.278).

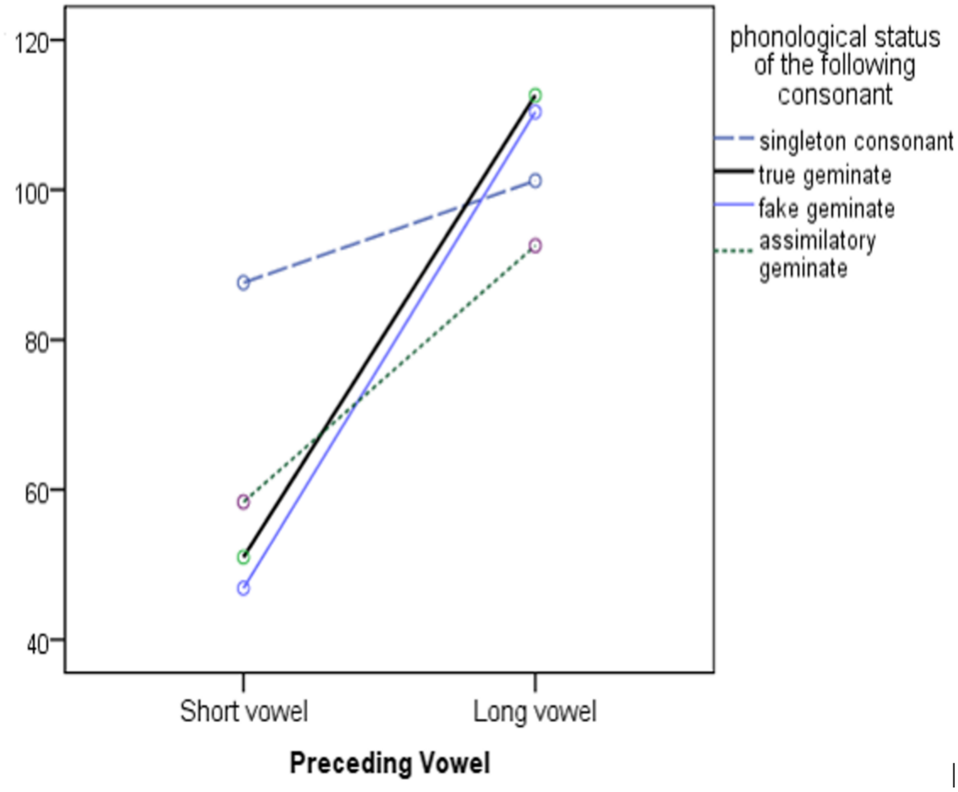


Figure 2.16: Significant interaction between the quantity of the preceding vowel and the phonological status of the following consonant.

Preceding Vowel Duration						
Geminate type	True geminate		Fake geminate		Assimilatory geminate	
Contexts	VCC	VVCC	VCC	VVCC	VCC	VVCC
Mean	50.9	112.6	46.8	110.4	58.3	92.5
S.D.	13.5	21.4	14	24.5	12.1	27.2
Ratio of V to VV	**1 : 2.21**		**1 : 2.35**		**1 : 1.58**	

Table 2.6: Mean duration and standard deviation of short and long vowels before the three geminate types, and the ratio of V to VV in these contexts.

Table 2.6 presents mean durations, standard deviations and ratio of V to VV before the three geminate types. The durational behavior of short and long vowels preceding assimilatory geminates rendered the ratio of V to VV in the case of assimilatory geminates (1: 1.5) smaller than in the case of both true and fake geminates (about 1: 2 for both geminate types).

2.4.2 Non-durational correlates

2.4.2.1 RMS amplitude

Root Mean Square (RMS) average amplitude was measured over the duration of the singleton and geminate consonants in decibels (dB). The RMS amplitude values were extracted automatically from the labelled files using a Praat script that was prepared for this purpose. Since the RMS amplitude is not an absolute measure that can be affected by differences such as loudness (see Ridouane, 2007, and Hankamer, Lahiri and Korenan, 1989), the RMS amplitude of the singleton and geminate consonants was normalised by dividing its value by that of the preceding vowel. Only /l/, /m/, and /r/ were tested for RMS amplitude differences. The cases for the alveolar nasal /n/ were excluded from the analysis since it has no vowels before the singleton cases in the sample, and, therefore, this can affect the validity of the results.

Normalised RMS values were analysed in factorial ANOVAs, which shows that the difference in RMS amplitude between singletons and true geminates is not significant ($F(1,3)=0.186$, $p=0.806$). The sound category and speaker has no effects ($F(3,06)=27.014$, $p<0.05$). The interactions between the singleton-geminate contrast and sound category ($F(2,6)=0,148$, $p=0.871$) and phonological status and speaker ($F(3,6)=0.324$, $p=0.809$) are also not significant. The interaction between the three factors is significant ($F(6,95)=3,061$, $p<0.05$).

The RMS differences between the singleton and each geminate type did not achieve significance either ($F(3,9)=0.344$, $p=0.790$). The sound category is not significant ($F(2,6)=1.300$, $p=0.340$) and the speaker effect is not significant

(F(3,4)=5.045, p=0.062). The interactions between the phonological status and sound category (F(6,18)=0.359, p=0.895) and phonological status and speaker (F(9,18)=0.731, p=0.676) are also not significant. This reflects a consistency in the RMS values for the sounds across speakers. Post hoc LSD tests failed to show any significant difference between the levels of the factors tested here. Figure 2.17 shows the RMS results for the singleton and the three geminate types.

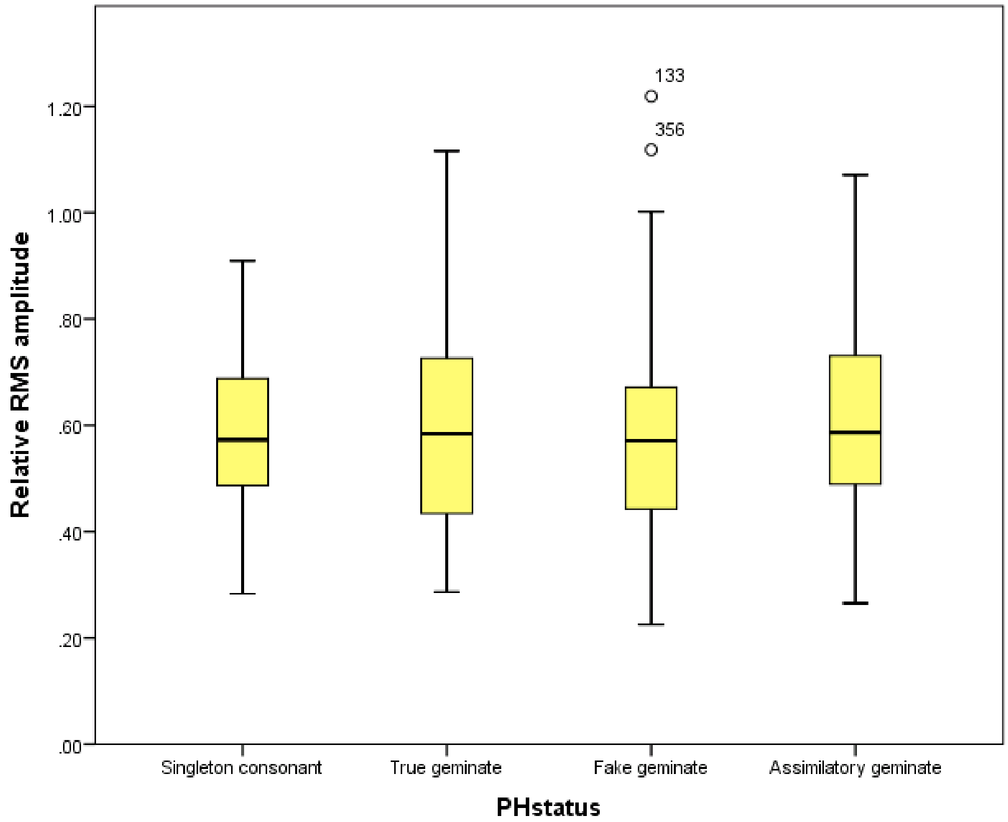


Figure 2.17: Relative RMS amplitude values for singleton and the three geminate types.

The RMS amplitude differences between the three geminate types did not achieve significance either (F(2,6)=0.412, p=0.680). The sound category is not significant (F(2,6)=0.803, p=0.491) and the speaker effect is not significant (F(3,5)=4.750, p=0.059). The interactions between the phonological status and sound category (F(4,12)=0.452, p=0.769) and phonological status and speaker (F(6,12)=30.967, p=0.486) are also not significant. The interaction between the three factors (geminate type x sound x speaker) is also not significant ($F(12,17)=1.496$, $p=0.129$). This reflects a consistency in the RMS values for the three sounds across speakers and across geminate types. Post hoc comparisons also fail to show significant differences in RMS amplitude between the three geminate types.

2.4.2.2 F1, F2 and F3 for the target consonants

Formant frequencies (F1, F2, and F3) were obtained at the mid-point of the target singleton and geminate consonants. The formant values were extracted automatically from the labelled files using a Praat script that was prepared for this purpose. The default Burg LPC algorithm implemented in Praat was used for formant estimation with a maximum frequency of 5 kH for male and 5.5 kH for female speakers. Formant frequencies were then verified manually to prevent potential errors that could result from automatic extraction (illustrations of formant positions in all consonant types are available in Appendix 4). The extracted F1, F2, and F3 values were analysed in factorial ANOVAs each separately to test the singleton-geminate contrast and the three geminate types.

Formant frequencies of F1, F2, and F3 at the mid-point of the four sounds as singletons, true, fake and assimilatory geminates are presented in Figure 2.18. As can be seen from Figure 2.18, even though the formant frequencies can be different for different sounds, it is clear that the general tendency indicates that a geminate consonant (and type) has no effect on the formant structure of the target segments in TLA. As Figure 2.18 shows, F1 does not contribute to the singleton geminate contrast. The phonological status of the geminate shows no effects on F1 across the four sounds either. ANOVA shows that the phonological status is not significant ($F(3,5)=0.038$, $p=0.989$), the sound category is not significant ($F(3,10)=2.268$, $p=0.141$), and the speaker is not significant ($F(3,7)=0.209$, $p=0.887$). The interactions between the phonological status and sound category ($F(8,24)=1.799$, $p=0.127$) and phonological status and speaker ($F(9,24)=0.817$, $p=0.563$) are also not significant. The three-way interaction of phonological status x sound x speaker is not significant ($F(24,30)=.686$, $p=0.865$). Post hoc LSD test also fails to show any significant differences between the levels of these factors.

This result suggests that the structure of F1 is consistent across the singletons and the three geminates types regardless of sound type and speaker.

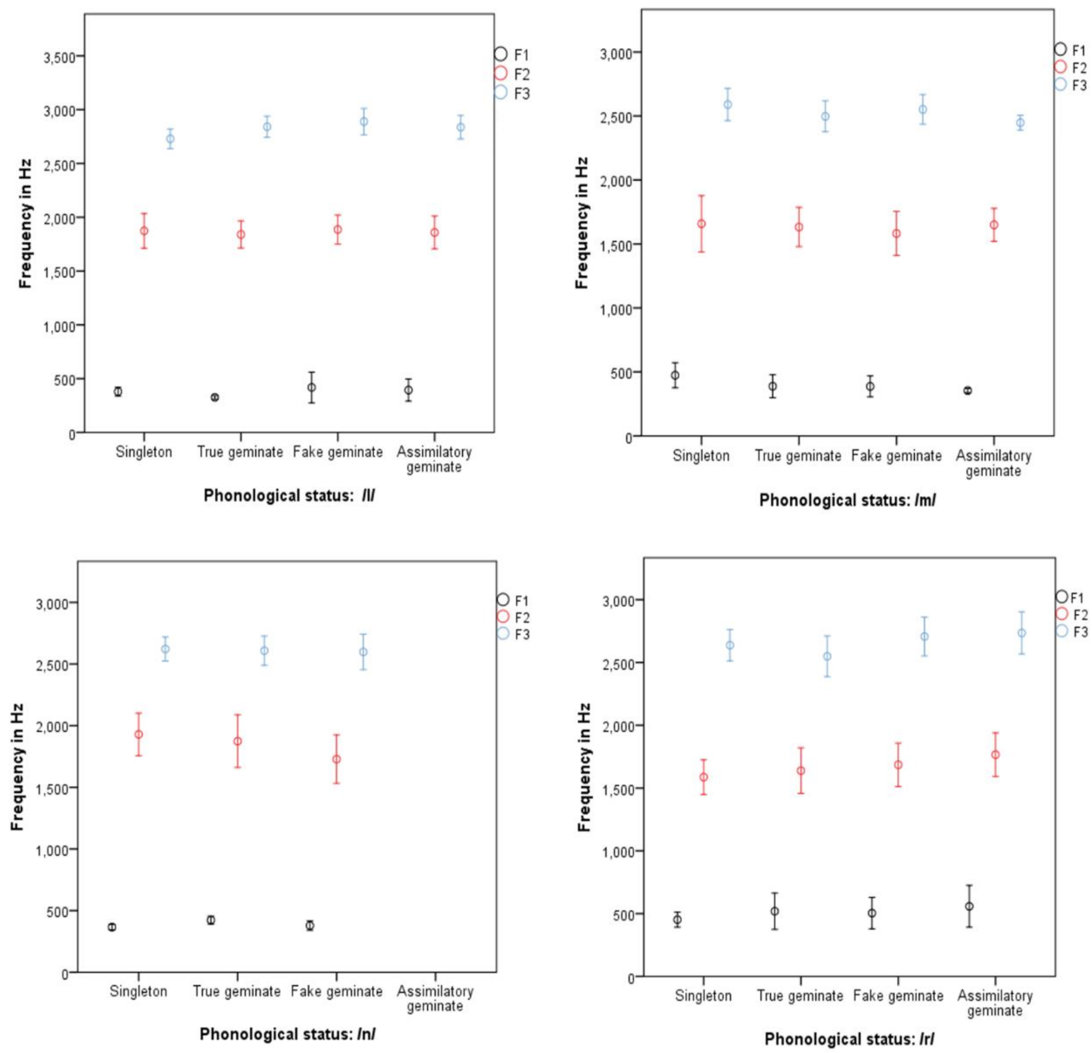


Figure 2.18: Mean frequency (in Hz) of F1, F2 and F3 in /l/, /m/, /n/ and /r/ as singletons, true, fake and assimilatory geminates.

Although it appear to be that there is increase in the frequency of the second formant for the /r/ as a geminate (see Figure 2.18), this is not confirmed by statistical testing since no significant differences could be found for F2 between the levels of the phonological status of this sound. The same applies to F2 of the alveolar nasal /n/, which seems to show decrease in frequency as true and fake geminates compared to singletons. ANOVA shows that the phonological status is not significant ($F(3,2)=0.798$, $p=0.584$), the sound category is not significant ($F(3,8)=1.077$, $p=0.408$), and the speaker is not significant ($F(3,8)=2.630$, $p=0.116$). The interactions between the phonological status and sound category ($F(8,24)=0.847$, $p=0.572$) and phonological status and speaker ($F(9,24)=0.882$, $p=0.555$) are also not significant. The three-way interaction of phonological status x sound x speaker is not significant either ($F(24,30)=1.176$, $p=0.262$). Post hoc LSD test also failed to show any significant differences between any of the levels tested. This result suggests that the structure of F2 is consistent across the singletons and the three geminates types regardless of sound type and speaker, which indicates that gemination has no effect on F2. That is, F2 does not seem to contribute to the singleton geminate contrast or to the distinction between the three geminate types.

It is clear from Figure 2.18 that the phonological status of the consonant has no effect on F3 for all the sound types. This is also confirmed by statistical testing. ANOVA shows that the phonological status is not significant ($F(3,1.7)=1.099$, $p=0.522$), the sound category is significant ($F(3,8)=5.389$, $p=0.022$), and the speaker is significant ($F(3,5)=14.075$, $p=0.006$). The interactions between the phonological status and sound ($F(8,24)=1.313$, $p=0.284$) and phonological status and speaker ($F(9,24)=0.384$, $p=0.913$) are not significant, however. The interaction between the three factors (phonological status x sound x speaker) is significant ($F(24,3)=1.557$, $p=0.049$).

This significant effect of the sound category is apparently resulting from F3 frequencies for the alveolar lateral /l/ that are considerably higher (around 2700 Hz for the singletons and 3000Hz for the three geminate types) than F3 for the other sound types. A deeper look at the data revealed that the significant effect of the speaker factor is resulting from the higher F3 frequencies of the female speaker compared to that of the male speakers. F3 is higher for the female speaker for all singletons and geminates (of all types) (around 2900-3000 Hz) across all sound types compared to male speakers (around 2500-2600 Hz), which is expected as an effect of gender on Formant frequencies. However, this gender effect is not present in the analysis of F1 and F2. Post hoc LSD tests failed to show any significant differences between any of the levels tested, which confirms that the significant sound and speaker effects found here do result from differences between the singleton and geminate consonants or the three geminate types. That is, gemination has no effect on F3 regardless of sound type and speaker.

2.5 Discussion and Conclusion

2.5.1 Hypothesis 1

Hypothesis 1 that 'geminate consonants in TLA are significantly longer than their singleton counterparts' is accepted by considering the significant durational differences between singleton and geminate consonants reported in section 2.4.1.1 above. Duration is found to be a robust cue for the distinction between singleton and geminate consonants in Libyan Arabic. This result supports previous findings from other studies, which emphasize the significant role of duration as consistent cue to gemination (e.g. Ghalib, 1984 and Ham, 2001). The duration of geminate consonants in this study is generally comparable to what has been found for Jordanian (e.g. Al-Tamimi, 2004), Iraqi (e.g. Al-Ani, 1970) (this is only applicable to the duration of nasal consonants reported by Al-Ani 1970, and not to the duration of liquids), and Lebanese (Khattab 2007 and Khattab and Al-Tamimi, 2008), with the duration of a geminate consonant being around twice as long as its singleton counterpart.

The duration of the sound categories investigated here is also comparable to what has been found for Jordanian (Al-Tamimi, 2004) with the bilabial nasal being longer than both the alveolar nasal and the alveolar lateral. However, unlike Jordanian, the present study shows that the alveolar nasal and the alveolar lateral show similar durational patterns. The fact that rhotics show the shortest duration followed by laterals and nasals in Libyan Arabic is in agreement with what has been found for Lebanese Arabic (Khattab 2007 and Khattab and Al-Tamimi 2008).

2.5.2 Hypothesis 2

It is hypothesised that 'there is a strong correlation between the duration of a geminate consonant and that of the preceding vowel in TLA'. That is, geminate consonants in TLA shorten the preceding vowels. This temporal compensation as a phonetic correlation of gemination was investigated in the current study, and, it is clear (see section 2.4.1.3) that there is a strong correlation between the duration of the preceding vowel and the presence of a single or geminate consonant. This study provides evidence that short vowels show absolute temporal compensation. That is, short vowels before geminates are found to be shorter than those before singletons. These findings agree with the findings for Jordanian Arabic (Al-Tamimi, 2004). Moreover, this study suggests that long vowels show temporal compensation in the proportional rather than the absolute level. This agrees with the findings from Khattab (2007). Khattab and Al-Tamimi (2014) also found that the preceding long vowels are shortened before geminates, however, unlike the current study, this was on the absolute level. The findings of the present study contrast with the findings for Iraqi Arabic (e.g. Ghalib 1984 and Hassan 2002, 2003), where the differences of the preceding vowels have been found insignificant. This suggests that the correlation between the preceding vowels and the intervocalic singletons/geminates seems to be dialect-specific

What is noticed here is that geminate consonants preceded by long vowels are longer than geminate consonants preceded by short vowels and that singleton consonants preceded by long vowels are longer than singleton consonants preceded by short vowels (see Table 2.4 and Figure 2.14). However, the duration of geminate consonants following short vowels still significantly longer than the duration of their singletons counterparts. This contrasts with the findings for Jordanian (Al-Tamimi, 2004) and Lebanese (Khattab and Al-Tamimi, 2008) whereby geminate consonants preceded by short vowels are longer than those preceded by long vowels exhibiting a form of proportional compensatory shortening that affects consonants.

The results of the current study also contradicts with Broselow, Chen and Huffman (1997) results: they examined the durational patterns of vowel and coda consonants in various Levantine Arabic dialects and found that (singleton) consonants following long vowels are shorter than consonants following short vowels. The work in Broselow, Chen and Huffman (1997) also demonstrated that even though the duration of a long vowel in a closed syllable is significantly shorter than its duration in an open syllable, it maintains a distinction from short vowels. Watson (2007) states that long vowels and long consonants can behave similarly in certain Arabic dialects in that geminates and long vowels can be reduced by degrees, still maintaining a distinction with simplex consonants. The results of the current study show that even though geminates following short vowels are shorter than geminates following long vowels, their duration is still significantly longer than the duration of their singleton counterparts.

These differences in the durational patterns of the preceding short and long vowels as well as the singleton and geminate consonants among the Arabic dialects can be possibly attributed to the speech rhythm variation in Arabic dialects. As discussed earlier in section 1.2, EA and WA varieties are found to show speech rhythm differences represented partially in different durational patterns of vowels in the two varieties (Ghazali, Hamdi and Barkat (2002). These differences in the durational distribution of the singleton and geminate consonants together with the preceding/surrounding short and long vowels serve to keep the overall rhythmic structure or duration of the word or utterance, which is clearly different between the EA and WA.

2.5.3 Hypotheses 3 and 4

2.5.3.1 Durational correlates

It is hypothesized that the different geminate types differ in their durational properties. There is no conclusive evidence to support this hypothesis (by the results presented in Figures 2.11 and 2.12). The three geminate types are found to have similar durational patterns across sound types with the exception of the alveolar rhotic /r/, which shows longer duration as a fake geminate compared to its duration as a true and assimilatory geminate. Something that could not be related to any manner distributions, which make it hard to assign this durational distinction to any particular reason. Assimilatory geminates seem to be phonetically distinctive from other geminate types. This distinction is not represented in the duration of the geminate segment itself, but rather in the duration of the vowel preceding it. It is clear from section 2.4.1.3 that short vowels preceding assimilatory geminates are significantly longer than those preceding both true and fake geminates (see Figure 2.16) and that long vowels preceding assimilatory geminates are significantly shorter than those preceding both true and fake geminates. Obviously, the behaviour of the VC sequence with the C element being an assimilatory geminate is different from its behaviour with a true or fake geminate. This seems to be the phonetic correlate associated with the phonological status of assimilatory geminates.

2.5.3.2 Non-durational correlates

Generally, in the singleton geminate distinction, the consonant duration is considered as the primary acoustic cue. However, recent findings (see section 2.1 above) argue for the existence of other acoustic parameters of gemination. One of these parameters is greater RMS amplitude for geminates. The higher RMS amplitude of geminate consonants compared to their singleton counterparts is considered as one of the manifestations of tense articulation by Ridouane (2010). He also considers that the higher amplitude of these segments is an automatic result of their longer duration. He relates this explanation of the higher RMS values of geminates to a longer time stop closure that would create higher oral air pressure and greater release amplitude. Hankamer, Lahiri and Korenan (1989) also suggest that the longer duration of the closure of the geminate plosive may lead to higher amplitude upon the release.

However, neither of these proposals has been supported by the data from the current study. That is, there were no differences in RMS between singleton and geminate consonants of any type (see Figure 2.17). RMS differences between the three geminate types were not significant either. I argue here that the higher amplitude of geminates reported in the literature might be considered as a concomitant correlate of manner of articulation and not to phonological length of these long segments. This can be supported by the fact that in the studies where RMS differences have been found to be significant, the analysis was dependent on results from geminate stops. And in case of geminate stop, high RMS amplitude is predictable due to the manner of articulation. On the contrary, in this study, where approximants are used, since there is no high air pressure build up (as a result of closure as in the case of stops), no RMS amplitude differences can be found. This interpretation needs further investigation, and future research should continue to investigate the interrelationships among the manner of articulating geminates and RMS amplitude.

Formant frequencies (F1, F2, and F3) of the target consonants at the mid-point were used in this study to evaluate potential qualitative differences linked with the singleton-geminate contrast and the three geminate types. The formant analysis was used by some researchers to test for the presence of gestural differences between geminates and non-geminates. Payne (2005) found evidence of lower F1 and higher F2 and F3 (measured at mid-point) for the geminate /l:/ in Italian. She interpreted this finding as a more palatalised configuration for the geminate /l:/ than for /l/, suggesting differences in gestural configurations between singleton and geminate laterals that are present in the consonant segment itself. Local and Simpson (1999) also found evidence of lower F1 and higher F2 (at mid-point) for geminate laterals in Malayalam. Their result was robust throughout the dataset. They interpreted this as clearer (more palatalised) resonance for geminates. They suggest that geminate consonants in Malayalam are produced with relative frontness and that non-geminates are darker in resonance than geminates irrespective of their place or manner of articulation based on both the formant analysis results and an impressionistic analysis. The results of these studies suggest that gemination has non-temporal gestural effects on the consonant sounds that is reflected in differences in the formant frequencies of these consonants. However, this proposal has not been supported by the data from the current study. No evidence could be found for the effect of the phonological status on the first three formants. The result of the current study provide evidence that the structure of F1, F2 and F3 is consistent across the singletons and the three geminates types regardless of sound type, which suggests that gemination has no effect on the formant structure of sonorant sounds in TLA. As can be seen from Figure 2.18, a geminate consonant (or type) has no effect on the formant structure of all sound types, suggesting a stability in the articulatory gesture. A possible interpretation for this result is that the presence of differences in F1, F2 and F3 (i.e. possible gestural differences) between singleton and geminate consonants and the three geminate types is language specific.

2.5.4 Conclusion

The aim of this study is to investigate whether the phonological status of singleton and (the three types of) geminate consonants condition their intrinsic acoustic properties. This study provides evidence that duration plays a major role in discriminating the singleton-geminate contrast in TLA. This study presents evidence that the duration of the preceding vowels is another cue to the distinction between singleton and geminate consonants in TLA. However, only short vowels show absolute temporal compensation. In the case of long vowels, the temporal compensation is found to be proportional rather than absolute. The phonological status of a geminate is also found to have phonetic output. This phonetic correlation is not present in the durational properties of the geminate segment itself, as in the case of assimilatory geminates, but rather it is represented in the durational properties of the preceding short and long vowels showing salient temporal alternation that is absent in the case of other geminate types.

As far as the non-durational correlates of geminates are concerned, it appears that the acoustic distinction between singleton and geminate consonants in TLA is dependant mainly on durational correlates. There was no evidence of differences in RMS between singleton and geminate consonants of any type. No RMS differences between the three geminate types as well. In addition, F1, F2 and F3 frequencies are found to show similar patterns for the singletons and the three geminate types of all sounds, suggesting no gestural effects (such as palatalization) of gemination in TLA.

This study serves to contribute to the understanding of the phonetic and phonological aspects of the singleton-geminate contrast and the difference between the three types of geminates in TLA.

Chapter 3: Articulatory study

3.1 Introduction and purpose of the study

The focus of this study is to investigate the articulatory correlates of the singleton-geminate contrast and the three geminate types in TLA using approximant consonants, and compare the findings with those of previous studies on the articulation of geminates in different languages. It is also aimed that the current study complements the acoustic study in Chapter 2.

In the literature, there are two main views on the phonetics of gemination. According to one, the production of a geminate consonant involves the rearticulation of a consonant, whereas the other denies the view of the two-phase articulation and deals with a geminate consonant as a long consonant (see e.g. Ghalib, 1984 and Majdi and Winston, 1993). Ghalib (1984) found no evidence of double articulation in Iraqi Arabic in his articulatory study. Al-Tamini, Abu-Abbas, and Tarawnah (2010) claim that the production of fake geminates involves re-articulation (two articulatory phases), and that the one of true geminates (which they call long consonants) involves one articulatory gesture, claiming that it is this articulatory configuration that lies behind the phonological representation of true geminates as a single melody unit. However, they do not support their claim by phonetic evidence. It is interesting to investigate whether these views are represented in the phonetic output of the singletons and the three geminate types in TLA.

As discussed in section 2.1 of Chapter 2, a number of non-durational correlates of geminates have been investigated by researchers for many languages. Some of these cues can be investigated acoustically, while others can also be investigated through articulatory analysis. For instance, Payne (2005, 2006) showed that, in Italian, geminate laterals are more palatalized compared with their singleton counterparts both acoustically and articulatorily. She also found articulatory evidence, using electropalatograpgy, for the existence of apical contact for singletons as opposed to laminal contact for geminates and a flatter shape of the tongue in geminate articulation (Payne, 2006). Using similar articulatory techniques, the flatter shape of the tongue was also observed for Iraqi Arabic geminates compared to their singleton counterparts (Ghalib, 1984). Although these geminate articulatory correlates have been investigated for some languages, they have not been investigated for TLA. It is interesting to investigate whether these correlates exist in TLA geminates and also whether these are different for the three geminate types.

Moreover, some studies showed that, in languages that allow word-initial voiceless geminate stops, even though the geminate contrast is neutralized perceptually and acoustically (in cases where no significant secondary cues to gemination exist), articulatorily, the distinction still holds in languages such as Tashlhiyt Berber (Ridouane, 2007) and Swiss German (Kraehenmann and Lahiri 2007, 2008). It is shown in these articulatory studies that word-initial geminates were systematically longer in their articulation than their singleton counterparts. Another finding of these studies was that stops were longer in phrase-initial position than in phrase-medial position, which was interpreted as prosodic lengthening and strengthening in cases whereby it involved more linguopalatal contact. Payne (2006) also reported that gemination in Italian involved longer consonant duration as well as greater linguopalatal contact and the use of different regions of articulators. Based on these findings, Payne (2006) analysed gemination in Italian as a fortitional (i.e. strengthening) process. Since approximant consonants are used in this study, it worth mentioning that it is difficult to understand the behaviour of an approximant or sonorant with respect to consonant strength, since they are inherently quite vowel-like and thus might weaken or strength by becoming less like a vowel. Lavoie (2001:81) suggests that "the weak sonorants will resemble vowels more closely, in terms of more formant structure and intensity. A strong sonorant will have less formant structure and perhaps less intensity." The results of the acoustic study in Chapter 2 (see sections 2.4.2.2 and 2.5.2.2) show that the singletons and the three geminate types have similar formant structure and intensity values, which indicates that gemination in TLA does not show strengthening effects. However, it will be interesting to investigate whether these results are mirrored at the articulatory level. That is, to find out whether the approximant geminates in TLA show longer and/or greater linguopalatal contact despite the fact that they do not show strengthening by the acoustic parameters. It will also be interesting to investigate whether the three intervocalic geminate types in TLA show different articulatory configurations in this domain as well.

Although (Arabic) geminates have been investigated phonetically and formed the basis of a wide phonological and theoretical analysis, the accurate articulatory properties of these sounds have not received much investigation and still poorly understood. As can be seen from the literature, only few articulatory studies, using Electropalatography (EPG), have been conducted on gemination. It worth highlighting that the parameters of investigation in these studies are very limited in terms of the measurements conducted and the articulatory properties and correlates investigated.

It is also obvious that the studies on Arabic gemination have concentrated on the durational cues of the singleton-geminate contrast (see review of the literature on Arabic gemination studies in section 1.8 of Chapter 1). This study contributes to the literature on gemination and the literature on Arabic language (and TLA) by providing a detailed investigation of the articulatory correlates of the singleton-geminate contrast and the three geminate types in TLA using Electropalatography (EPG) in TLA. The drive for investigating the three geminate types articulatorily is to ascertain whether underlying differences are reflected in phonetic dissimilarity.

Currently, many aspects of speech research are best entered armed with articulatory data. Instrumental information on the movement of the tongue has been particularly of great importance because the tongue is involved in all vowels and almost all consonants in language (Byrd etal, 1995). Although EPG has predominantly been used for clinical applications, its use for phonetic research is still limited. The parameters employed by researchers for phonetic investigation are also limited.

Although EPG records information on the articulatory contact overtime (see section 3.3.1 for more explanation), phonetic research has not used it efficiently yet. Previous EPG studies typically rely on visual inspection of the articulatory data with limited measurements focusing on the spatial properties alone such as the percent of electrode activation at the middle frame. The current study, on the other hand, will expand the number of measurements and advance the articulatory techniques used for phonetic research to explore and quantify both the spatial and spatio-temporal (dynamic) properties of singleton and geminate consonants. This will give us a complete picture of the articulatory gestures and plans involved in the production of these sounds. This also will allow for cross-linguistic comparisons.

The spatial and spatio-temporal properties that will be measured for investigation in this study will include visual inspection of the frames, the mount of contact at specified region, the centre of gravity, the contact profile over time, the skewness index, the articulatory peak contact duration and the flatness index of the tongue. Combining these measurements will give a complete picture of the articulatory configurations and plans involved in the production of each sound type and geminate type and will allow for comparisons between the singletons and the three geminate types. This study will fill a striking gap in scholarship concerning the articulatory information available for gemination and will allow the results to be compared with those for other languages.

In this articulatory study, the singleton-geminate contrast and the three geminate types will be investigated to see whether they involve: (1) double articulation or rearticulation of geminates of any type; (2) apical contact for singletons as opposed to laminal contact for geminates; (3) a flatter shape of the tongue in geminate articulation; (4) greater linguopalatal contact for geminates; (5) the use of different regions of articulators; and (6) any differences between the absolute acoustic duration and articulatory duration

3.2 Research Questions and Hypotheses

This study investigates the articulatory properties of the singletons and the three geminate types in TLA. There are two main research questions:

1. What are the articulatory correlates of the singleton-geminate contrast in TLA?
2. Does the phonological status of a geminate (true vs. fake vs. assimilatory) influence its articulatory configurations? That is, are they distinguished articulatorily?

In order to answer these questions, the following hypotheses have been suggested:

(H1) Singletons and geminates in TLA are different in their articulatory configurations.

(H2) The different geminate types are different in their articulatory configurations.

3.3 Methodology

In this section, the methods and procedures of investigating the research questions are presented.

3.3.1 Electropalatography (EPG)

To obtain the desired articulatory information, the Electropalatography (EPG) will be used. EPG is an instrumental technique for recording information about the spatial and temporal contact between the tongue and the hard palate during speech. It runs through personal computers and displays results on the PC screen. “It is well established as a relatively non-invasive, conceptually simple and easy-to-use tool for the investigation of lingual activity in both normal and pathological speech” (Toutios and Margaritis, 2005). An essential component of EPG is a custom-made pseudo palate, which is moulded to fit the hard palate (roof of the mouth) of the speaker, and usually made from acrylic or similar material. The artificial palate is embedded with electrodes which serve as sensors for tongue contact (see e.g. Hayward 2000; Byrd, Mueller, and Tan 1995; http://www.articulateinstruments.com/ and http://www.qmu.ac.uk/casl/DownSyndrome/EPG.htm). When the tongue touches these electrodes the pattern is recorded by a computer using specially designed software. These patterns can either be viewed straight away or analysed later by the researcher to infer the tongue movements and trace the contact patterns.

The system used in the current study is the WinEPG (Articulate Instruments Ltd.). The model of the custom-made electro-palate that was used by the subject in the current study is that of the Articulate-style. In this system there are eight rows of electrodes in the electro-palate, six electrodes on the first row (the one behind the front teeth) and eight on each of the other seven rows, forming a total of 62 electrodes. These sensors are spread between the point behind the upper front teeth and the back of the hard palate (see Figure 3.1). In comparison to the Reading-model palate used in some EPG experiments, the position of the first row on the Articulate palates is placed closer to the upper incisors, which allows to distinguish the dental-alveolar and alveolar articulations more easily. Moreover, the position of the electrodes in row 8 is closer to the posterior edge of the palate on the Articulate palates than on Reading palates (see Ramsammy, 2013).

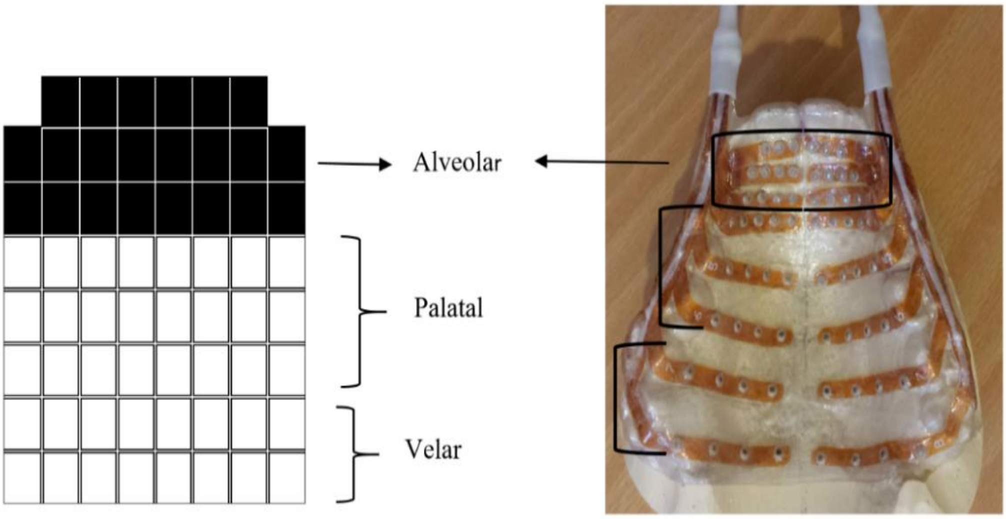


Figure 3.1: Articulate-style palate (right) and EPG frame (left) showing complete closure at the alveolar region (measurement region for the sounds in this study). Black squares record tongue contact; white squares mean no contact.

3.3.2 Subject

One male native TLA speaker participated in this experiment. He was naive as to the purpose of the study. At the time of the experiment, he was 34 years old, and had no obvious speaking or hearing defects. He was born and lived in Tripoli. He had lived and been educated there until he got his first degree. He speaks a typical TLA dialect. He was monolingual during childhood and his parents do not speak languages other than TLA. He was a postgraduate student who speaks English as a second language and he lived in West Yorkshire during the time of the recording. He had been in the UK for about four years. He agreed to take part in the study and signed a consent form.

3.3.3 Stimuli and compiling the word list

The general principles of designing the stimuli and compiling the word list for this study are the same as those of the acoustic experiment reported in section 2.3.1 and 2.3.2 of Chapter 2. Only one set for each sound category was used here. The test tokens compiled for the alveolar nasal /n/ and alveolar rhotic /r/ were the same as those used in the acoustic study, whereas the set of tokens that contains the alveolar lateral /l/ was modified so that all the tokens in the three sets have the tri-syllabic form /CVCV:CV/ with the preceding vowel being the short high front vowel /i/. See Table 3.1 for list of the utterances used in this study. Choosing one set for each sound category and modifying the set compiled for the alveolar lateral /l/ contributed to getting better matching utterances both across and within the sound sets. All the tokens that were used are real spoken utterances which are used in everyday life (even when embedded in the carrier sentence). The carrier sentence used in this experiment was “ma tɡuli:ʃ ____________ ta:ni” ‘Don't say (fm)___________ again’. The bilabial stop /m/ was excluded from the current study since EPG can only register sounds which involve tongue-palate contact.

The set compiled for /l/					
		[ˈlili:na]	‘for Lina’	CVCV:CV	Singleton
		[ˈfil:i:na]	‘cork’	CVC:V:CV	True geminate
/til#li:na/	→	[ˈtil:i:na]	‘pull Lina’	CVC:V:CV	Fake geminate
/min#li:na/	→	[ˈmil:i:na]	‘Who is Lina?’	CVC:V:CV	Assimilatory geminate [n→l]
The set compiled for /r/					
		[ˈli ri:ma]	‘for Rima’	CVCV:CV	Singleton
		[ˈbir:i:ma]	‘valve’	CVC:V:CV	True geminate
/sir#ri:ma/	→	[ˈsir:i:ma]	‘the secret of Rima’	CVC:V:CV	Fake geminate
/min#ri:ma/	→	[ˈmir:i:ma]	‘Who is Rima?’	CVC:V:CV	Assimilatory geminate [n→r]
The set compiled for /n/					
		[ˈli na:ʒi]	‘for Naji’	CVCV:CV	Singleton
		[ˈbin:a:ʒi]	‘I wish’	CVC:V:CV	True geminate
/min#na:ʒi/	→	[ˈmin:a:ʒi]	‘Who is Naji?’	CVC:V:CV	Fake geminate

Table 3.1: Word-list used in EPG experiment with gloss and syllabification

3.3.4 EPG data collection and recording

The WinEPG system equipped with the Articulate assistant software package (Balch and Wrench, 2003-2010: version 1.18, Articulate Instruments Ltd.) was used to record the acoustic and EPG data simultaneously. The recordings were carried out in the Language Research Laboratory in the department of Linguistics and Phonetics at the University of Leeds. The audio signal was sampled at 22.05 KHz and the EPG sampling rate was 100 frames per second.

The speaker was asked to read a list composed of 45 utterances embedded in the carrier sentence (11 utterances x 3 repetitions + 4 filler words x 3 repetitions) at normal speech rate. The test tokens were randomized and the 4 filler words (x 3 repetitions) were inserted after each 2-3 utterances. The filler words (which are the same as those used in the acoustic study) took the form of /CCVC/, which is different from the form of the test tokens, were used in order to divert the speaker's attention away from the purpose of the experiment and to avoid the list effect in any of the target utterances.

The speaker had experience participating in EPG studies and was already equipped with a custom-made pseudo-palate. With his palate on, the speaker was instructed to commence speaking each sentence when hearing a "Beep" sound. He read the first half of the list (23 tokens), and then a break was taken. After that, the second half (22 tokens) was recorded. The typewriting and display of the word list and mood of the subject were treated by the researcher in the same way as in the acoustic study (see the 2nd and 4th paragraphs of section 2.3.3 of Chapter 2 respectively)

In their evaluation of the effect of the pseudo-palates on the acoustic and perceptual integrity of consonants produced by normal adults, Searl, Evittis and Davis (2006) found that there is initial alteration to the speech, but the speakers rapidly adapt to the appliance within 30 minutes as indicated by the acoustic parameters. Perceptually, no change was found in the consonant identification and distortion rating when wearing the artificial palate. McAuliffe, Robb and Murdoch

(2007) also found similar results in their study that investigated adaptation to the standard EPG palate. Generally, mild perceptual change was found upon inserting the palate, but resolved after adaptation. The acoustic findings indicated that the palate did not affect segment duration or vowel formant frequencies. A minimum period of 45 minutes of adaptation is suggested in this study prior to participating in EPG studies.

Before taking part in the current experiment, the speaker had taken part in a number of experiments using EPG over a period of two and a half years. This means that he had gained previous experience of speaking whilst wearing a pseudo-palate (a minimum of 5 hours had been gained already by the time of the current experiment). Prior to participating in this experiment, the speaker wore the pseudo-palate for an acclimatisation period of about 45 minutes. The speaker was asked to read the randomized list of words before and after wearing the pseudo-palate (i.e. during the acclimatisation period) for three reasons: the first is to make sure that he understood the target dialectal words (see section 2.3.3 of Chapter 2), the second is to compare the subject's production of the stimuli auditorily before and after wearing the palate, the third is to make sure that he is adapting the palate before the recording session. I also chatted with him on different topics while wearing his pseudo-palate for about 30 minutes before starting the recording. I can confirm that the way he speaks with the palate on is very close to his normal speech. The palate does not seem to influence or affect the way he speaks.

The recordings have been checked during and after the recording session by the researcher for the rate of speech, adaptation and naturality of production and clarity. Also, a judge, who is a native TLA speaker, was present during the process of recording and judging, and he assured/confirmed (together with the researcher) that the pronunciation was clear, natural and representative of the TLA dialect.

3.3.5 Limitations of using EPG

EPG has predominantly been used for clinical and linguistic applications. It has many advantages, such as: allowing the direct observation of how articulation unfolds over time and the availability of the acoustic signal that can be recorded simultaneously while individuals speak with an artificial palate. However, it has some drawbacks. For example, it cannot show anything other than the actual contact. In addition, in palatogram reading, there are no visual cues for voicing, nasalisation, bilabial articulation or sounds with no oral constriction. For this reason, the waveform and spectrogram are also provided to assist in reading the palatograms. Another drawback is that there is a difficulty in finding subjects willing to undergo such a process. Another equally restricting factor is the financial cost of creating an artificial palate. EPG is relatively expensive for large-scale studies involving many participants. Due to the financial restrictions, there was only one subject in this study, which can affect the power of the statistical analysis. However, it can still give an in-depth insight into the articulatory configurations of the tongue while producing the target segments. It can also contribute to complement the results of the acoustic study in Chapter 2.

3.3.6 Data analysis and measurements

The analysis of articulatory data was done with the Articulate assistant software (version 1.18). The EPG data was annotated using the analysis task window of the software, in which the waveform display, spectrogram display and EPG palate display are presented simultaneously. Some of the required data were extracted manually and then analysed using MS Excel and SPSS software. This is mainly the number of electrodes activated for each row of the target region separately. The constriction area for the alveolar region was defined as the first three rows from the front of the palate (R1-3).

In this study, I have developed and employed a number of new spatial and dynamic parameters to investigate gemination. These new measurement indexes allowed me to gain a detailed description of the articulatory gesture involves in the production of the sounds investigated. Both temporal and spatial properties of the target segments were measured. In particular, the properties measured were the following:

3.3.6.1 Temporal properties:

The recording of EPG data and acoustic signal (spectrogram and waveform) is time-synchronised by the software. Therefore, all target segments labelled with consonant duration defined based on acoustics, with reference to the EPG record. The acoustic segmentation criteria is the same as in Chapter 2 (section 2.3.4). The onset and offset of the consonant interval is usually accompanied with the start and end of the EPG linguopalatal contact at the alveolar region (R 1-3). In the tokens where the start and/or end of the electrode activation in the region does not match that of the acoustic data, a degree of co-articulation of the target segment with the adjacent vowels was observed. Therefore, the start and end of the articulatory gesture was labelled at the point where both the acoustic and articulatory cues match. See Figures 3.2, 3.3, and 3.4 for illustrations of data labelling and segmentation for the three consonant types. This segmentation process was not conducted to do any durational measurements on the target segments (since these were covered in Chapter 2), but rather to be used as a means to determine the onset and offset of the articulatory gesture so as to be able to extract data to be analysed spatially and dynamically (spatio-temporally).

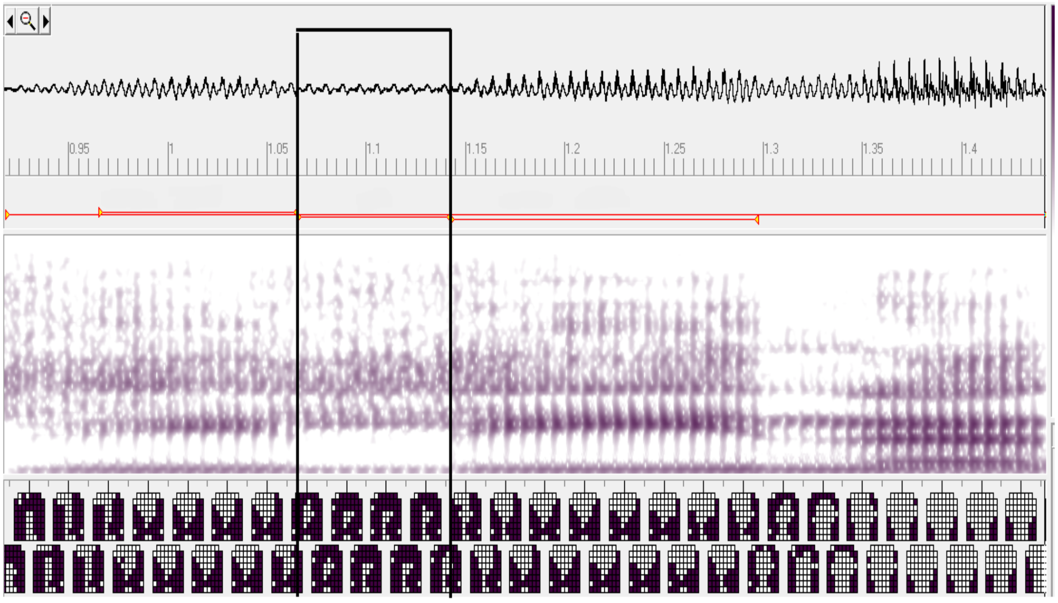


Figure 3.2: EPG frames waveform and spectrogram of the alveolar lateral /l/ in [lili:na] 'for Lina'

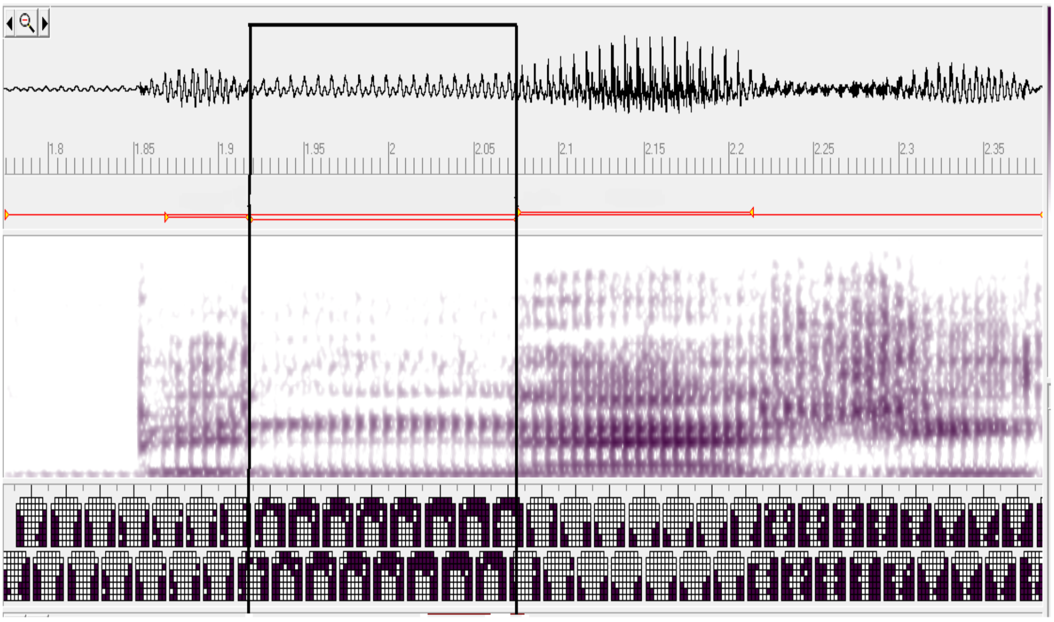


Figure 3.3: EPG frames, waveform and spectrogram of the alveolar nasal /n/ in [bin:a:ʒi] 'I wish'

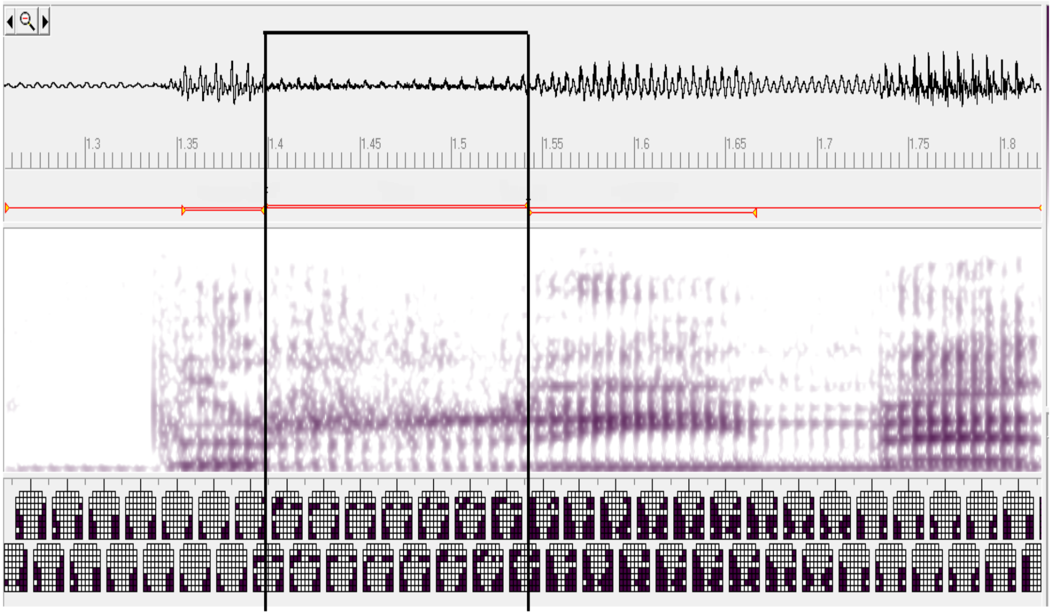


Figure 3.4: EPG frames, waveform and spectrogram of the alveolar rhotic /r/ in [bir:i:ma] ‘valve’

3.3.6.2 Spatial properties:

In addition to the consonant interval, the midpoint (the middle frame of the articulatory gesture) and the point of maximum contact (the frame with the maximum electrode activation within the consonantal interval) were also labelled based on the EPG record. These two points were chosen because the frame with the maximum electrode activation was not typically around the middle of the articulatory gesture as expected. The point of max contact tends to be in the middle in the case of singletons. However, in the case of geminates, it can be found at the periphery of the articulatory gesture. The measurements extracted from these points were converted into several articulatory indices described below:

1. The location, size and shape of contact. These properties were investigated mainly by visual comparisons of the palatograms for each sound combination separately. The contact patterns can provide information about the location of contact on the passive articulator and can be suggestive of the involvement of the active articulator. The depth of the constriction was taken into account as well in order to extrapolate tongue configurations (see Payne 2006: 88).

2. The amount of contact (AoC) at the middle frame and at the frame with the maximum electrode activation. It was measured as the percentage of the electrodes activated of the first three rows in these frames. This index of linguopalatal contact is indicative of a consonant's degree of lingual displacement (see e.g. Byrd et al, 1995).

3. Centre of Gravity (CoG) measurements. These quantify the concentration of activated electrodes over a pre-defined palatal region (see e.g. McAuliffe and Ward, 2006). Two CoG measurements were extracted from the experimental tokens in this study: at mid-point frame and frame with maximum contact. CoG is a weighted mean of contact that provides information about where the contact occurred. A higher value represents contact closer to the alveolar region while a lower value represents contact closer to the velum. In this study, CoG measurements are used to extract information on how anterior the tongue configuration is for the test tokens. qThat is, the higher CoG values, the more anterior the excitation of the electrodes. Alveolar CoG variable was calculated as follows:

$$\frac{(1 \text{ x } R3) + (2 \text{ x } R2) + (3 \text{ x } R1)}{R3 + R2 + R1}$$

where R is the number of activated electrodes in the horizontal palatal rows.

3.3.6.3 Dynamic spatio-temporal properties:

The Dynamic spatio-temporal properties/indices that were measured in this study are described below:

1. The contact profile of segments (rate of contact in R1-3), which was defined as the percent of electrodes contacted at each frame over time (see

Byrd et al, 1995). For each repetition of the test tokens a graph of electrode activation as a function of time was generated for visual evaluation of the rate of articulatory movement during the constriction. Since the target tokens can be of different durations, the time was normalised across the repetitions to have a better view of the general trend of the articulatory gesture. A way to quantify the contact profile in order to be entered into statistical analysis is by treating the resulting graphs as distributions of the amount of contact over time, and thus calculating two properties of the distributions:

a. The distribution skewness as a measure of the degree of asymmetry between the onset and offset portion of the contact profile (see Byrd et al, 1995). This index is useful to compare the speed of closing and release of the constriction. A distribution that is skewed to the right (i.e. positively skewed) implies that the closure formation occurs more quickly than its release, while a distribution that is skewed to the left (i.e. negatively skewed) implies the reverse.

b. Peak contact duration (PCD). I have designed and developed this measurement to quantify the articulatory patterns recorded with EPG. This calculation/index is based on proportional rather than absolute measurements of differences of articulation. It is based on the comparison of the variability in what I called PCD among the articulatory records. PCD was defined as the duration of the articulatory gesture that involves maintenance of peak contact. This, of course, excludes the duration of the build-up and decrease of the constriction at the beginning and end of the articulatory gesture. This was measured as a percentage of the period of maintained peak constriction of the contact profile for each of the test tokens. These measurements were made after normalising the time for all tokens (standardised to an equal length), and hence, these proportional durations can be compared. Each segment is expected to achieve a peak contact at a specific time of the articulatory gesture and maintain this contact for a specific duration. The point or percentage at which this peak contact starts and ends can be different for different sound segments or geminate types. This was the main assumption and/or expectation when this calculation was designed by the author. The criteria for labelling the start and end of this PCD is at the point from which the articulatory gesture starts to look stable or linear and at the point where the percentage of contact starts to decrease (see Figure 3.5 for a schematic illustration of the PCD measurement period).

2. Flatness of the tongue. This is the mean contact divided by the maximum possible contact (i.e. 22 electrodes) of the relevant region (Byrd et al, 1995). If the contact profile is relatively flat, then the contact remains near maximum for more of the duration of the consonant and, therefore, this index will be closer to 1. The assumption is that gestures that maintain a constriction will be flatter than those that form a closure that is quickly released. The index of flatness was measured for two reasons: to investigate whether geminates are produced with flatter tongue configurations than singletons, and to see if the three geminate types are different in this context.

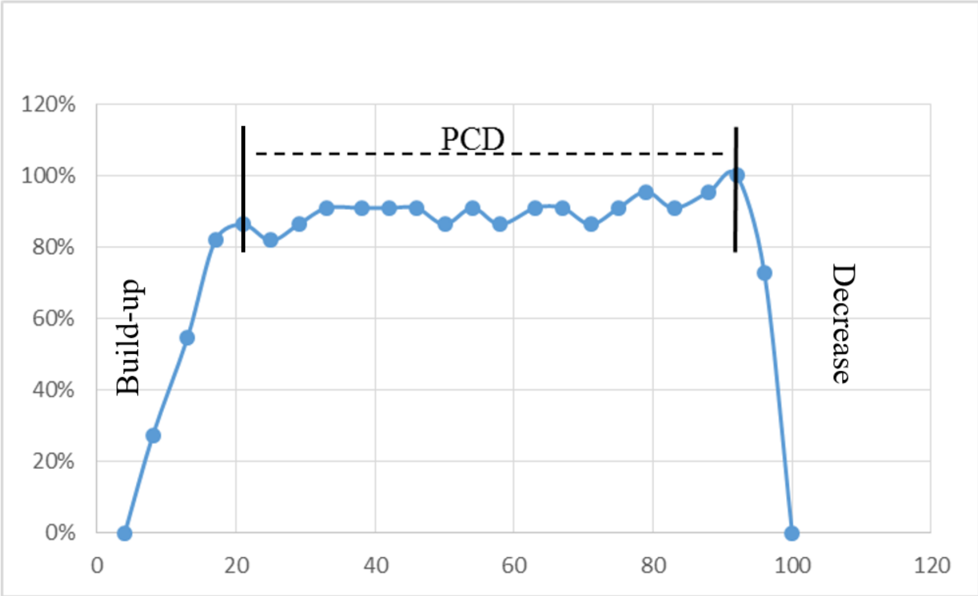


Figure 3.5: Sample contact profile for one repetition of the fake geminate /l/ in which the PCD index is shown schematically

3.3.6.4 Statistics

The results are based on a series of independent analysis of variance (ANOVAs) tests performed using SPSS statistical software package. The reason behind choosing this statistical test are the same as the ones mentioned in section 2.4 of Chapter 2. In all the tests, the fixed factor was phonological status of the target consonants (singletons vs. true geminates vs. fake geminates v. assimilatory geminates) and the random factor was the sound category (/l/, /r/ and /n/). LSD comparisons were performed to determine differences between levels within factors. The dependent variables are five, namely (1) AoC, (2) CoG, (3) Skewness, (4) PCD, and (5) Flatness.

Following Studebaker (1985) proposal, the three variables involving percentages (AoC, Skewness and PCD) were first transformed using the rational arcsine transformation to become suitable for entering the statistical analysis. Expressing the variable as percentages makes it inappropriate for statistical testing, since proportional scales are not normally distributed around the mean. The most important assumption in statistical analysis is that the data are normally distributed and are free to vary widely around the mean with no imposed limits.

Clearly, this is not true of percentages, which cannot be more than 100 nor less than 0. Studebaker (1985) proposed a data transformation for proportional scales, which normalises the data, and thus makes it suitable for statistical testing. He named this method 'rationalised arcsine transform'. It is based on arcsine transformation, with additional linear transformation to make the transformed units numerically close to the original percentages.

3.4 Results

This section reports on the results of the EPG investigation of the articulatory correlates of gemination in TLA. Section 3.4.1 presents the spatial correlates of geminates and section 3.4.2 presents the dynamic correlates.

3.4.1 Spatial parameters

3.4.1.1 The location, size and shape of contact

The location, size, and shape of contact are presented graphically using representative palatograms for each sound combination separately. For each sound, four average palatograms for the singleton and the three geminate types are presented. These average palatogrames were extracted from the Articulate Assistant software by selecting the annotated regions for each of the target sound segments and displaying the average contact patterns. These palatograms represent the percentage of activation of each electrode over time for the whole constriction period of the target segment. This percentage is indicated in the figures both numerically and by shades of purple (the darker the shade, the higher the percentage).

Figure 3.6 presents the palatograms for the alveolar lateral /l/. All three geminates show more linguopalatal contact than singletons at rows 2 and 3. They also show somewhat deeper contact (i.e. go further back in the mouth – in this case, extends to row 4) than singletons, something that could be interpreted as a more laminal contribution to the articulation of geminates and an apical production of singletons. In regards to the differences between the three geminates, it is clear that fake geminates show more contact at rows 1-4 than both true and assimilatory geminates, with the whole constriction area (R1-3) completely occluded. This observation could be interpreted as a more laminal contribution to the consonant as a fake geminate. Regarding the size of contact, considerably more electrodes were activated in the case of geminates than singletons.

An interesting point to notice here is that, in the case of both singletons and geminates, there is lateral contact throughout the articulations, thereby precluding any lateral airflow. The contact indicates sealing of the closure around the sides of the palate (i.e. the lateral contact is complete on both sides). However, a closer look at the percentage of activation of the electrodes show that the closure of the-mid-sagittal line of the palate (2-4 rows) at the alveolar region was not maintained throughout the whole constriction period and will allow for some central escape of air. In addition, it is likely that the escape around the oral obstruction is further back in the mouth than the palatogram is able to show since the percept remains that of an authentic lateral.

Ladefoged and Maddieson (1996) state that laterals do not always have the airflows around one or both sides of the tongue. They explained that although most lateral segments in the world’s languages are made with an occlusion in the dental/alveolar region, the area of contact may extend further back in the mouth, meaning that the lateral escape is located further back. Supporting their argument with examples of laterals from many languages, they also add that laterals do not always have complete central closure and even when they have some central airflow they have a larger escape channel further back in the mouth.

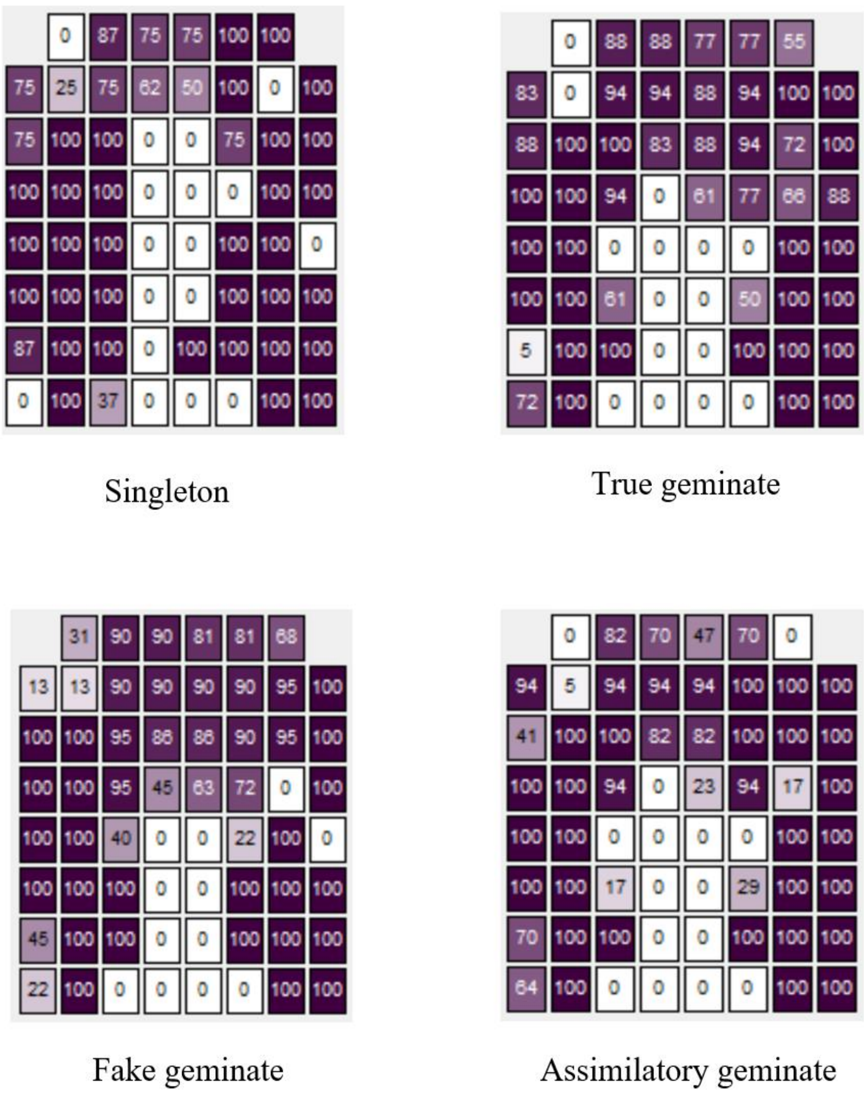
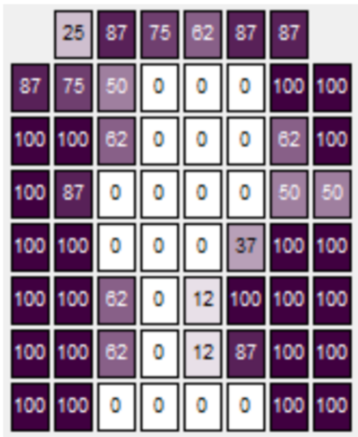
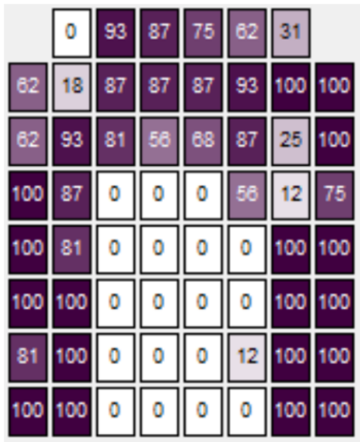


Figure 3.6: Palatograms of the singleton and the three geminates types of /l/.

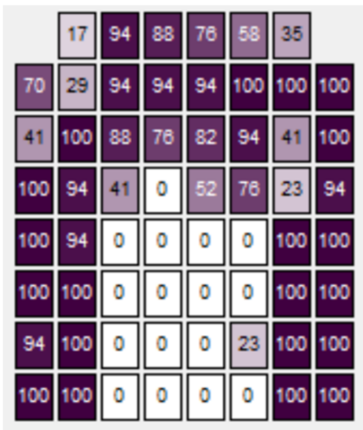
The differences between the singleton and geminate palatograms in the case of the alveolar nasal /n/ are presented in Figure 3.7. Geminates show more linguopalatal contact than singletons. Regarding the location of the contact, for singletons, the main contact lay along the first row indicating an apical articulation; in the case of true geminates, the occlusion occurred in the first three rows with more linguopalatal contact percentages at rows 2-3, something that could be taken to indicate an apico-laminal articulation; in the case of fake geminates, the occlusion occurred in the first four rows (with R1-3 showing more contact than R4), something that could be interpreted as a more laminal contribution to the articulation. The firm contact at the two lateral columns for both singletons and geminates could correspond to a ‘cupped’ (concave) tongue configuration. This shape of contact is compatible with the apical and apico-laminal interpretation of the contact patterns.



Singleton



True geminate



Fake geminate

Figure 3.7: Palatograms of the singleton and two geminate types of /n/.

Figure 3.8 presents the palatograms for the alveolar rhotic /r/. Geminates show more linguopalatal contact than singletons. The amount of contact in the second row is more in the case of fake geminates than assimilatory and true geminates, though the main contact lies in the third row for all geminate types. True geminates show less amount of contact in rows 2-3 than fake and assimilatory geminates. It is clear that the /r/ is produced with an apical tongue configuration in all cases. However, the tongue is fronted in the case of singletons and retracted in the case of the three geminate types. That is, as an apical anterior alveolar for singletons vs. apical posterior alveolar for geminates.

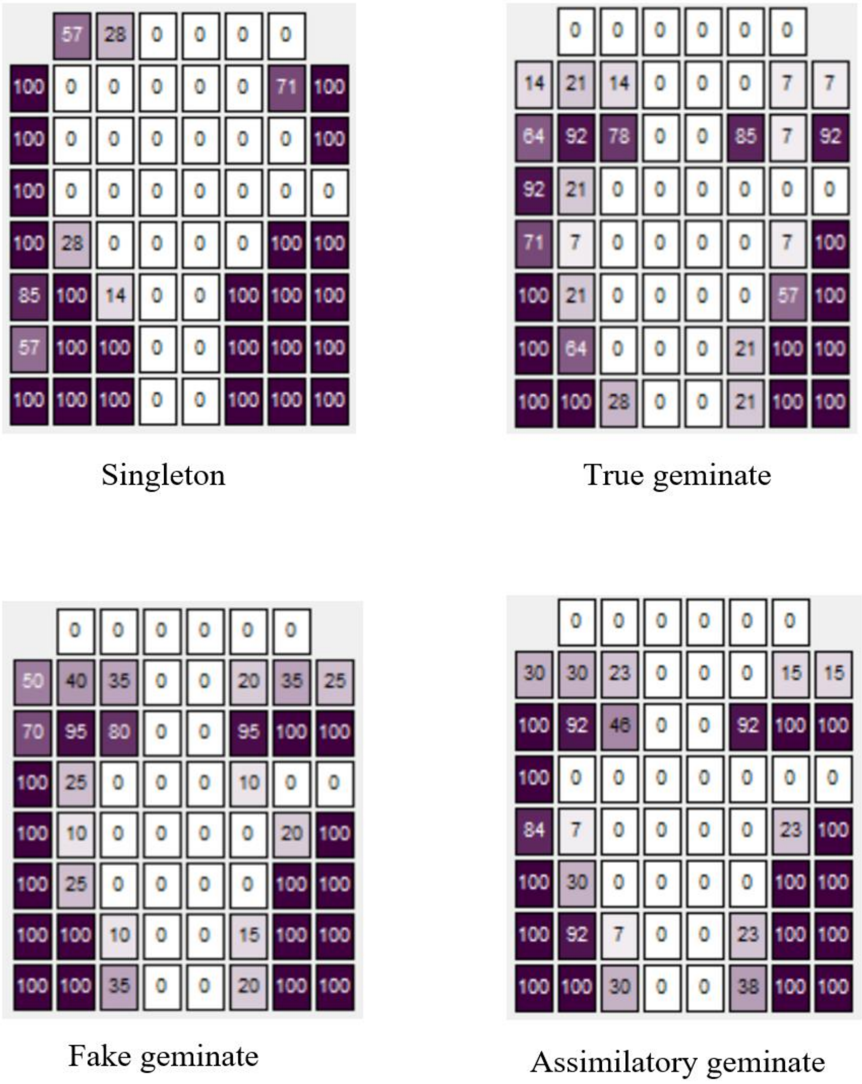


Figure 3.8: Palatograms of the singleton and three geminate types of /r/.

Auditory analysis of these rhotic sounds reveals that these are realised as approximant rhotics, but the fact that there is a degree of contact at the alveolar region makes it hard to judge on the articulatory configurations or the manner of articulation involved in the production of this sound in TLA. In her tutorial on palatogram reading, Byrd (1994: 23) states that the typical production of the approximant /r/ shows “no information on the position of the tongue tip except that there is no contact with the palate”. She explained that the raising of the rear of the tongue can be observed, however. The production of the alveolar rhotics of the current speaker show a degree of contact, and hence may not be considered approximants. However, this contact did not form a close constriction (as can be seen in Figure 3.8 above) and so they cannot be considered as taps. The durational configurations and auditory analysis also confirms that these are not taps. Also, no trill realisations were recorded for the speaker in this study. Figure 3.9 presents illustrative EPG palatograms of the fake geminate /r/. It is clear that the linguopalatal contact mainly starts at the second and third rows of the alveolar region of the palate, and, then, a kind of retraction occurs where only electrodes from the third row are activated. The marginal electrodes on the second row are activated again towards the end of the articulatory gesture. This articulatory configuration is typical for all the geminate types of /r/ for the speaker. Apparently, this articulatory configuration for the rhotics in TLA needs more investigation.

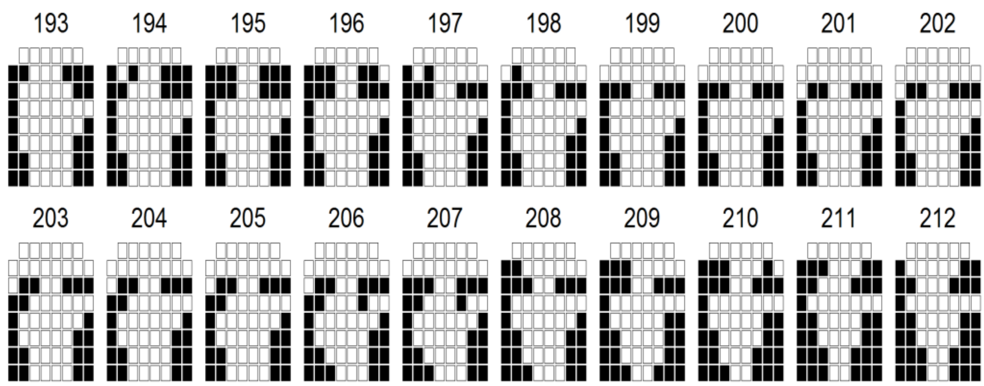


Figure 3.9: EPG palatograms of the fake geminate /r/.

In summary, it is clear from the above description of the location, size and shape of contact that both the singleton and geminates in the case of /l/ show a somewhat more and deeper contact than in the case of /n/, which in turn show more contact than /r/. It is also clear that all three geminate types show more linguopalatal contact than singletons. They also show somewhat deeper contact than singletons, something that could be interpreted as a more laminal contribution to the articulation of geminates and an apical production of singletons. Also, fake geminates tend to involve more linguopalatal contact than both true and fake geminates in all three sounds, suggesting even more laminality in their production. It worth highlighting that the assimilatory geminates in this study were found to be the result of total assimilation. This is confirmed by the palatograms of the relevant tokens where traces of the assimilated segments could not be found.

3.4.1.2 Amount of contact (AoC)

Figures 3.10 and 3.11 show the mean of the AoC at the frame with the maximum electrode activation and at the middle frame for the singletons and the three geminate types. An ANOVA testing the AoC at the maximum frame shows that the phonological status is significant ($F(3,5)=6.186$, $p<0.05$), the sound category is significant ($F(2,5)=80.829$, $p<0.001$) and the interaction between them is not significant ($F(5,22)=2.188$, $p=0.092$). Post hoc LSD tests show that the differences in the AoC between singletons and both true and fake geminates are significant ($p<0.001$). However, the differences between the singletons and the assimilatory geminates did not achieve significance ($p=0.114$). The maximum contact in the case of fake geminates is significantly different from both true and assimilatory ($p<0.05$ and $p<0.001$ respectively). However, the differences between true and assimilatory geminate did not achieve significance ($p=0.079$). Overall, these results indicate that geminate consonants at the maximum frame show larger AoC than singletons in TLA. The three geminate types show different configurations as well, with the fake geminate showing largest AoC. These results are consistent among the three sound categories. As can be seen in Figure 3.10, the general trend of the AoC among the three sounds is the same with the fake geminate showing the highest amount of contact for /l/, /r/ and /n/. It is also obvious that /l/ and /r/ show similar AoC in the case of true and assimilatory geminates. This is reflected in the non-significant results of the interaction between the phonological status and the sound category reported above.

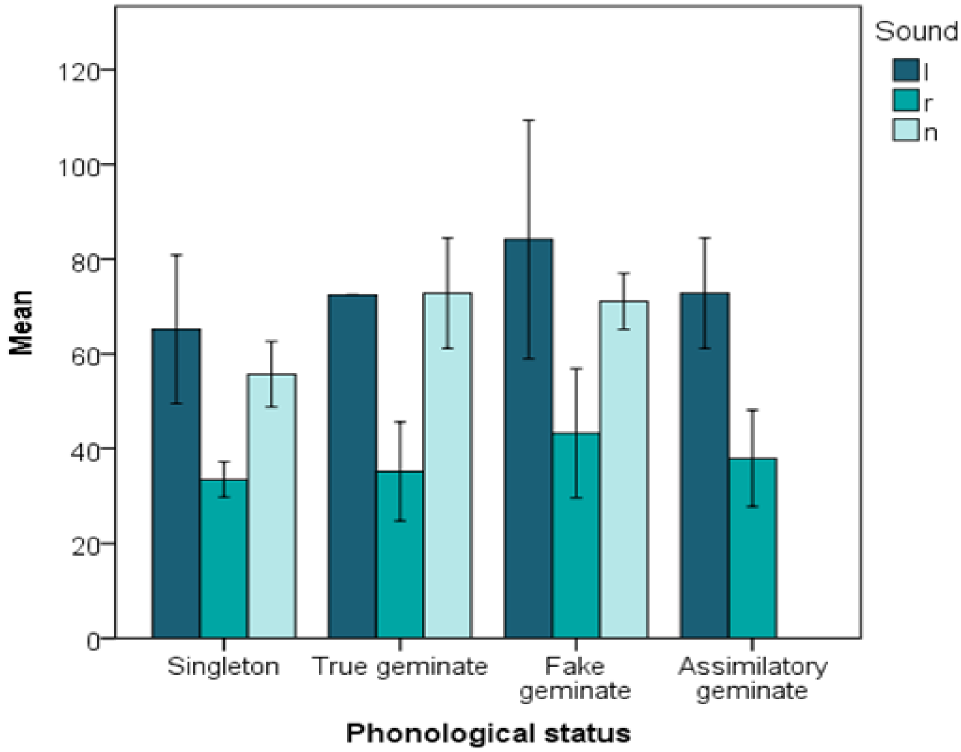


Figure 3.10: Mean of the AoC at the maximum frame

A factorial analysis of variance ANOVA testing the AoC at the mid-frame show that the phonological status is not significant ($F(3,5)=0.102$, $p=0.955$), the sound category is significant ($F(2,5)=54.608$, $p<0.001$), and the interaction between them is significant ($F(5,22)=3.724$, $p<0.05$). Post hoc comparisons reveal that the AoC at the mid-frame of the singletons is not significantly different from that of both true and fake geminates. However, it is significantly different from assimilatory geminates ($p<0.05$). Assimilatory geminates show significant differences from both true and fake geminates ($p<0.5$). The differences between true and fake geminates did not achieve significance, however ($p=0.794$).

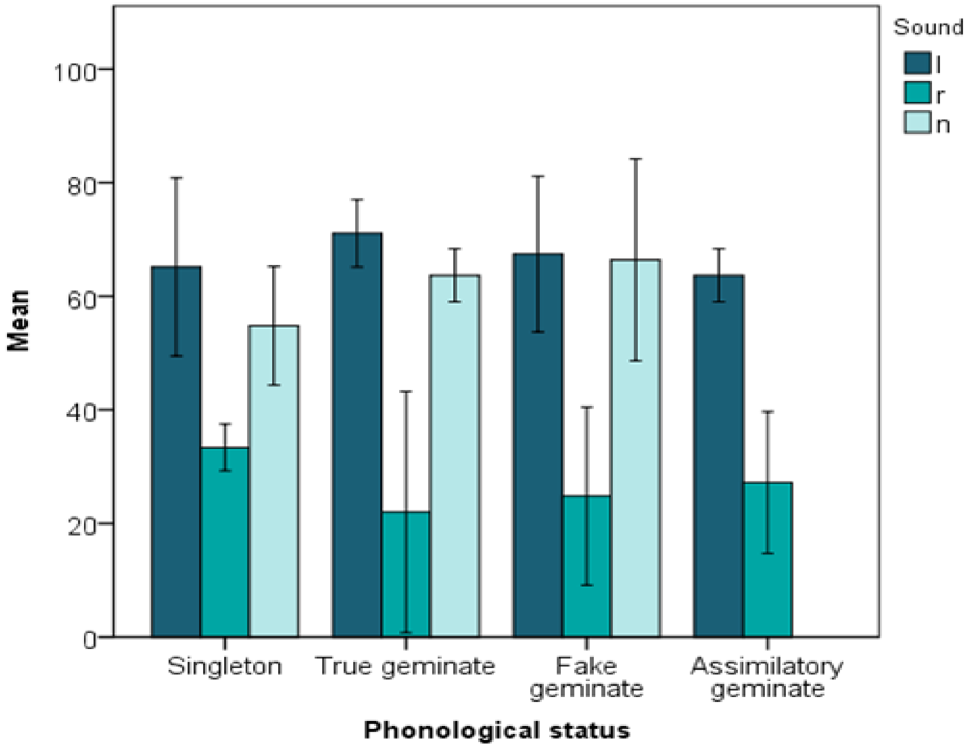


Figure 3.11: Mean of the AoC at the middle frame

As shown in Figure 3.11, the alveolar rhotic /r/ shows a higher AoC at the mid-frame in the case of singletons than in the case of the three geminate types with little variation. In contrast, the geminate alveolar nasals /n/ involved more linguopalatal contact than its singleton counterpart. The same can be said regarding the alveolar lateral /l/, where it shows slightly higher amount of contact, as a true and fake geminates, than their singleton counterpart. However, the assimilatory geminate /l/ shows similar amount of linguopalatal contact as that of the singletons.

Figures 3.10 and 3.11 show clearly that at both the maximum and middle frames the /r/ has the least AoC followed by the /n/ and then the /l/ with the largest contact mean regardless of their phonological statuses. For the three sounds, it is clear that the AoC at the maximum frame show a somewhat different configuration than that of the mid frame.

3.4.1.3 Centre of Gravity (CoG)

Figure 3.12 presents the mean values of the CoG at the maximum frame for the singletons and the three geminate types of /l/ /r/ and /n/. CoG at the maximum frame shows no significant differences among the levels of the phonological status ($F(3,5)=2.450$, $p=0.179$), a significant effect of the sound category ($F(2,5)=14.207$, $p<0.01$) and a significant interaction between them ($F(5,22)=3.932$, $p<0.05$). LSD post hoc tests show that singletons have significantly higher CoG than the three geminate types. It is clear from Figure 3.10 that the three consonants show higher CoG values in the case of singletons than in the case of the three geminate types. This suggests that singletons are produced with more anterior tongue configuration than geminates regardless of the sound type. True geminates are not significantly different from either fake ($p=0.121$) or assimilatory ($p=0.258$) geminates. Although the comparison tests show significant differences between assimilatory and fake geminates ($p<0.05$), this significance seem to be the result of the fake and assimilatory geminate /r/ values as it is clear from Figure 3.12.

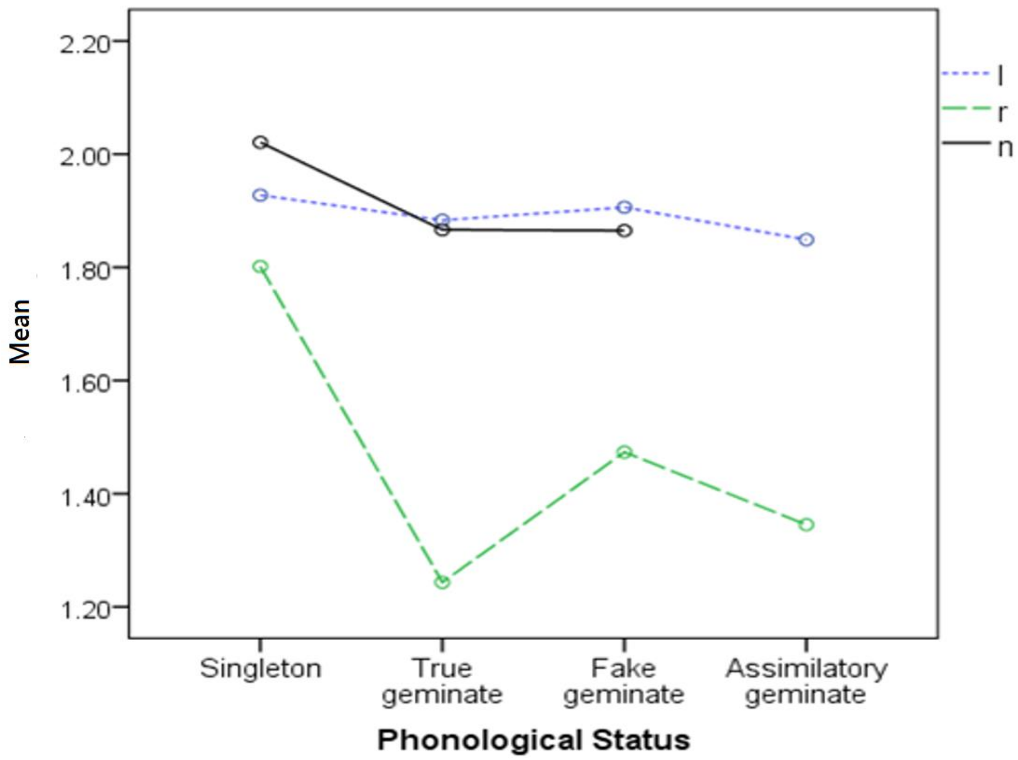


Figure 3.12: Mean of the CoG at the maximum frame.

The results of testing the CoG at the mid-frame (Figure 3.13) are generally similar to those obtained at the maximum frame. ANOVA shows that the phonological status is not significantly different ($F(3,5)=1.609$, $p=0.299$), the sound category is significant ($F(2,5)=11.913$, $p<0.05$) and the interaction between them is significant ($F(5,22)=30.119$, $p<0.001$). Post hoc LSD tests show that the CoG for singletons is significantly higher than that of the three geminate types ($p<0.001$). Assimilatory geminates show significant differences from both true and fake geminates ($p<0.01$), but the differences between true and fake geminates did not achieve significance ($p=0.607$). As in the case at the maximum contact, it is clear from the graphs that the singletons show higher CoG values than geminates for all sounds.

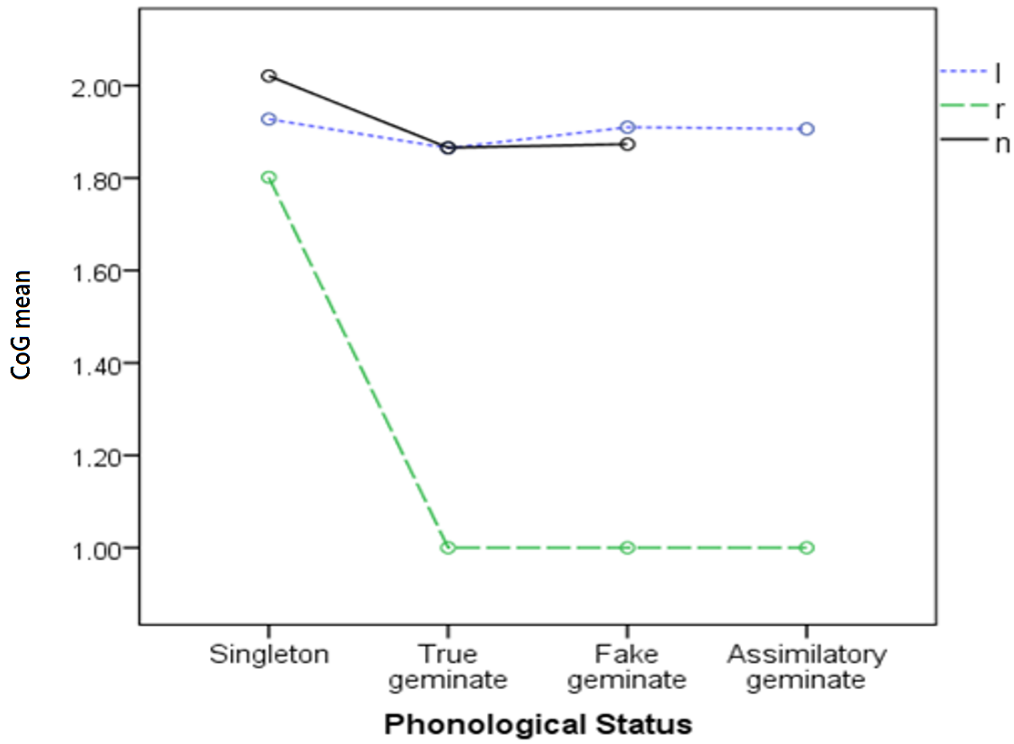


Figure 3.13: Mean of the CoG at the middle frame.

It is clear from Figures 3.12 and 3.13 that the alveolar rhotic /r/, at both the maximum and middle frames, has lower CoG mean values than that of /n/ and /l/. These results reflect the observations found in section 3.4.1.1 above. It is also clear that the CoG for /l/ and /n/ at both the maximum and mid-point frames show similar configurations across the three geminate types. However, the CoG values for /r/ vary across the three geminate types in these frames.

3.4.2 Dynamic spatio-temporal properties

3.4.2.1 The contact profile of segments

3.4.2.1.1 The alveolar lateral /l/

Figure 3.14 shows the contact profiles for the singleton and the three geminate types of the alveolar lateral /l/. There is no evidence of re-articulation (or double articulation) in the articulatory gesture of the three geminate types of this sound. In the first repetition of the assimilatory geminates, there seems to be a kind of re-articulation trend, but not in the second or third.

The graphs show that the number of EPG frames (i.e. as an indirect indication of the articulatory duration) involved in the production of geminates is clearly larger than singletons. The graphs also show that up to 80% of the electrodes in the alveolar region are activated in the case of singletons, whereas the percentage can reach up to 100% in the case of the three geminate types, which can be interpreted as a flatter tongue configuration in the case of geminates.

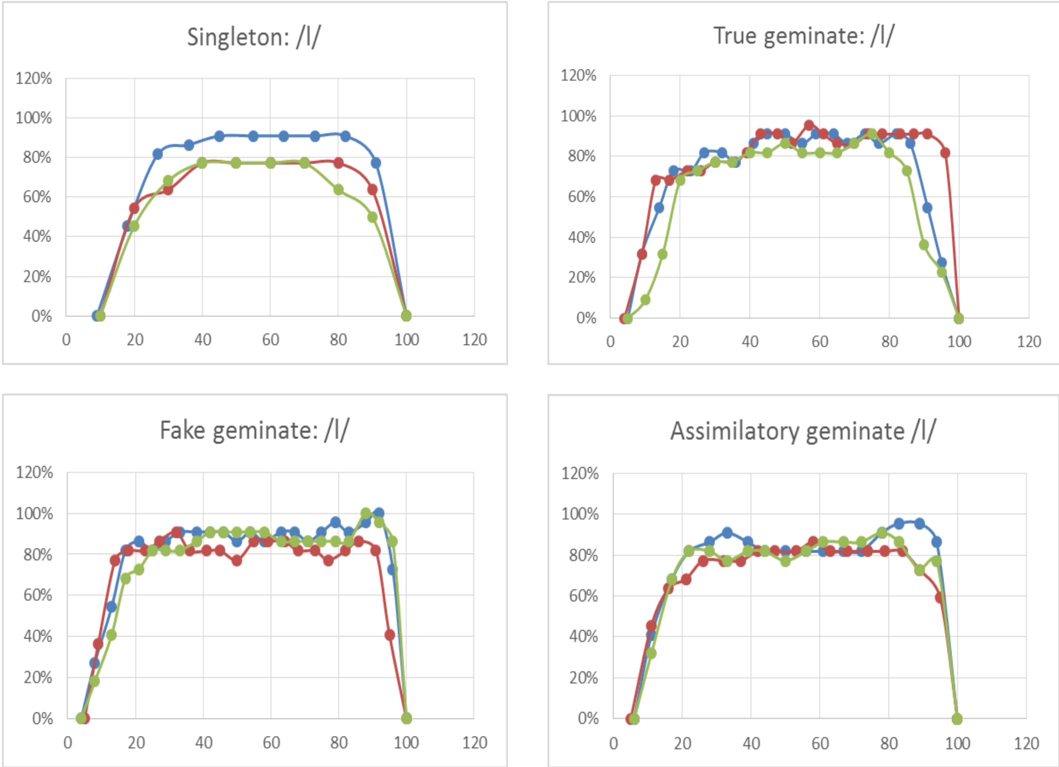


Figure 3.14: Contact profiles of the singleton and the three geminate types of the alveolar lateral /l/.

3.4.2.1.2 The alveolar rhotic /r/

Figure 3.15 shows the contact profiles of the singleton and the three geminate types of the alveolar rhotic /r/. Unlike the singleton /r/, the overall articulatory gesture of the three geminate types looks like a two-phase articulation (re-articulation). However, by comparing these profiles with the illustrative frames in Figure 3.9 above, it is clear that this is not an actual re-articulation. Apparently, this is a single articulatory gesture. This two-phase like contact profile is a result of the fact that the linguo-palatal contact starts mainly at the second and third rows of the alveolar region of the palate, and then, a kind of retraction occurs where only electrodes from the third raw are activated. The marginal electrodes on the second row are activated again towards the end of the articulatory gesture. Therefore, the drop in the percentage of articulation at the middle of the contact profile is the result of a retraction in the tongue movement rather than re-articulation of the sound. See Figure 3.16 for a schematic illustration of the production of the geminate alveolar rhotic /r/ combining acoustic display, EPG frames and corresponding contact profile.

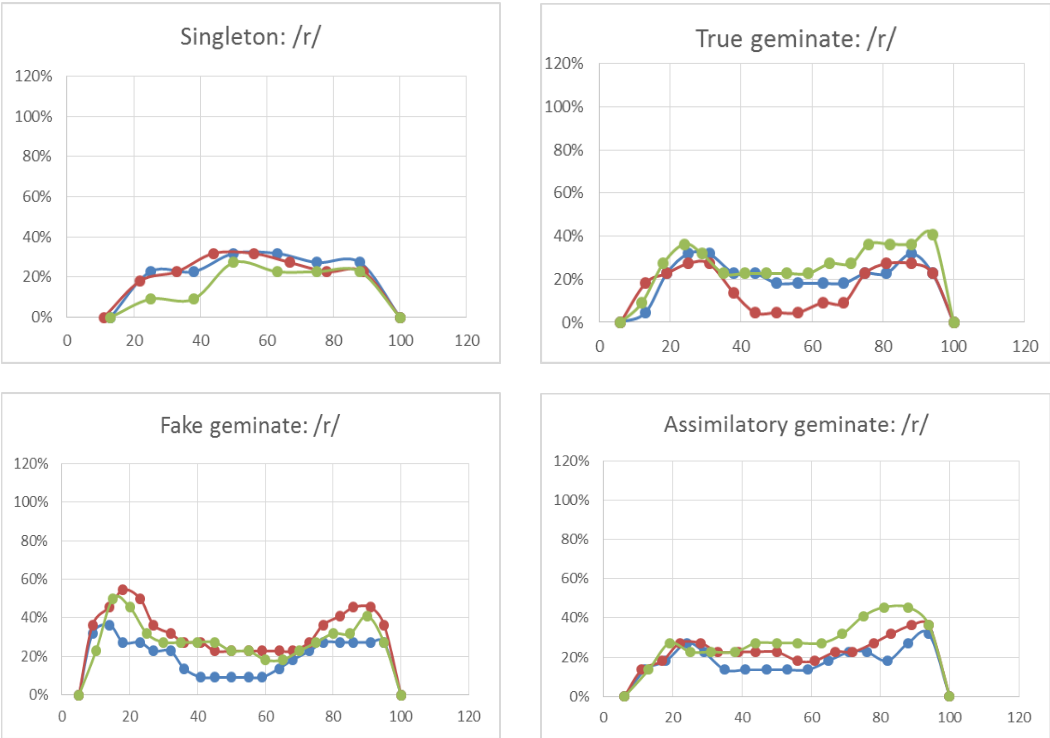


Figure 3.15: Contact profiles of the singleton and the three geminate types of the alveolar rhotic /r/.

As Figure 3.16 shows, the articulatory gesture starts by the tongue contacting the alveolar region at rows 2 and 3. Then, when the tongue retracts, only the tip of the tongue will be able to contact the hard palate. As a result, we got the single row contact in the middle frames corresponding to the lower in the percentage of contact at the middle of the articulatory gesture -- i.e. the dip in the middle of the contact profile. In this position, the tongue will be slightly retroflexed or retracted and, as a result, it is mainly the tip of the tongue that is able to touch the alveolar region and, consequently, only one row will be activated. Towards the end of the articulatory gesture, the tongue moves forward to its previous position contacting the alveolar region at rows 2 and 3 again.

To sum up, the right and left electrodes of the alveolar region show increase of contact at the start and end of the articulatory gesture but decrease towards the middle of the gesture due to inward tongue tip retraction. Therefore, it can be said that the three different phases in Figures 3.16 are, in order, onset/approach, target, and offset/release phases reflecting the dynamic nature of this rhotic in TLA.

The graphs in Figures 3.15 and 3.16 show that only about 40% of the electrodes in the alveolar region are activated during the two peaks and between 5% and 23% at the middle of the sound production.

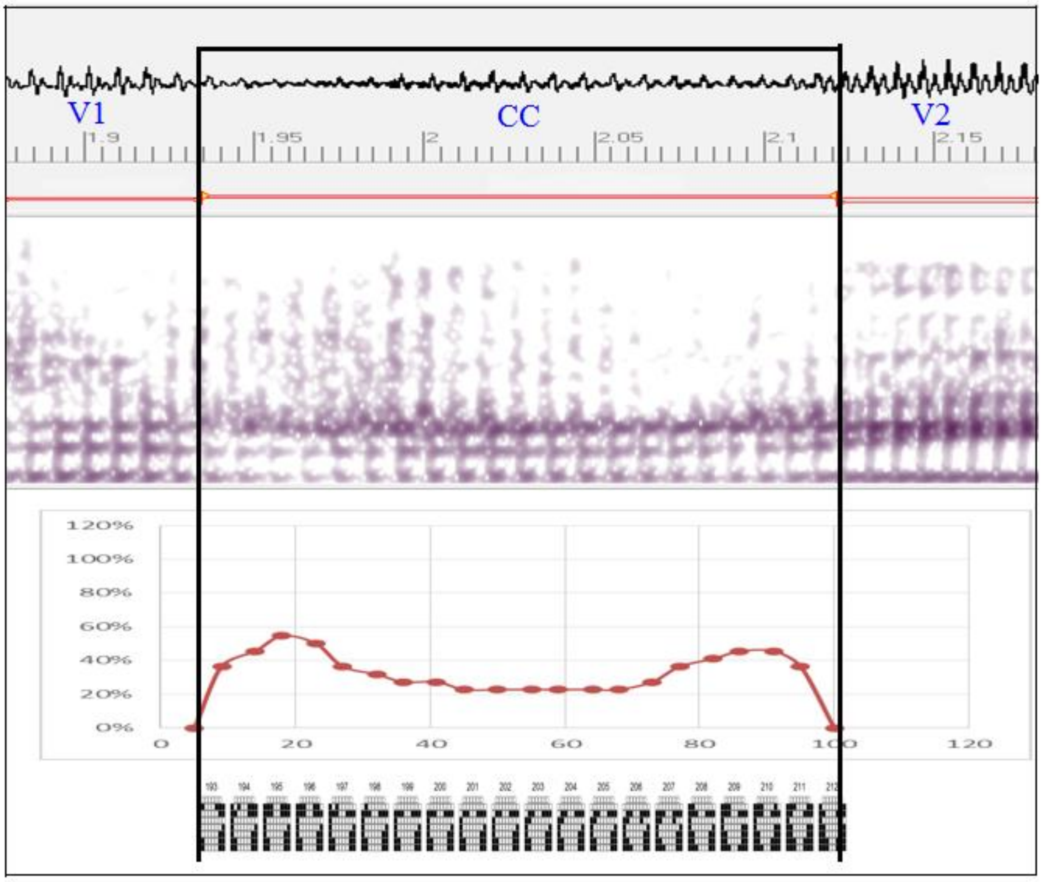


Figure 3.16: Acoustic display, EPG frames and contact profile of the geminate /r/ in in /sir:i:ma /.

3.4.2.1.3 The alveolar nasal /n/

Figure 3.17 shows the singleton and two geminate types of the alveolar nasal /n/. Only about 70% of the contact area is activated during the production of the singleton /n/, whereas in the case of fake geminates up to 90% of the electrodes in the contact area are activated. In the case of true geminates, the percentage of contact keeps increasing overtime to reach its maximum towards the end of the articulatory gesture resulting in a negative skewness of the contact profile.

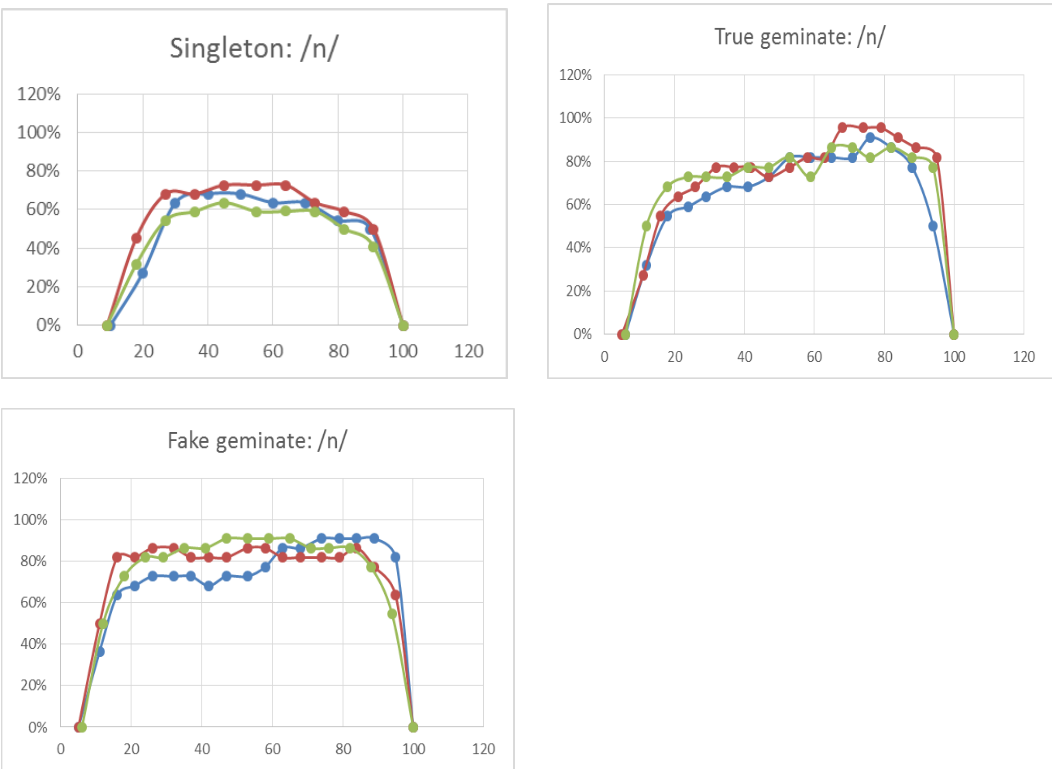


Figure 3.17: Contact profiles of the singleton and the two geminate types of the alveolar nasal /n/.

3.4.2.2 Skewness

Figure 3.18 presents a scatter dot plot for skewness in the articulatory gestures of the singleton and the three geminate types. It is clear from the scatter plot that the values for the skewness index are gathered/accumulated around zero for singletons which indicates a symmetric shape of the articulatory gesture. This symmetry suggests that the build-up and decrease in contact of the articulators (onset and offset portions) in the case of singletons are of the same speed or performed at equal or similar speed. In the case of geminates, however, it is clear that there is a general tendency for negative skewness (skewed to the left). This skewness is clearer in the case of true geminates which achieve significant differences from the singletons in statistical testing.

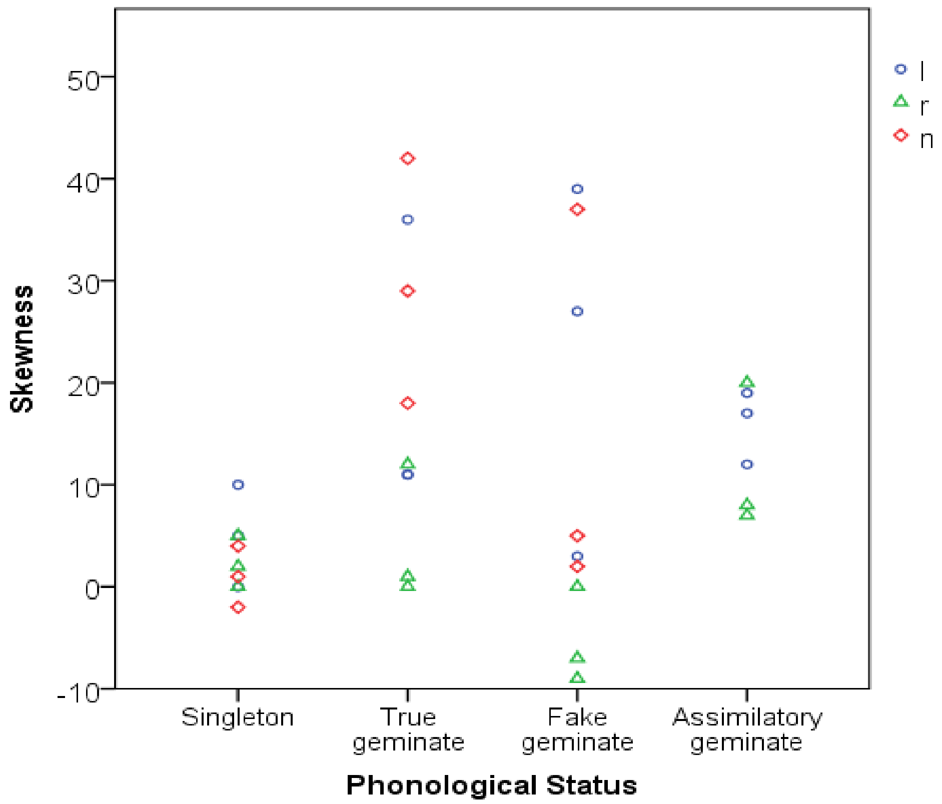


Figure 3.18: Scatter dot plot for skewness in the articulatory gestures of the singleton and the three geminate types.

ANOVA shows that the phonological status is not significant (F(3,5)=1.835, p=0.258), the sound category is not significant (F(2,5)=2.949, p=0.143), and the interaction between them is not significant (F(5,22)=1.875, p=0.140). However, LSD Post hoc tests reveal that singletons are significantly different from true geminates (p<0.01), but not from both fake (p=0.124) and assimilatory (p=0.061) geminates. The three geminate types are not significantly different from each other; (true x fake, p=0.175, true x assimilatory, p=0.488 and fake x assimilatory, p=0.590). As Figure 3.18 shows, fake geminates can be skewed to the right, but this is mainly restricted to the profile of the /r/ tokens. This positive skewness may have an influence on the statistical difference between fake geminates and singletons. That is, there could be a statistical difference that could not be seen as a result of the negative values accompanying the /r/ as a fake geminate. Assimilatory geminates are only slightly skewed to the left. This may be the reason why they have not achieved significant differences from singletons. However, it is clear that the articulatory configurations of this geminate type is different from that of the singletons. Apparently, the speed of closing (onset) in assimilatory geminates is slower than the release (offset), which is not the same in the case of singletons.

3.4.2.3 Peak contact duration (PCD)

Figure 3.19 shows box plots for PCD of the singletons and the three geminate types of /l/, /r/ and /n/. ANOVA reveals significant main effect of the phonological status ($F(3,5)=12.882$, $p<0.01$), with no effect of sound ($F(2,5)=0.031$, $p=0.969$), the interaction between them is significant, however ($F(5,22)=8.151$, $p<0.001$). Post hoc comparisons reveals that singletons are significantly different from all geminate types ($p<0.001$). Fake geminates also achieved significant differences from both true and assimilatory geminates ($p<0.001$ and $p<0.05$, respectively). However, true and assimilatory geminates are not significantly different ($p=0.237$). This results suggests that the articulatory configurations of singletons and geminates are different in this domain.

As can be seen from Figure 3.19, there is a consistency in the distribution for PCD across the three sound categories with the /r/ showing more PCD than /l/ and /n/ as a geminate and less PCD than /l/ and/n/ as a singleton. The general pattern for the distribution of the PCD is the same across the three sounds and geminate types with the singletons showing the least PCD for all three sounds followed by true and assimilatory geminates, which show similar maintained contact duration, and then fake geminates showing the highest PCD values. The PCD distribution for fake and assimilatory geminates is comparatively short which suggests that the overall PCD patterns of the relevant tokens are very similar. On average, fake geminates show higher PCD configuration than both true and assimilatory geminates, which in turn show similar distributions. However, the spread of the distribution of PCD in the case of the true geminates is much larger than that of assimilatory geminates with the exception of the true geminate /r/ which show similar distribution patterns as those of the assimilatory geminates. The distribution of the PCD values in the case of singletons also show a degree of variance.

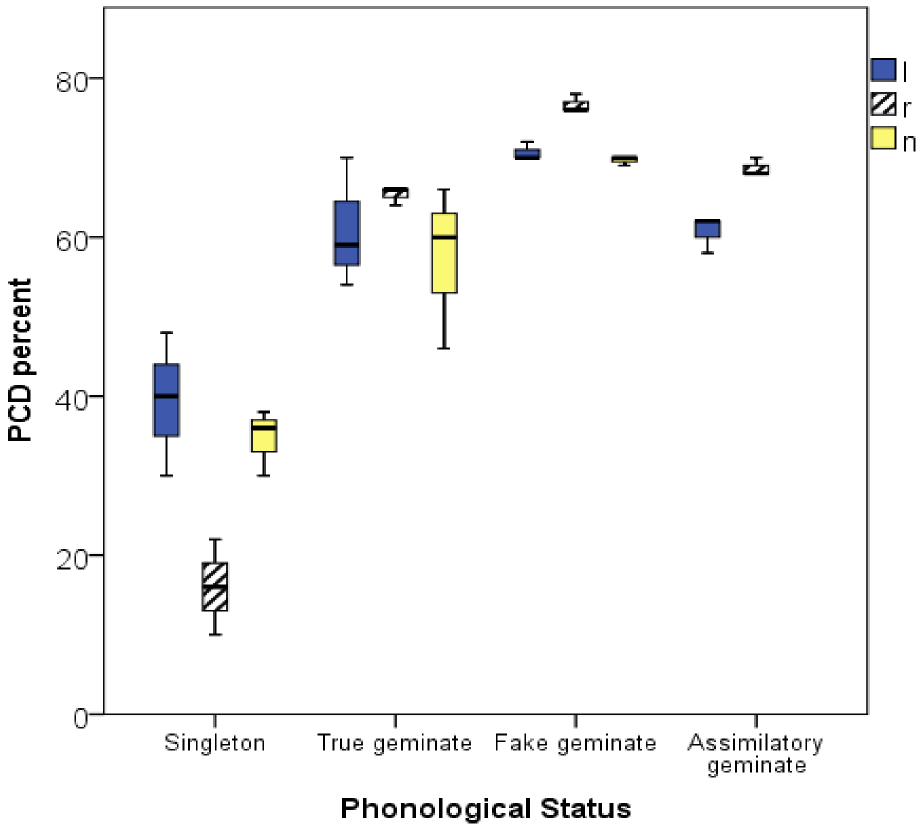


Figure 3.19: Box plots for the PCD in the singleton and the three geminate types.

3.4.2.4 Flatness

Figure 3.20 shows the flatness of the tongue degree for the singleton and the three geminate types. ANOVA reveals no significant effect of the phonological status ($F(3,5)=2.656$, $p=0.160$), the sound category is significant ($F(2,5)=139.088$, $p<0.001$) and the interaction between them is not significant ($F(5,22)=2.501$, p=0.061). Post hoc LSD tests reveal that singletons are significantly different from both true ($p<0.05$) and fake ($p<0.001$) geminates, but not significantly different from assimilatory geminates ($p=0.920$). The three geminate types are significantly different from each other ($p<0.05$).

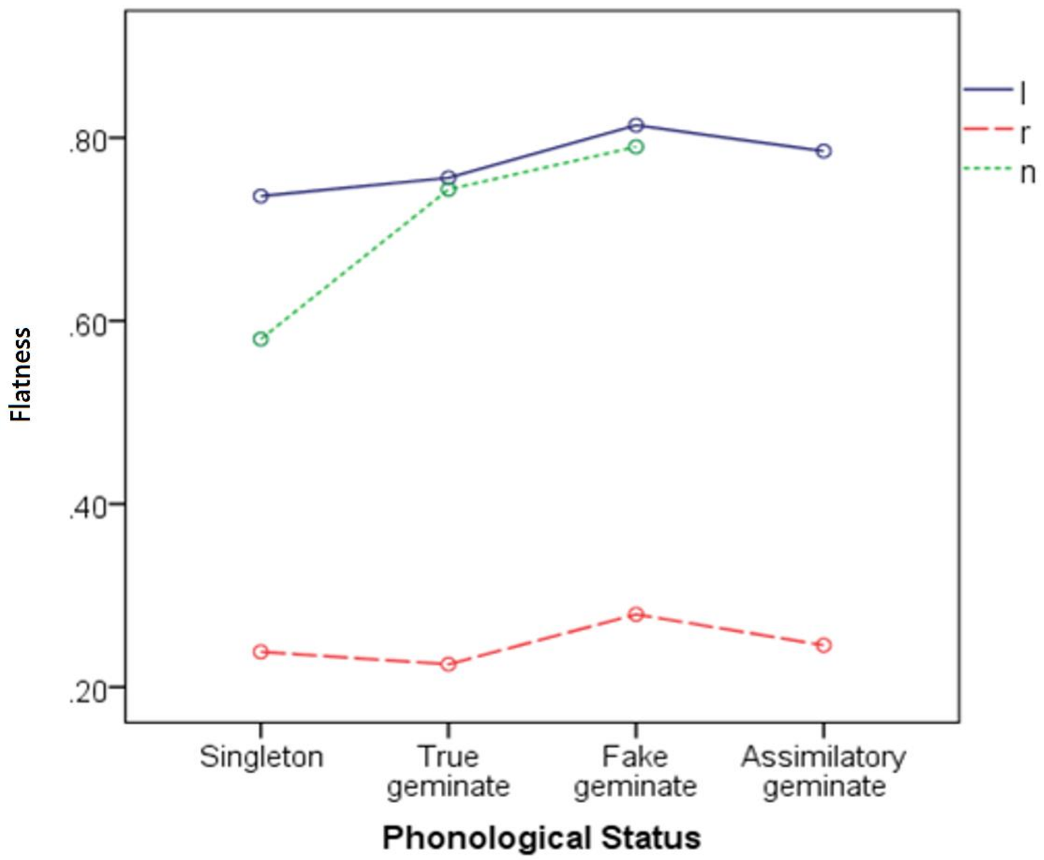


Figure 3.20: Flatness degree for the singleton and the three geminate types.

It is clear from Figure 3.20 that there is difference in the degree of flatness between the three sounds tested in this study with the alveolar rhotic /r/ showing the least degree of flatness for the four phonological statuses compared to /n/ and/l/. The results of the flatness of the tongue degree supports the visual observations of the average frames presented above in section 3.4.1.1 and Figures 3.6, 3.7 and 3.8.

3.5 Discussion and Conclusion

3.5.1 Hypothesis 1

Hypothesis 1 that the singletons and geminates in TLA are different in their articulatory configurations is accepted by considering the spatial and spatio-temporal differences between singleton and geminate consonants reported in sections 3.4.1 and 3.4.2 above. Each one of these parameters will be discussed separately in sections 3.5.1.1 and 3.5.1.2 respectively.

3.5.1.1 Spatial correlates

The location, size and shape of contact are found to be robust articulatory cues for the distinction between singleton and geminate consonants in TLA (see section 3.4.1.1 above). This study provides evidence that the articulation of geminate consonants involves deeper contact than singletons, something that could be interpreted as a more laminal or apico-laminal contribution to the articulation of geminates and an apical production of singletons. This observation of the existence of apical contact for singletons as opposed to laminal contact for geminates is generally comparable to what has been found for Italian (Payne 2006).

Geminates also show more linguopalatal contact than singletons. The AoC responses provide further confirmation of the differences between articulatory configurations of the singletons and geminates. It is clear (see Figures 3.10 and 3.11) that the AoC values are high for geminates both at maximum and middle frames. By contrast, the AoC percentages are at a lower level for singletons of all sound types at both maximum and middle frames. One striking exception is the alveolar rhotic /r/, which involve less linguopalatal contact as a geminate in the mid-frame. Apparently, this has to do with the manner of articulation and gestural configurations of this sound as it is clear from the sound profiles in Figure 3.15. These findings of the AoC are generally comparable with what has been found for

Italian nasals, laterals and stops by Payne (2006) with the geminates involving more linguopalatal contact than singletons. Ghalib (1984) also found evidence of greater amount of contact in the case of geminates as opposed to singletons in Iraqi Arabic, which he interpreted as a firmer contact in the case of geminates. The greater AoC as a phonetic correlation of gemination is an interesting finding because it confirms the robustness of the effect of the phonological status on the AoC values.

As discussed in section 3.1 above, the results of longer articulatory duration together with the greater amount of linguopalatal contact for geminates have been interpreted as lengthening and strengthening for some languages. The general assumption is that if geminates involve a stronger articulation, then the amount of contact with which it is produced is expected to show positive correlation. In the current study, and as mentioned above, geminates are found to involve more linguopalatal contact than singletons. However, whether to consider this as a strengthening effect for TLA geminates may not be straightforward since the behaviour of sonorant consonants may be difficult to understand with respect to consonant strengthening. That is, they are inherently quite vowel-like and thus might weaken or strengthen by becoming less like a vowel. As suggested by Lavoie (2001), weak sonorants will resemble vowels more closely in terms of formant structure and intensity whereas strong sonorants will have less formant structure and less intensity. In the current study, geminates are found to have more linguopalatal contact than singletons. However, and as the results in section 2.4.2 of Chapter 2 show, the singleton and geminate consonants have similar formant structure and intensity values. Based on the acoustic evidence alone, there seem to be no indication of strengthening effects for gemination in TLA. However, and by considering the AoC results, it could be that the strengthening effects for TLA sonorants are evident only on the articulatory level.

The greater AoC, together with visual inspection of the shape of contact, was also interpreted as possible palatalized vocal tract configuration for Italian geminates by Payne (2006). The ‘palatal effect’ that she has found did not mainly involve an articulation or a constriction in the palatal area, but, as she suggests, involves that the tongue is higher and flatter in the mouth, resulting in greater amount of contact and, consequently, giving the overall tongue configuration a more palatalised quality. This interpretation was supported by finding a gradient of increasingly palatalised tongue configuration from /n l/> /nː lː/ > / ɲː ʎː/ as well as a previous acoustic observation of gradiency of the formant structure of laterals (Payne 2005). In the current study, however, and as has been mentioned above, no formant differences could be found between singleton and geminate consonants. Additionally, the constriction during the target consonants was formed in the alveolar area, ruling out the possibility of any palatal constriction. Also, palatal consonants are not common in LA dialects (the only palatal sound is the semi-vowel /j/) and, so, it is not possible to control, compare and test this suggestion so as to reach concluding results. Therefore, Payne's interpretation of the 'palatal effect' cannot be adapted here. Differences in the AoC between singleton and geminate consonants can be simply the result of differing temporal windows available for an articulation to occur. These different temporal windows can possibly result in a firmer and flatter contact configuration of the tongue in the case of geminates, which can in turn serve to strengthen and/or lengthen the sounds. The more linguopalatal contact in the case of geminates, can also be interpreted here as possibly contributing to a more laminal contact for the geminates as opposed to an apical contact for the singletons.

As indicated in section 3.4.1.3, singletons have significantly higher CoG than geminates (of all types) both at the maximum and middle frames, which suggests that singletons are produced with a more anterior tongue configuration than geminates. This anteriority is persistent regardless of the sound type. This result is in agreement with the observations of the palatograms in section 3.4.1.1, where it is clear by visual observation (especially in the case of the alveolar rhotic) that the tongue is fronted in the case of singletons and retracted in the case of geminates.

The general results of observing the palatograms are compatible with that of the Aoc and CoG, and all of them provide a clear evidence that singletons are spatially distinct from geminates in TLA.

3.5.1.2 Dynamic correlates

It is clear from the contact profiles (see section 3.4.2.1) that the articulatory gestures of geminate consonants show more contact frames than those of the singletons reflecting an increased articulatory duration. The percentages of the activated electrodes in the alveolar area tend to be higher in the case of geminates compared to singletons regardless of sound type. There is also no conclusive evidence of the re-articulation or double articulation in the case of geminates. It is clear that the contact profiles of the alveolar lateral and the alveolar nasal geminates (of all types) show no evidence of double articulation. The alveolar rhotic geminate, however, seems to show a trend that can be thought of as double articulation, but the fact that there was still evidence of linguopalatal contact (activated electrodes) between the two-phase-like articulatory gesture rules out this possibility. This is also supported by the acoustic data where no evidence of double articulation could be found. Apparently, and as discussed in section 3.4.1.1, this shape of the contact profile is possibly the result of a retraction of the tongue tip at the middle of the articulatory gesture before it returns to its original position (see Figure 3.16) resulting in a posterior tongue configuration for the case of geminates. The findings from the contact profiles of the current study supports Ghalib’s (1984) results where no evidence of double articulation in Iraqi Arabic could be found.

The articulatory profiles of the singleton consonants look relatively symmetric regardless of sound type, geminates look much less so. This observation provides evidence that the build-up and release for singletons is performed at equal speed. The articulatory configuration for geminates can vary on this domain, however.

This finding is reflected in a more detailed and precise way in the results of the skewness index where the singleton values are found to be gathered around zero (see section 3.4.2.2 and Figure 3.18) providing clear evidence that singletons have a symmetric shape of the articulatory gesture. This indicates that the build-up and decrease in contact of the articulators (onset and offset portions) in the case of singletons are of the same speed. Geminates, on the other hand, are found to show a general tendency to be negatively skewed, which implies that the closing of the articulators is slower than the release. The results of skewness provide evidence of different gestural plans for singleton and geminate consonants in TLA.

The PCD results reported in section 3.4.2.3 provide evidence that different articulatory gestural configurations are employed for singleton and geminate consonants in TLA. This study provides evidence that PCD for singletons is significantly shorter than geminates (of all types, regardless of sound type). This provides clear indication of differences in gestural plans. The PCD of the sound categories investigated here is also interesting. What is noticed here is that this peak contact duration patterns are different from the absolute durational patterns of the three sound types found in the acoustic study of Chapter 2. As shown in Figure 3.19, there is a consistency in the distributions of PCD across the three sound categories with the /r/ showing more PCD than /l/ and /n/ as a geminate and less PCD than /l/ and/n/ as a singleton. On the contrary, the acoustic absolute durational results in chapter 2 (see Figure 2.10) show that rhotics have the shortest duration in all contexts followed by the alveolar lateral and alveolar nasal (which show similar durational patterns). This gives indication that the articulatory configurations while producing these sounds are independent from the actual durational patterns of the sounds.

As regarding the flatness of the tongue index, the results of the current study (see section 3.4.2.4) provide clear evidence that the tongue is flatter during the production of geminates. The degree of flatness among the sound categories investigated here is different, however. The /l/ shows the highest degree of tongue flatness followed by /n/ and then /r/. The results of the flatness of the tongue among the three sound categories matches the extrapolated observations of the location, size and shape of contact in section 3.4.1.1.

These findings support Ghalib's (1984) study in which he found evidence of flatter articulation for geminates in Iraqi Arabic based on visual observation of the frames using the 'Direct Palatography'. Payne (2006) also found some evidence of the 'flattish' tongue configuration during (lexical) geminate articulation as opposed to a slightly cupped (concave) tongue during non-geminate stops. Again, these findings were purely inferred from the shape and location of contact of the averaged palatograms and not by calculating the flatness of the tongue index.

The observation of the contact profiles together with the results of skewness, PCD and flatness provide a clear evidence that singletons are dynamically distinct from geminates in TLA. These results confirm the robustness of the effect of the phonological context on the articulatory gestural and temporal plans of the singleton and geminate consonants.

3.5.2 Hypothesis 2

It is hypothesised that the different geminate types are different in their articulatory configurations. There is evidence to support this hypothesis by considering the spatial and spatio-temporal results presented in sections 3.4.1 and 3.4.2 above. Each one of these parameters will be discussed separately in sections 3.5.2.1 and 3.5.2.2 respectively.

3.5.2.1 Spatial correlates

The location, size, and shape of contact are found to show differences among the three geminate types. It is clear from Figures 3.6, 3.7 and 3.8 that fake geminates show more linguopalatal contact than both true and assimilatory geminates. This observation can be possibly interpreted as a more laminal contribution to the consonant as a fake geminate in the case of both /l/ and /n/. In the case of /r/, although fake geminates can still show more contact than the other geminate types, it is produced as an apical posterior alveolar. These palatograms also show that the contact is deeper in the case of fake geminates compared to both true and assimilatory geminates.

These observations are reflected in the results of the AoC. The results of this study show that fake geminates generally have greater AoC than both true and assimilatory geminates (see the results in section 3.4.1.2). Payne (2006) suggests that the greater amount of contact around the actual constriction area is likely to be the result of a general raising of the tongue body. By adopting this view, it can be argued that fake geminates are likely to be involving a higher tongue configuration than the other geminate types. The same is applicable to the singleton-geminate contrast where geminates always show higher percentage of contact. Again, it is assumed here that there is no evidence of palatalised vocal tract configuration differences among the three geminates types as this is not supported by the results of the acoustic study in chapter 2, where no formant differences could be found between the three geminate types (see also the discussion above in section 3.5.1.1). True and assimilatory geminates are found to have similar AoC patterns. This result provides evidence that these two types of geminates have similar vocal tract configurations, which are distinct from that of fake geminates.

As mentioned earlier in section 3.5.1.1, differences in the AoC between singleton and geminate consonants may possibly be the result of differing temporal windows available for an articulation to occur. However, there was no evidence for temporal differences between the three geminate types as reported in the acoustic study of chapter 2 which raises the question as to what it is that contributed to the greater amount of contact in the case of fake geminates. Bearing in mind the positive correlation between the AoC and consonant strengthening mentioned above, it could be possibly argued that fake geminates are produced with stronger tongue configuration than both true and assimilatory geminates. This strengthening effect in the articulation can be simply the result of its distinct phonological status. The fact that it occurs across word boundary may have an effect making the speaker reinforce its articulation so to achieve the target geminate sound. This strengthening may result in a higher and flatter tongue configuration compared to the other geminate types as can be extrapolated from the palatograms in section 3.4.1.1, where fake geminates show greater and deeper contact. This seems to be one of the phonetic correlates associated with the phonological status of fake geminates.

This study provides evidence that fake geminates are also distinct from both true and fake geminates in their CoG configurations. Fake geminates at maximum frame (see section 3.4.1.3) are found to have higher CoG values than both true and assimilatory geminates, although this is much more clear in the case of the alveolar rhotic. These results provide evidence that there are differences among the three geminates in their spatial correlates. That is, there is a spatial evidence that fake geminates are distinctive from the other geminate types.

The observations of the palatograms together with the results of AoC and CoG provide evidence of different gestural plans for the three geminate types in TLA. These results confirm the robustness of the effect of the phonological context on the articulatory gestural configuration of the three geminate types.

3.5.2.2 Dynamic correlates

As can be seen from the contact profiles (section 3.4.2.1), the three geminate types for each one of the sounds investigated in this study show a general similar trend in that they show no evidence of double articulation. Even in the case of the alveolar rhotic (see section 3.5.1.1 above for more discussion), the three geminate types show somewhat similar trends. The findings of the present study contrast with Al-Tamimi, Abu-Abbas, and Tarawnah’s (2010) claim that the production of fake geminates would involve re-articulation as opposed to one phase articulation for true geminates, arguing that this articulatory configuration lies behind the phonological representation of these two geminate types.

As regarding the skewness index, it is clear (see Figure 3.18) that there is a general tendency for the three geminate types to be negatively skewed. This implies that the closing of the articulation is slower than the release. The degree of skewness seems to be different among the three geminate types. However, no significant differences could be found between them. Only true geminates achieved significant differences from singletons. However, fake and assimilatory geminates show different skewness patterns than those of the singletons. The skewness index results provide of evidence of differences in gestural plans for the three geminate types.

It is clear from section 3.4.2.3 and Figure 3.19 that fake geminates have a significantly higher PCD than both true and assimilatory geminates. Again, true and assimilatory geminates show similar PCD patterns by statistical testing. However, the spread of the distribution of PCD in the case of true geminates is generally much larger than that of assimilatory geminates. In addition, the PCD distribution for fake and assimilatory geminates is comparatively shorter than true geminates. It is worth mentioning here that the general pattern for the distribution of the PCD of the three sound categories is the same across geminate types.

This articulatory proportional distribution of duration provides evidence for different temporal and gestural configurations employed for the articulation of the three geminate types that cannot be seen by acoustic means when comparing the durational patterns of these geminate types. Unlike absolute acoustic durations provided in section 2.4.1.2 of Chapter 2 (where no durational differences could be found between the three geminate types), these proportional peak contact durations provide clear indication of differences in, what can be called, 'tempo-gestural' plans for the three geminate types.

The results of the flatness index (see section 3.4.2.4) provide a clear evidence that the three geminate types are different in the degree of flatness of the tongue. Although the degree of flatness among the sound categories investigated in this study is different, fake geminates are found to show the highest degree of flatness regardless of sound type followed by assimilatory geminates and, then, true geminates. These results of flatness match the extrapolated observations of the location, size and shape of contact together with the AoC results in which deeper and higher AoC were interpreted as contributing to flatter tongue configurations.

The observation of the contact profiles together with the results of skewness, PCD and flatness provide clear evidence that the three geminate types are dynamically distinct from each other in TLA. These results confirm the robustness of the effect of the phonological status on the articulatory gestural and temporal plans of the three geminate types.

3.5.3 Conclusion

The aim of this study is to investigate whether the phonological status of singleton and (the three types of) geminate consonants condition their articulatory properties. This study provides evidence that singletons and geminates are different in their gestural configurations. All the parameters that have been investigated for the spatial correlates of the singleton-geminate contrast in this study provided clear evidence that singleton and geminate consonants in TLA are articulatorily distinct. This study presents evidence that the location, size and shape of contact are robust articulatory cues for the distinction between singleton and geminate consonants in TLA. The constriction during the production of geminates is found to be firmer, deeper and flatter than that of singletons. It also involves more linguopalatal contact. These parameters signpost a more laminal contact for geminates as opposed to an apical contact for singletons. The AoC responses provide further confirmation of the differences between singleton and geminate' articulatory configurations. The greater AoC for geminates can be interpreted as an indication of a stronger articulation for geminates. This study also provides evidence that singletons are produced with a more anterior tongue configuration than geminates.

The singleton-geminate contrast is also found to be distinctive dynamically (spatio-temporally). This study provides evidence that the contact profile of singleton and geminate consonants in TLA are different. The findings of this study confirms that the build-up and decrease in contact of the articulators in the case of singletons are of the same speed, whereas the closure of the articulators is slower than the release for geminates. No conclusive evidence of re-articulation or double articulation in the case of geminates could be found. This study provides clear evidence of differences in 'tempo-gestural' plans for singleton and geminate consonants in TLA. PCDs are found to be different from acoustic durational patterns for the sounds tested in this study.

The phonological status of a geminate is also found to have a phonetic output. This phonetic correlation is represented in the both the spatial and spatio-temporal parameters of the geminate types. This study provides evidence that the contact is deeper in the case of fake geminates compared to both true and assimilatory geminates. Moreover, fake geminates are found to have greater AoC than both true and assimilatory geminates, which have similar AoC patterns, which implies even more liminality in the production of fake geminates. This study provides evidence that true and assimilatory geminates have similar vocal tract configurations, which are distinct from that of fake geminates. Fake geminates are also distinct in their CoG configurations since they have higher CoG values than both true and assimilatory geminates. These results confirm that the three geminate types are different in their spatial correlates. That is, there is spatial evidence that fake geminates are distinct from other geminate types. This distinction seems to be the phonetic correlate associated with the phonological status of fake geminates.

Regarding the dynamic (spatio-temporal) correlates of geminates, it appears that the three geminate types show a general similar trend in that they show no evidence of double articulation. This study provides clear evidence that there is a general tendency for the three geminate types to be skewed to the left. This implies that the closing or build-up of the articulation is slower than the release. The degree of skewness seems to be different among the three geminate types, however, indicating differences in gestural plans for the three geminate types. PCD is found to be higher for fake geminates than the other geminate types. Again, true and assimilatory geminates show similar PCD patterns. This articulatory proportional distribution of duration provides evidence of differences in tempo-gestural plans for the articulation of the three geminate types that cannot be seen by acoustic durational means. Moreover, this study provides evidence that fake geminates have the highest degree of flatness followed by assimilatory geminate and then true geminates. The observations of the contact profiles together with the results of Skewness, PCD, and Flatness provide clear evidence of different gestural configurations available for the three geminate types in TLA.

To sum up, it is clear that the spatial and spatio-temporal parameters as phonetic correlates of gemination confirm the robustness of the effect of the phonological status on the gestural configuration of sounds.

Chapter 4: General discussion and conclusions

4.1 Introduction

This thesis aimed to investigate the phonetic and phonological patterns of gemination in TLA, using the sonorant sounds /r, l, m, n/. The investigation focused on the phonetic correlates of the singleton-geminate contrast on the one hand, and the phonetic differences between the three geminate types on the other. This study examined the influence of the phonological status of a geminate on the phonetic output, to ascertain whether underlying differences are reflected in phonetic dissimilarity. Also, the thesis aimed to shed some light on theoretical implications of these different phonetic realizations.

In order to address this thesis' questions and hypotheses, data were gathered using two phonetic techniques: Electropalatography (EPG) and acoustic analysis. Due to its ability to record contact between the tongue and the hard palate during speech, EPG was used to investigate the articulatory correlates of the singleton-geminate contrast and the three geminate types of the target consonants. The second technique was used to investigate acoustic properties of the singleton-geminate contrast and the three geminate types. These tools were used to address the study's general research questions and hypotheses stated in Chapter 1 (section 1.12) as well as the specific sub-questions stated in Chapter 2 and Chapter 3 (sections 2.2 and 3.2). The combination of acoustic and articulatory data provided a fuller account of the actual phonetic events since just a single source of data may fail to fully illustrate the articulation.

The acoustic study consisted of quantitative and qualitative analysis of the target words/utterances to find evidence of phonetic correlates of gemination by testing a number of proposed correlates of consonant gemination; namely, the duration of the target segments and that of the preceding vowels, intensity and formant structure. The articulatory study also consisted of quantitative and qualitative analysis to quantify the spatial and dynamic correlates of the target segments as a measure of the articulatory output of gemination. The results of both studies are used to test whether the phonological status of the singletons and the three geminates are signalled in phonetic realisation.

This thesis provided evidence that acoustic data alone cannot always provide a complete picture of articulation and that the articulatory data provide important information on linguopalatal contact that is not otherwise available. Integrating the acoustic and articulatory data provided a more complete picture of the consonant articulation and phonetic events. As the results from Chapter 2 and Chapter 3 illustrate, similar acoustics may result from different contact profiles. Using data from both sources provided an additional check on the results so that evidence congregating from acoustic and articulatory sources can be taken to represent a robust generalisation.

This chapter is organised as follows. In section 4.2, the major acoustic and articulatory results of this thesis will be summarised and discussed in light of the general hypotheses of this thesis. In section 4.3, the more general implications of these results will be discussed in an attempt to shed some light on possible theoretical implications of the findings. After that, areas of further research will be suggested in section 4.4. Section 4.5 will present the conclusion.

4.2 Findings of the study

The acoustic investigation confirms that duration is a robust cue for the singleton-geminate distinction in TLA. The duration of a geminate consonant is found to be around twice as long as its singleton counterpart. There is also evidence that the duration of the preceding vowels is another cue to the distinction between singleton and geminate consonants in TLA. There is no evidence of differences in intensity values or formant structure between the singleton and geminate contrasts.

The EPG investigation points to a firmer vocal tract contact configuration for geminates, involving more linguopalatal contact than singletons. This firmness may reflect a higher tongue configuration. Geminates are also found to be produced with a flatter tongue configuration. These can be indications of a stronger articulation for geminates. This strengthening is not mirrored in the acoustic findings, however; something that is hard to assign to any particular reason. The EPG records also indicate that a different part of the tongue, and different overall shape of the tongue, is involved in the articulation of geminate consonants. The evidence suggests that geminates are produced more with the tongue blade or blade and tip, while singletons are more straightforwardly apical. The EPG dynamic records also confirm that the speed of the build-up in contact of the articulators for geminates is slower than singletons. They also show that the articulatory contact duration patterns of the target sounds are different from the acoustic durational patterns, suggesting differences in 'tempo-gestural' plans for singleton and geminate consonants in TLA. The various parameters of difference observed are mutually compatible, since a flatter, more laminal constriction would correspond with a greater degree of contact, a slower closure formation and stronger articulation for geminates.

It is clear that singletons and geminates in TLA are different in their gestural plans and articulatory configurations. These findings together with the acoustic findings support the first general hypothesis of this thesis that 'Geminate consonants in Libyan Arabic are acoustically and articulatorily different from their singleton counterparts'.

This thesis provides evidence of a possible acoustic output of the phonological status of a geminate. This acoustic correlation could not be found in the durational parameters of the geminates themselves, but rather it is represented in the durational properties of the preceding short and long vowels showing a clear temporal alternation that may contribute to their perceptual effect. Assimilatory geminates seem to be phonetically distinct in that the behaviour of both short and long vowels before assimilatory geminates is significantly different from the other geminate types. This seems to be the phonetic correlate associated with this geminate type.

The phonological status of a geminate is also found to have an articulatory spatial and spatio-temporal output. The EPG investigation points to a firmer, greater and deeper vocal tract configuration for fake geminates. This firmness may reflect a higher tongue configuration than both true and assimilatory geminates. Fake geminates are also found to be produced with a flatter tongue configuration. This can be an indication of a stronger articulation for this geminate type, something that does not support the prediction that duration and amount of linguopalatal contact increase or decrease together. Fougeron (1999a, 1999b and 2001), for example, found that duration and amount of contact increased together in French articulatory strengthening. The similar acoustic durations of the three geminate types in the current study do not support this finding. The EPG records also indicate that a different overall shape of the tongue may be involved in the articulation of fake geminates. The EPG dynamic records also confirm that the articulatory contact durational patterns are different from the acoustic durational patterns, with fake geminates showing longer articulatory contact duration, suggesting differences in the 'tempo-gestural' plans for this geminate type. This finding of the proposed PCD measurement may give explanation for the strengthening effects found for the fake geminate that are not reflected in the acoustic durational results. The various parameters of difference observed are mutually compatible, since a flatter, more laminal constriction would correspond with a greater degree of contact, and possibly, stronger articulation. That is, there is a spatial and dynamic evidence that fake geminates are distinct from the other geminate types, which seem to pattern together.

It is clear that the spatial and spatio-temporal parameters as phonetic correlates of gemination confirm the robustness of the effect of the phonological status on the gestural configuration of sounds. These findings together with the acoustic findings support the second general hypothesis of this thesis that 'True, fake and assimilatory geminates are different in their acoustic and articulatory properties'.

4.3 Implications

The different spatial and dynamic correlates in the case of the singleton-geminate contrast can be possibly interpreted as an unintended result of different duration. During the singleton, there is less time for the articulators to reach their target, and, consequently, a gestural undershoot occurs, resulting in less linguo-palatal contact and, also, less peak contact duration. This is the analysis proposed for domain-initial strengthening in Korean by Cho and Keating (2001), who find a strong correlation between linguo-palatal contact and duration and conclude that strengthening and lengthening are a single effect in Korean. This is a mechanical interpretation of phonetic differences of the same underlying gestural target. However, differences in the shape of the tongue are more difficult to explain as the result of temporal differences. If temporal differences were the reason behind the spatial and dynamic correlates found in this study, then how can one explain the differences in the gestural plans that distinguish fake geminates from the other geminate types. For example, if articulatory 'strengthening' (i.e. greater amount of linguopalatal contact) is a pure result of longer duration, one would expect the three geminate types to be uniform, and this is not the case in TLA. A possible interpretation for the observed differences in the spatial and dynamic correlates is that they are the result of underlying structural differences that are not merely temporal. That is, the underlying gestures for /l: n: r:/ would be spatially and dynamically different from the gestures for /l n r/. This may be an appropriate explanation in the case of the singleton-geminate contrast. However, if this was the case, one might reasonably expect fake and assimilatory geminates to resemble singletons more closely than true geminates, since underlyingly they originate from non-geminates. This distinction was found by Payne (2005 and 2006:92), particularly with respect to F1, where she concluded that "non-durational indices of gemination are a more robust feature of lexical geminates, and that only this type of geminates is gesturally different from non-geminates". However, in the current study, and as reported earlier in this thesis, data from both the acoustic and articulatory studies does not support this finding. Interestingly, what is noticed here is that fake and assimilatory geminates are acoustically closer to true geminates than to singletons. Articulatorily, all three geminate types are distinct from singletons, and fake geminates are different from both true and assimilatory geminates, which show similar patterns.

This similarity between assimilatory and true geminates can be reasonably attributed to the observations in this study (see section 3.4.1.1) that assimilatory geminates result from total assimilation in TLA (based on EPG data). This possible categorical ‘articulatory’ distinction may have contributed to the similar articulatory gestures of both geminate types. However, the acoustic results of the behaviour of the vowels that precede assimilatory geminates reported in Chapter 2 may challenge this interpretation. That is, this correlation makes assimilatory geminates distinct even from true geminates, acoustically. This raises the question as to why they pattern together articulatorily. In fact, this finding may support a number of studies, specifically within the gestural overlap model, which have in effect cast doubt on the traditional assumption of categorical phonological modifications at word boundaries (see e.g. Browman and Goldstein 1990, Nolan 1992 and Ellis and Hardcastle 2002).

Actually, it is clear from the results and discussions reported in this thesis that the singleton-geminate contrasts as well as the three geminate types are all distinct from each other when considering both the acoustic and articulatory correlates. The acoustic results show similar temporal properties for the three geminate types. Fake rhotics show the only exception to this similarity, a behaviour that is hard to assign to any particular reason. Moreover, and most importantly, this exception does not always hold in the articulatory investigation, where all sound types show similar results of the different parameters investigated here. This consistency of the results among the different sound types and across the geminate types provides a possible indication of underlying structural distinction between the three geminate types in their articulatory plans and gestural configurations. The finding that these gestural plans are not reflected acoustically even by the non-temporal indices, such as intensity and formant structure, poses a challenge to this interpretation, although these acoustic findings might be attributed to the unclear strengthening behaviour of the approximant sounds as discussed earlier in sections 3.1 and 3.5.1.1. Nevertheless, the general tentative conclusion that can be drawn from the above discussion is that the singleton-geminate contrast and the phonological status of geminates do have a phonetic realization.

As regards the phonological representation of geminates, and as indicated in section 1.8, in general, a true geminate is represented either as a consonant that comprises two timing units (McCarthy, 1982) or as a single mora-projecting consonant (see Hyman, 2003). A fake geminate is represented as a sequence of two identical segments each linked to its own timing slot (see Spencer 1996 and Gussmann 2002). An assimilatory geminate is represented either as a true geminate or as a fake geminate depending on its behaviour in the language (Hayes, 1986).

The representation of geminates is not unproblematic, however. In his discussion on the issue of representing geminates, focusing on the representational view of geminates cross-linguistically, Davis (2011: 20) concluded that “the issue of the representation of geminate consonants has been a controversial matter and will most likely remain so in future investigations. This is because geminates do not display uniform behavior. ... It seems that the very nature of the data under examination determines what type of representation must be appropriate”. Regardless of the frameworks within which gemination has been treated and the many languages for which it has been proposed, there is extensive evidence that the phonetics, in effect, adds the quantitative dimensions to the more abstract phonological representation. In other words, phonetic implementation acts on the phonological structure (Cohn, 2003). Generally, there is evidence in the literature for a tight relationship between phonetic and phonological representations (see e.g. Pierrehumbert 1990, Harris 2007, and Cohn 2003).

Assuming that this closeness should be reflected in linguistic theory, the findings of the present study raise the question as to whether the phonetic correlates that have been found here should be implemented in the phonological representation of TLA geminates. The phonetic investigation of this thesis shows that the singletons and the three intervocalic geminate types are phonetically implemented by different correlates and supports the view that this contrast is not limited to the duration of the target segments. For example, the results show that the phonetic properties of assimilatory geminates are distinct from those of true and fake geminates, which suggest that assimilatory geminates would be better represented in a way that is different from both the true and fake geminates. This representation can be accounted for as a reflection of the phonetic parameters associated with this geminate type. Also, it is not only duration that distinguishes singleton from geminate consonants in TLA; a number of articulatory correlates contributed to this distinction (as discussed in section 3.5.1) which may need to be implemented in the phonological representation of TLA as well.

In his investigation of the phonetic correlates of geminates in Tashlhiyt Berber, Ridouane (2010) also found that singletons and geminates are phonetically implemented differently. He considered duration as the primary correlate for this opposition and interpreted other parameters such as vowel shortening and higher RMS as manifestations of 'tense' articulation, that can be considered as secondary correlates. He assigned this enhancing feature [tense], which may contribute to the duration added to geminates, to the representation of geminates through a phonetic implementation rule so as to solve the problem raised by the properties of geminate consonants in Tashlhyit Berber. As mentioned earlier, the articulatory results of geminates compared to singletons in TLA also suggest stronger articulation that may need to be implemented in the representation of geminates. Ridouane (2010) also found that phonologically derived geminates (assimilated and concatenated 'fake') display the same temporal values as lexical (true) geminates. Unlike the current study, however, his non-temporal acoustic results show that assimilatory and true lexical geminate pattern together in shortening the preceding vowel and showing higher RMS amplitude, concatenated (fake) geminates do not. In other words, and as he suggests, assimilated geminates, being phonetically implemented with additional enhancing correlates, manifest the same characteristics as "true" geminates. This finding, which shows that post-lexical geminates arising from total assimilation are categorically identical to underlying true geminates, has also been observed in Sardinian (Ladd and Scobbie 1999). The articulatory results of the current study also show that assimilatory geminates resulting from total assimilation and lexical true geminates pattern together articulatorily. Interestingly, in terms of phonological behavior, lexical and assimilated geminates do pattern together as opposed to fake geminates (see Kenstowicz 1994). The former are, for example, universally unaltered by spirantization, while the latter can be. Nevertheless, the acoustic data from TLA challenges this generalization since assimilatory geminates resulting from total assimilation are found to be distinct from lexical true geminates. Following Ridouane's interpretation of the phonetic implementation of geminates, assimilatory geminates in TLA will not surface with the same enhancing correlates as true geminates due to the behavior of their preceding vowel. Also, while in Ridouane's study fake geminates fail to surface with the same enhancing correlates as true geminates (i.e. they show weak articulation), fake geminates in the current study are shown to display characteristics of a strong articulation (i.e. stronger than true and assimilatory). This result provides supporting evidence that fake geminates are represented differently from both true and assimilatory geminates (in TLA). The manifestation of which are mainly articulatorily and different from the general phonological assumptions, however.

Following Ridouane's interpretations, the results of this thesis suggest that, in TLA, the singletons and the three geminate types are correlated with certain enhancing features, which can contribute to the distinction between them. These enhancing features can be vowel shortening, behaviour of the preceding vowel, higher amount of linguopalatal contact, higher PCD, flatter shape of the tongue, more anterior tongue configurations and slower closure of the articulation. In general, the results obtained from this study are suggestive in that these phonetic traces raise the need for proposing a phonological representation in which all three types of geminates are represented differently from each other. That is, the phonological representation of gemination in TLA should be accounted for in light of these findings.

This study serves to contribute to the understanding of the phonetic and phonological aspects of the singleton-geminate contrast and the difference between the three types of geminates in TLA. There has been little work that specially relates the role of Arabic geminates to the on-going controversy within phonological theory regarding the representation of geminate consonants (Davis and Raghab, 2014). This thesis tried to highlight and touch upon some of the issues regarding geminate representation in Arabic. Geminates have been the source of much debate in the literature concerning their phonetic implementation, their phonological realization, as well as the way they account for their particular behaviour. This study tried to uncover some of these phonetic implementations and highlight possible interpretations. This thesis tried to provide empirical background for phonological descriptions. Additionally, it provided a more accurate description of the phonetics of the language. This thesis, then, has attempted to demonstrate the usefulness of the experimental approach to phonological issues.

4.4 Future prospects

The present study is a comprehensive experimental investigation of consonant gemination in Tripolitanian Libyan Arabic. There remain a number of points that need to be investigated so as to clarify the overall picture of the phonetic correlations and implications of gemination in TLA. Although the current study provides a detailed investigation of the phonetic manifestations of geminates, it is fair to say that the study has only examined sonorant sounds and further research involving other segment types and other acoustic parameters will be necessary. The gemination of obsturents, for example, may be quite different, as manner of articulation is known to affect the output of gemination (see e.g. Payne, 2005). Also, more work is needed to implement the phonetic manifestations found in this study in the phonological representation of geminates in TLA.

Another investigation worth pursuing is a synthetic speech analysis to investigate whether the differences found in the acoustic experiment correspond to perceptual differences. In addition, I would recommend investigating whether the duration of the preceding vowel contributes to the perceptual contrast of gemination in TLA; as a secondary cue that enhance the singleton-geminate perceptual contrast, and as a primary cue in discriminating the three geminate types.

One other area that certainly calls for detailed investigation is whether the articulatory differences found in the EPG experiment correspond to perceptual differences between the three geminate types. Also, investigating other consonant types using EPG, preferably employing more subjects.

The phonetic characteristics of initial and final geminates have not been as much investigated as word-medial ones. This fact is unsurprising knowing that these geminates are cross-linguistically rare (Davis, 1999). It will be useful to investigate initial and final geminates in TLA acoustically, articulatorily and perceptually. Additionally, it would be interesting to investigate whether the phonetic correlation of the geminate types found in this study is language-specific or dialect-specific.

4.5 Concluding remarks

The aim of this thesis was to investigate whether the phonological status of singleton and (the three types of) geminate consonants condition their phonetic properties. This thesis tried to analyse a broad and informative range of new data about gemination through controlled investigation of approximant consonants in TLA. Using both acoustic and articulatory criteria, the phonetic manifestation for the singleton-geminate contrast and the three geminate type have been identified. This thesis provided evidence that the singleton-geminate contrasts and the three geminate types are all distinct from each other when considering both the acoustic and articulatory correlates. That is, there is indeed a phonetic out-put of the phonological status of a segment. The phonetic correlates of the singleton-geminate contrast as well as the three intervocalic geminate types shed light on the true phonetic and phonological nature of gemination in TLA. The analysis of the experimental results of the thesis have certain theoretical implications regarding possible underlying structural differences. The discussion of these issues raised new research directions of theoretical and experimental interest to be pursued.

Appendix 1 Basic word-list with gloss and syllabification (acoustic study)

/l/				
1	/ˈmilik/	‘property’	CV**<u>C</u>** VC	singleton
	/ˈmil:i:ta/	‘Mil:ita’ (place)	CV**<u>C:</u>**V:CV	true geminate
/ʕamil#li:na/→	[ʕaˈmil:i:na]	‘the worker of Lina’	CVCV**<u>C:</u>**V:CV	fake geminate
/min#lina/→	[ˈmil:i:na]	‘who is Lina?’	CV**<u>C:</u>**V:CV	assimilatory geminate [n→l]

2	/ˈxa:li:/	‘my uncle’	CV:**<u>C</u>**V:	singleton
	/ˈdˤa:l:i:n/	‘lost (people)’	CV:**<u>C:</u>**V:C	true geminate
/xal#li:na/ →	[ˈxa:l:i:na]	‘Lina’s uncle’	CV:**<u>C:</u>**V:CV	fake geminate
/xan#li:na/→	[ˈxa:l:i:na]	‘(he) betrayed Lina’	CV:**<u>C:</u>**V:CV	assimilatory geminate [n→l]

Basic word-list with gloss and syllabification (acoustic study) (continued)

/m/				
1	/ˈmiʃma:ʃa/	‘apricot’	CVC**<u>C</u>**V:CV	singleton
	/ˈkam:a:ʃa/	‘pliers’	CV**<u>C:</u>**V:CV	true geminate
/kam#maʃi/→	[ˈkam:a:ʃi]	‘how long did you go’	CV**<u>C:</u>**V:CV	fake geminate
/ka:n#maʃi/→	[ˈka:m:a:ʃi]	‘he was going’	CV:**<u>C:</u>**V:CV	assimilatory geminate [n→m]

2	/ˈxa:ma:t/	‘ore’	CV:**<u>C</u>**V:C	singleton
	/ˈsa:m:a:t/	‘toxic’	CV:**<u>C:</u>**V:C	true geminate
/ʕisˤa:m#ma:t/ →	[ʕiˈsa:m:a:t]	‘Esam died’	CVCV:**<u>C:</u>**V:C	fake geminate
/sina:n#ma:t/ →	[siˈna:m:a:t]	‘Sinan died’	CVCV:**<u>C:</u>**V:C	Assimilatory geminate [n→m]

Basic word-list with gloss and syllabification (acoustic study) (continued)

/n/				
1	/ˈna:skum/	'your relatives'	**<u>C</u>**V:CCVC	singleton
	/ˈkan:a:skum/	'your sweeper'	CV**<u>C:</u>**V:CCVC	true geminate
/min#naskum/→	[ˈmin:a:skum]	'who are your relatives?'	CV**<u>C:</u>**V:CCVC	fake geminate
2	/ˈna:ʒi/	'Naji'(name)	**<u>C</u>**V:CV	singleton
	/ˈbin:a:ʒi/	'I wish'	CV**<u>C:</u>**V:CV	true geminate
/min#na:ʒi/→	[ˈmin:a:ʒi]	'who is Naji?'	CV**<u>C:</u>**V:CV	fake geminate

Basic word-list with gloss and syllabification (acoustic study) (continued)

/r/				
1	/ˈri:ma/	‘Rima (name)’	**C**V: CV	singleton
	/ˈbir:i:ma/	‘valve’	CV**C:**V:CV	true geminate
/sir#rima/ →	[ˈsir:i:ma]	‘the secret of Rima’	CV**C:**V:CV	fake geminate
/min#rima/ →	[ˈmir:i:ma]	‘who is Rima’	CV**C:**V:CV	assimilatory geminate [n→r]
2	/ˈmaraːmi/	‘goalkeepers’	CV**C**V: CV	singleton
	/ˈbarːaːni/	‘stranger’	CV**C:**V:CV	true geminate
/sir#rami/ →	[ˈsirːaːmi]	‘the secret of Rami’	CV**C:**V:CV	fake geminate
/min#rami/ →	[ˈmirːaːmi]	‘who is Rami?’	CV**C:**V:CV	assimilatory geminate [n→r]

Appendix 2 Arabic word-list and the carrier sentence (acoustic study)

قال أحمد ....تاني

1. ريمَة
2. مَرَامِي
3. مِلِك
4. عَامِل لِينا
5. بريّمَة
6. نْدِم
7. ضَالِّين
8. بَرّانِي
9. مِليتة
10. مِشمَاشَة
11. عِصَام مَات
12. نقَزْ
13. سِر رّيمَة
14. خَامَات
15. كَمّاشَة
16. مِن ناجِي
17. خَان لِينا
18. نشَد
19. كَم مَاشِي
20. كنّاسكُم
21. مِن رّيمَة
22. سَامّات
23. مِن لِينَا
24. نْكَرْ
25. بنّاجِي

26.سنان مَات

27.كَان مَاشِي

28.نَاسكُم

29.مِن رَامِي

30.نْجَح

31.خَال لِينا

32.ناجِي

33.سِر رّامِي

34.خَالِي

35.مِن ناسكُم

36.نكَدْ

Appendix 3 Arabic word-list and the carrier sentence (articulatory study)

ماتقوليش...تاني

1. لناجي
2. بريّمَة
3. من لِينا
4. نشَد
5. بناجي
6. مِن رّيمَة
7. لِلِينا
8. نجح
9. فلِينة
10. سِر رّيمَة
11. مِن ناجي
12. ربَح
13. لريمَة
14. تِل لِينا
15. ندِم
16. لناجي
17. بريّمَة
18. من لِينا
19. نشَد
20. بناجي
21. مِن رّيمَة

22. لِلينا

23. نجح

24. فلِينة

25. سِر رّيمَة

26. مِن ناجي

27. ربَح

28. لريمَة

29. تِل لِينا

30. ندِم

31. لناجي

32. بريّمَة

33. من لِينا

34. نشَد

35. بناجي

36. مِن رّيمَة

37. لِلينا

38. نجح

39. فلِينة

40. سِر رّيمَة

41. مِن ناجي

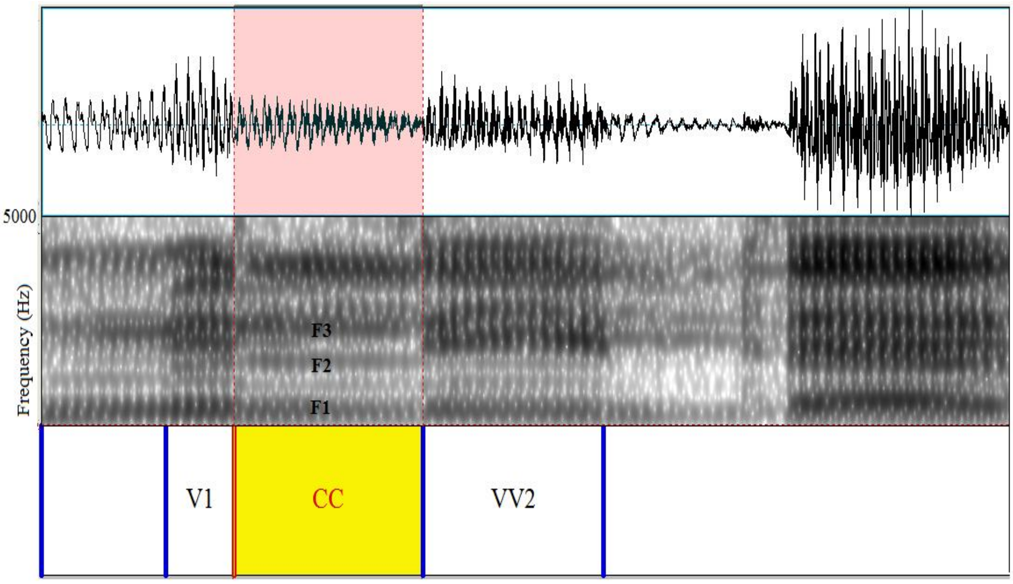
42. ربَح

43. لريمَة

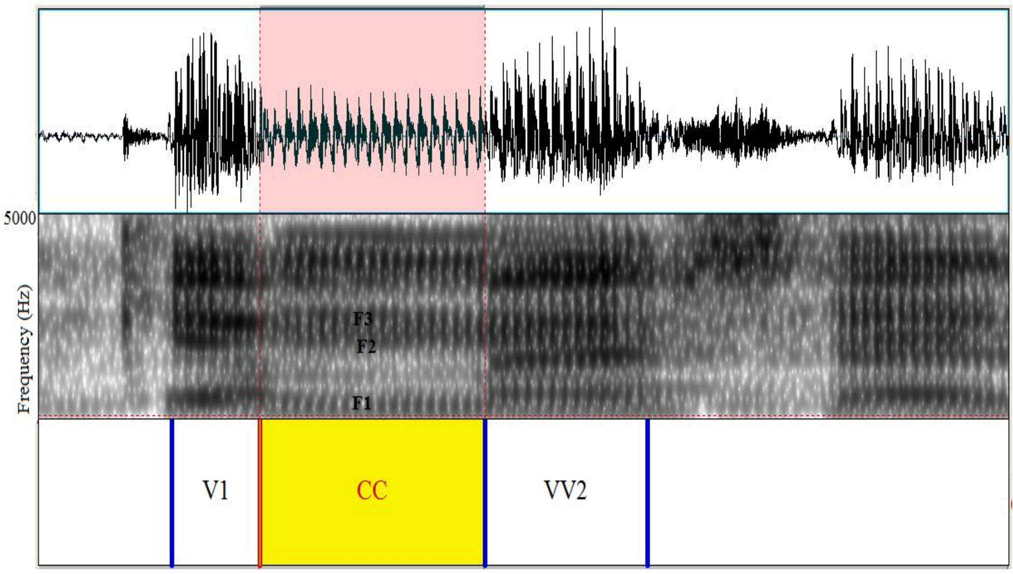
44. تِل لِينا

45. ندِم

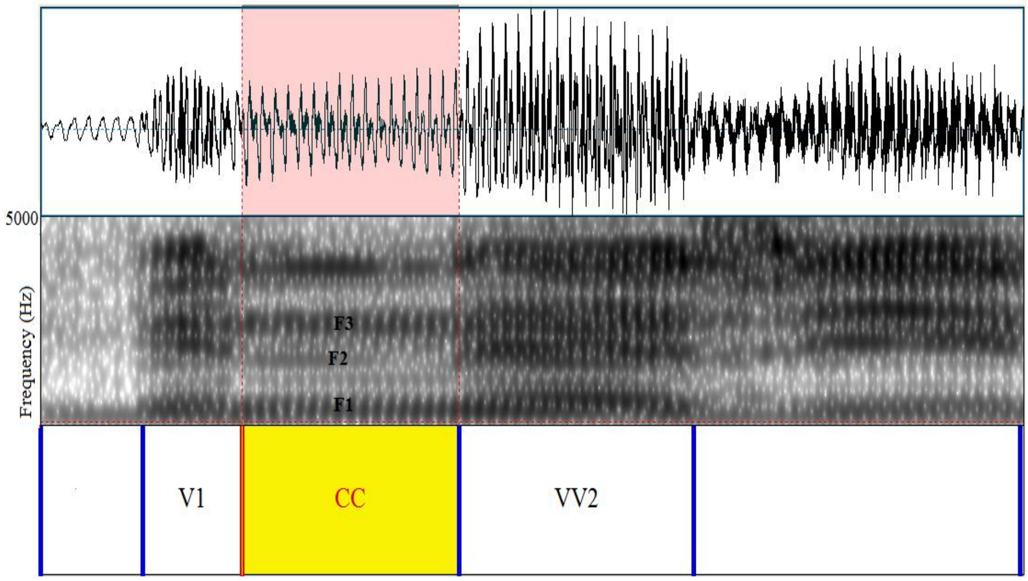
Appendix 4 Illustrations showing formant positions in all consonant types



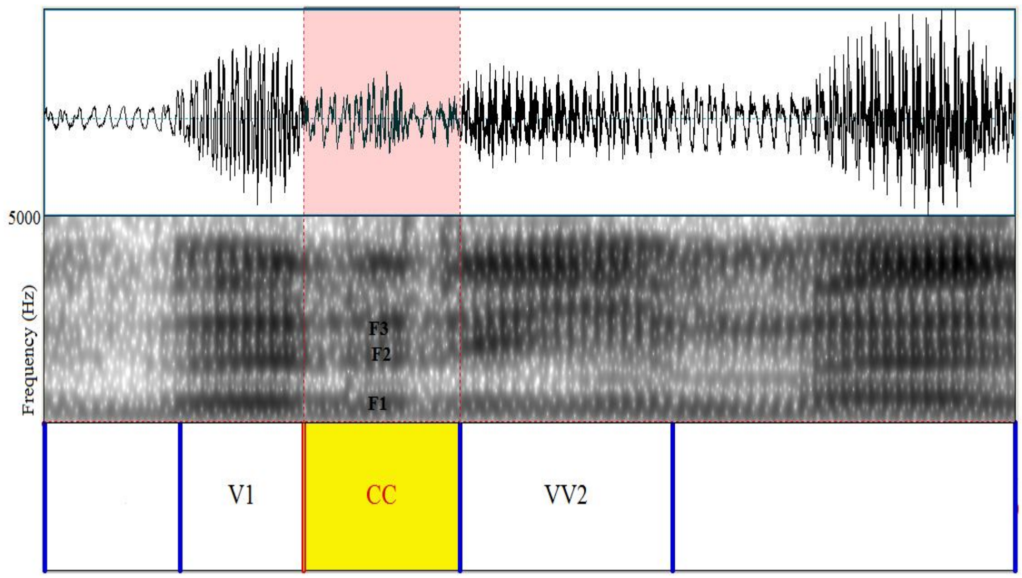
Waveform and spectrogram of /l/ in /mil:i:ta/, with F1 (at 326 Hz), F2 (at 1800 Hz) and F3 (at 2470 Hz).



Waveform and spectrogram of /m/ in /kam:a:ʃa/ with F1 (at 314 Hz), F2 (at 1900 Hz) and F3 (at 2500 Hz).



Waveform and spectrogram of /n/ in /bin:a:ʒi/, with F1 (at 355 Hz), F2 (at 1820 Hz) and F3 (at2450 Hz).



Waveform and spectrogram of /r/ in /bir:i:ma/, with F1 (at 436 Hz) F2 (at 1710 Hz) and F3 (at 2434 Hz).

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