SYLLABLE STRUCTURE AND GEMINATION IN MALTESE

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Abstract

Little is known on the phonetics and the phonotactic constraints of Maltese. This dissertation sheds light on aspects of syllable structure and geminates in Maltese in order to contribute to understanding how the sound system of the language is structured. The study begins by describing the possible syllable structures in Maltese, carefully defining the onsets, nuclei and codas attested in its syllables. Furthermore, the syllabification processes employed in Maltese are discussed.

The dissertation then moves on to its primary focus: geminates in Maltese. In relation to syllable structure, geminates in word-medial position are considered to be ambisyllabic, however, the syllable affiliation of word-initial and word-final geminates is under scrutiny. In addition to word-medial geminates, Maltese also has word-initial and word-final geminates. Previous descriptions of Maltese word-initial geminates (e.g, Azzopardi 1981) have claimed that such geminates are preceded by the epenthetic vowel [ɪ]. Based on a series of production studies, I provide acoustic evidence to examine the articulation of word-initial geminates, and show that this epenthesis occurs almost always when the preceding word ends in a consonant. However, when the preceding word ends in a vowel, there are a number of strategies which speakers employ. Subsequently, in a perception experiment, I show that native speakers of Maltese are insensitive to true word-initial geminates (#ss); results indicate that native speaking Maltese listeners could not discriminate between true word-initial geminates (#ss) and word-initial singletons (#s). However, they were able to discriminate between word-initial geminates that were preceded by the epenthetic vowel (#ɪss) and word-initial singletons (#s). Therefore, I argue that this vowel is part of the phonological representation of word-initial geminates, and I discuss implication of these results for lexical access.

In addition, I compare word-initial and word-medial geminates and word-final and word-medial geminates. As expected, the most robust correlate is constriction duration as geminates are always longer than singletons. Other correlates, such as voice onset time, does not serve as a correlate to gemination in Maltese. However, the duration of the vowel before word-medial geminates is

shorter than the vowel before word-medial singletons and this can serve as a correlate to gemination in production.

Finally, I address the consequences that these results have for phonological representation. Following the current literature on gemination, I propose a moraic representation for geminates in Maltese, regardless of their position in the word.

To *Doris*,

For weathering the storms (and the hurricanes),

[*wara d-dlam, toħroġ ix-xemx*]

Well done, you.

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Chapter 1: Introduction

The aims of this dissertation are twofold. Firstly, it illustrates syllable structure in Maltese by answering the following questions: How is the syllable organized in Maltese? What restrictions are there with respect to onsets and codas? What is the process of syllabification in Maltese? Secondly, it establishes the correlates of gemination and discusses the phonological representation for gemination in Maltese. This is guided by the following research questions: What are the phonetic correlates of geminates in word-initial, word-medial and word-final positions? How do these correlates influence the phonological representation of geminates? How does this fit within a cross-linguistic overview of the phonetics and phonology of geminates?

1.1 Aims of the dissertation

The first aim of this dissertation is to provide a much-needed description and analysis of syllable structure in Maltese. In order to answer the research questions on syllable structure above, the analysis of syllable structure is couched in Onset-Rhyme theory and the possible syllable constituents are described in relation to Sonority (cf. Jesperson 1904; Clements 1990). The analysis seeks to identify all possible syllable types in Maltese by extending previous work by Borg and Azzopardi-Alexander (1997), and to incorporate other syllable types which have not been discussed previously for Maltese. To this end, the syllable constituents (*onsets*, *nuclei* and *codas*) for Maltese have to be well defined. In order to describe the organization of the syllable in Maltese, I adopt Parker's (2011) sonority framework. However, the analysis shows that a language like Maltese, poses a number of problems in relation to sonority. This is because onset clusters in Maltese allow for sonority reversals (/ft/ in /fti:t/ *ftit* 'a little', /zb/ in /zbɐ:ll/ *żball* 'mistake') and sonority plateaus (/tk/ in /tku:n/ *tkun* 'he was', /bd/ in /bdi:l/ *bdil* 'change'), which are not predicted by sonority-based approaches. Given the potential syllable structures in Maltese and the possible constituents within these structures, syllabification processes are analyzed.

The second and central aim of the dissertation is to investigate the phonetics and phonology of gemination in Maltese by looking at both acoustic correlates (in three production studies) and perceptual correlates (in an AX discrimination study). This dissertation serves as the first full-length study on gemination in Maltese. Gemination in Maltese occurs in word-initial, word-medial and word-final positions as in (1).

(1) Gemination in Maltese

a) Word-initial: /**tt**ɐmɐ/ 'he hoped'
b) Word-medial: /rɐ**tt**ɐb/ 'he softened'
c) Word-final: /ʔɐ**tt**/ 'never'

The production studies I carried out provide evidence for acoustic correlates for gemination in Maltese: they investigate constriction duration, voice onset time (VOT), the duration of the vowel after word-initial geminates/singletons, the duration of the vowel before word-medial and word-final geminates/singletons and the vowel after word-medial geminates/singletons. Of particular interest are word-initial geminates in Maltese. In general word-initial geminates are quite uncommon cross-linguistically (cf. Thurgood 1993; Muller 2001; Kraehenmann 2011). In addition, the representation of word-initial geminates is a highly debated phenomenon within phonology (cf. Hume et al. 1997; Davis 1999; Topintzi 2008). One particularly interesting property of word-initial geminates in Maltese is that they are considered to trigger vowel epenthesis, which is context-dependent (cf. Mifsud 1995; Aronoff and Hobermann 2003). As a result, the first production study (in Chapter 5) investigates the production of different word-initial geminates types and the presence or absence of the aforementioned epenthesis. In a second production study (in Chapter 6), the production of word-initial geminates is compared to the production of word-medial geminates across different manners of articulation. In a third production study (in Chapter 7), the production of word-final geminates is compared to the production of word-medial geminates. A closely related research question deals with whether word-initial geminates in Maltese can be perceived by listeners, and the role of epenthesis in the lexical representation of such words; this research question is addressed in a perception experiment (in Chapter 8). Finally, I propose that geminates in different positions in the word lead to a unified phonological representation.

1.2 Theoretical starting points

In §1.2.1, I outline the main principles of Onset-Rhyme theory and Sonority that I have employed in the description of syllable structure in Maltese in Chapter 2. In §1.2.2, I present the definition of geminates which I have employed throughout the dissertation. I also give an overview of different geminate types, such as assimilated geminates and concatenated geminates. Furthermore, I briefly touch upon certain issues related to the phonetic correlates and the representation of geminates, which serves as a preliminary to the overview of word-initial, word-medial and word-final geminates in Chapter 3.

1.2.1 Syllable structure

The internal structure of the syllable has been widely discussed in the field of phonology. The structure in Figure 1.1 is the one that is most commonly adopted (Kiparsky 1979, Harris 1983, Nespor and Vogel 1986 and Goldsmith 2011). Other syllable structures involving different constructs such as the mora[1] and flat models, have also been postulated (Hayes 1995; Goldsmith 2011; van der Hulst & Ritter 1999).[2]

A generally accepted view of the syllable is one involving an Onset-Rhyme model consisting of two constituents: the onset and the rhyme,the rhyme being made up in turn of the nucleus and the coda (cf. Figure 1.1). The nucleus, typically a vowel, is considered to be the syllable's obligatory element.[3] The onset and the coda are optional constituents in some languages but not in others. For instance, in English and Maltese, both the onset and the coda are arguably optional

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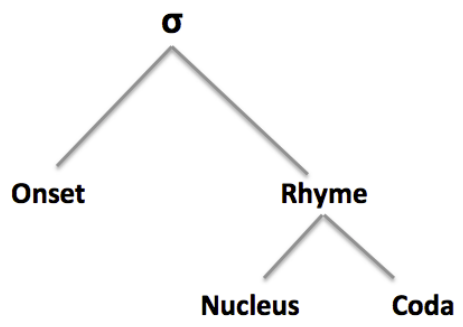
[1] I provide an overview of moraic representations and its implications to syllable structure and, more particularly, geminates in Chapter 3 §3.4.2.
[2] For a recent thorough overview of different models of the syllable see Bosch (2011).
[3] Tashlhiyt Berber is considered to be a language which allows syllables without vocalic nuclei (Dell and Elmedlaoui 2002).

constituents. However, in Arabic the onset is an obligatory constituent of a well-formed syllable (cf. Gadoua 2000 on Standard and Egyptian Arabic; and, Wiltshire 1998 on Cairene Arabic).

Figure 1.1: Onset-Rhyme binary branching



The sequencing of segments within syllables is often seen to be a function of the relative sonority of segments (Blevins 1995, Zec 2007, Parker 2011). Nonetheless, the relevance of sonority to the organization of segments within the syllable has been a bone of contention in the field of phonology (cf. Blevins 1995, Bosch 2011, Goldsmith 2011). The nucleus, which can be filled by a vowel or a syllabic consonant, is the most sonorous element in the syllable. The surrounding segments are typically organized into rising sonority sequences up to the nucleus (i.e., in the onset) and falling ones towards the right-hand margin of the syllable (i.e., the coda). The relationship between sonority and syllable constituents is captured by the *Sonority Sequencing Principle* (SSP). According to the SSP, constituents in a syllable should have one peak of sonority in the nucleus (e.g., Selkirk 1984; Parker 2011 and references therein). Blevins (1995:210) employs a different version of the SSP, namely one suggesting that "a sonority rise or plateau" can occur between a syllable constituent and the syllable peak. In order to capture what the SSP states, a number of sonority scales have been proposed in the literature (cf. Jespersen 1904; Steriade 1982; Clements 1990; Parker 2008; Parker 2011). The scales vary with regards to how different segmental/natural classes are viewed with respect to their relative sonority. For instance, Zec (1995, 2007) proposes a scale where vowels are the most sonorous elements and obstruents are the least sonorous (> means more sonorous than):

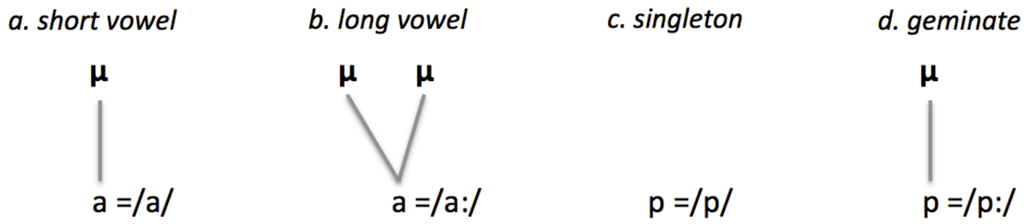
vowel > laterals > nasals > obstruents

However, for the discussion of onsets and codas in Maltese, I show that this scale does not give the necessary information to describe the possible margins in Maltese. Therefore, I opt for a finer-grained scale presented in Chapter 2 §2.2.

1.2.2 Moraic theory and syllable weight

In moraic theory, syllables can be heavy or light, a distinction that is motivated by the number of moras in each syllable. Following Hayes (1989), short vowels bear one mora (Figure 1.2a) whereas long vowels or diphthongs bear two moras (Figure 1.2b). Consonants do not typically bear underlyingly moras (Figure 1.2c). Curtis (2003) comments that since consonants are usually in onset position, they do not bear any moras since this position is not associated with weight. However, Topintzi (2010; 2011) argues that in a number of languages onsets contribute to weight and as a result participate in weight-related phenomena. In particular Topintzi (2010) refers to Karo, Pirahã and [CV] words in Bella Coola, where in her analysis onsets in these languages are moraic. This is why word-initial geminates are special as they belong to the syllable onset, a constituent which is normally *not* associated with weight. On the other hand, the rhyme, which is made up of the nucleus and the coda, is typically associated with syllable weight and determines the position of stress in a word (cf. Halle and Vergnaud 1980; Clements and Keyser 1983; Hayes 1995). In some languages, coda consonants can acquire weight through the principle of Weight by Position (Hayes 1989). Gordon (2002) discussed Weight by Position and gives numerous languages in which Weight by Position applies, some example language are Finnish, English and Egyptian Arabic. Hayes (1989) and Davis (1999) posit that geminates are assigned a mora underlyingly, whereas singletons are not (cf. Figure 1.2c and d). By assigning a mora to geminates, it is assumed that such segments, also contribute to weight. Since geminates are underlyingly moraic, Weight by Position does not apply in such cases (c.f. Chapter 3 §3.4.2).

Figure 1.2: Moraic representation of vowels and consonants



1.2.3 On the phonetics and phonology of geminates

The next issue that this dissertation addresses is the production of geminates in Maltese, as well as the perception of word-initial geminates in Maltese. Geminates are defined as long consonants or doubled consonants that contrast phonemically with their singleton counterparts (cf. Lehiste 1970; Ham 2001; Davis 2011), as in (2):

(2a) *Maltese*

[pɐ**p**ɐ] *papa* ‘pope’

[pɐ**pp**ɐ] *pappa* ‘food’

(2b) *Italian*

[se:**t**e] *sete* ‘thirst’

[se**tt**e] *sette* ‘seven’

(2c) *Japanese*

[ha**t**o] *hato* ‘dove’

[ha**tt**o] *hatto* ‘hat’

Geminates are typically found flanked between two vowels, normally referred to as word-medial or intervocalic geminates (cf. Thurgood 1993; Blevins 2004; Pajak 2013).

Underlying lexical geminates make up minimal pairs with their singleton counterparts, as in (2) above. ‘Fake’ or surface geminates may arise by the concatenation of two identical sounds next to each other spanning a word/morpheme boundary (as in 3a) or through assimilation (as in 3b).

(3a) concatenation (Maltese example)

[tɔ**m m**ɐːr jɔwm] *Tom mar jgħum* 'Tom went swimming'

(3b) assimilation of the definite article from Maltese:

[ɪ**n-n**ɐːs] 'the sleep'

It has widely been reported that underlying lexical geminates have longer durations than their singleton counterparts (Lahiri et al. 1988; Esposito and DiBenedetto 1999; Kraehenmann 2001, refer to Chapter 3 §§3.1-3.3 for a cross linguistic overview of empirical findings on gemination). Furthermore, empirical studies have shown that, like underlying lexical geminates, surface geminates have longer durations than singletons. Moreover, the duration of lexical and surface geminates has been reported to be comparable, as in Tashlhiyt Berber (Ridouane 2010) and Sardinian (Ladd and Scobbie 2003). The duration of geminates in relation to singletons is usually reported in terms of a duration ratio. The singleton-to-geminate duration ratio varies depending on the language under investigation. For instance, Ladefoged and Maddieson (1996) suggested that geminate stops are on average 1.5 to 3 times longer than their singleton counterparts. The overview presented in Chapter 3 shows that in some languages the singleton-to-geminate duration ratio fall below or above the ratios suggested by Ladefoged and Maddieson (1996). Furthermore, the singleton-to-geminate duration ratio is also affected by the manner of articulation, where sonorants tend to have longer duration ratios than obstruents. In this study, singleton-to-geminate duration ratios are considered for word-initial, word-medial and word-final geminates in Chapter 5, 6 and 7 respectively.

The phonological representation of geminates is controversial in the literature (cf. Davis 1999; 2011; Muller 2001; Hume et al. 1997; Curtis 2003; Ringen and Vago 2011). Numerous models have been proposed for the representation of geminates. Nonetheless, word-medial geminates are considered throughout as being ambisyllabic, where they span across two syllables. In contrast, true word-initial and word-final geminates are not considered to be ambisyllabic since they occur within one syllable. Predominantly, geminates are explained either through a syllable weight analysis (for a current overview see Davis 2011 and references therein) or through a segmental length analysis (Leben 1985; Ringen and Vago 2011). Both representations are discussed in Chapter 3 §3.4. Moreover, hybrid models which incorporate elements from both analyses have also been proposed; e.g., Hume et al. (1997), Muller (2001) and Ham (2001). In the literature, contrasting representations are proposed for word-initial, word-medial and word-final geminates (which are also discussed in Chapter 3 §3.4). Furthermore, separate representations for underlying and surface geminates have been proposed (e.g., Hayes 1989, in Chapter 3 §3.5). The starting point for the representation of geminates in this dissertation is Onset-Rhyme theory, where I show which constituent position geminates hold in the syllable. However, this does not fully encompass the true nature of geminates, and, consequently, I turn to a syllable weight analysis and moraic theory to provide a holistic representation for geminates in Maltese.

1.3 Structure of the dissertation

In the following chapter, the issue of syllable structure in Maltese is taken up. In Chapter 2, I provide a thorough list of the possible syllable structures in Maltese. I also discuss the possible syllable constituents in Maltese and how some of them, such as stop-stop clusters and sibilant-initial clusters, pose a problem for sonority-based models.

In Chapter 3, which serves as a literature review, I give an overview of the acoustic correlates for gemination and the representation of geminates. I start off this overview by looking at empirical work on word-medial geminates, due to the large number of studies on such geminates. This is followed by a discussion of the correlates of word-initial and of word-final geminates, which are typologically less common in languages in world (and as a result less studied). The second step is to consider the phonological representation of geminates by discussing two main analyses proposed in the literature (i.e., a segmental analysis and a moraic analysis). The third step is to provide a description of gemination in Maltese. In this description, I discuss which sounds can be geminated in Maltese, and also discrepancies in relation to the position of the geminate in the word. This is followed by a description of how gemination occurs in Maltese, most of which is triggered by morphological or morpho-phonological processes.

In Chapter 4, I establish the general methodology adopted in the three production studies (i.e., in Chapter 5, 6, 7).

In Chapter 5, I present the first production study of this dissertation, in which I compare lexical and surface word-initial geminates in Maltese. This is mainly motivated by the controversy of the presence of an epenthetic vowel before word-initial geminates. The study looks at two different contexts, which might trigger this vocalic insertion. In addition, the voice onset time (VOT) of voiced and voiceless stops; and the duration of the stressed vowel are measured.

In Chapter 6, I present the second production study, in which word-initial geminates are compared to word-medial geminates. Segments from different manners of articulation are compared, and, subsequently, their singleton-to-geminate duration ratios are presented. VOT in stops in word-initial and word-medial geminates is measured.

In Chapter 7, the third production study is analyzed, where word-final geminates are also compared to word-medial geminates. The duration of the vowel before geminates/singletons is investigated as a secondary correlate to word-medial and word-final geminates/singletons. In addition, the implications of the rhyme, which includes word-final geminates, on syllable structure are discussed.

In Chapter 8, the role of the epenthetic vowel before word-initial geminates in perception is discussed. Accuracy rates in a discrimination task from a perception task are analyzed. The ramifications of the results on the lexical representation of the vowel before word-initial geminates is tackled. Before considering the results of a perception experiment, a brief overview of the main components on the perception of word-initial geminates in typologically diverse languages is given.

Chapter 9 sums up the dissertation by addressing the main findings of the four studies carried out in the dissertation. Furthermore, the results are discussed with respect to the implications they have on phonological representation. As a result, I propose a representation of geminates in Maltese.

Chapter 2: On the phonetics and phonology of Maltese

Maltese is the language spoken in the islands of Malta and Gozo (located in southern hemisphere of Europe). The population of Malta (and Gozo) is of approximately 400,000 inhabitants. In addition, there are also numerous speakers of Maltese outside Maltese, like Europe, Australia, Canada and the U.S. Maltese and English are the official languages of the island. However, the island is rich in dialectal varieties, which are at the heart of a number of villages in Malta and Gozo. For these reasons, people in Malta and Gozo are considered to be bilingual or multilingual. The idea of a language continuum has been proposed by Borg (1988) and further discussed by Vella (2012) to discuss the rich Maltese linguistic landscape.

Maltese can be described as a mixture of Semitic (mostly Arabic), Romance (mostly Italian and Sicilian) and English. Maltese is a case of language mixing, as it encompasses elements from languages belonging to three typologically diverse families – Semitic, Romance and Germanic. As a result, Maltese is viewed as consisting of three strata (Mifsud 1995, Brincat 2004, Spagnol 2011). First, the Semitic stratum is the foundation of the language, as it forms the basis of the phonology, morphology and basic lexicon. Second, the Romance stratum is mainly represented by lexical and syntactic formations. Third is the English stratum, which is represented by extensive lexical items. The language contact between these three distinct linguistic influences has led to the growth of Maltese. Comrie (2009) states that typologically Maltese is closer to Semitic than to Romance, even though the Romance influence has moved Maltese closer to Romance typology. This suggests that the Semitic characteristics in Maltese are very salient, despite the Romance and, more currently, English influence on the language.

This chapter aims to describe the syllable structure and phonotactic constraints of onset and coda consonants in Maltese. Prior to a discussion of these phonological elements, an outline of the sound inventory of Maltese is put forward. The current work is based on the phonetic and phonological description of Maltese in Azzopardi (1981) and Borg and Azzopardi-Alexander (1997). The phonological account provided here, however, is grounded in a perspective, which involves discussing the syllable structure of Maltese in terms of an Onset-Rhyme model. Furthermore, the phonotactics of Maltese are described in terms of sonority. After establishing the nature of onset and coda consonants in Maltese, the process of syllabification in Maltese is discussed. This discussion is followed by an analysis of vowel epenthesis in Maltese. In discussing the phonotactic constraints and syllabification in Maltese, I also address certain issues related to geminates.

The structure of this chapter is as follows. §2.1 aims to familiarize the reader with the sound system of Maltese by providing the vowels and consonants in Maltese. §2.2 is an attempt to give a detailed description of syllable structure in Maltese, also by applying sonority principles to the possible onsets and codas in Maltese. This is the first description of this kind. A small digression is done in §2.3, where epenthesis in Maltese in relation to onset clusters is discussed. Finally, syllabification in Maltese is discussed in §2.4. A summary of the chapter is given in §2.5

Conventions used

Here I list the conventions that are used throughout the dissertation. Following Davis (2011), geminates are transcribed as a sequence of two identical consonants. Long vowels are always transcribed as a vowel with the IPA length mark. The dash ('-'), which is used in Maltese between the definite article and the following noun or adjective, is maintained in the transcriptions of such words. *C* and *V* refer to *C*onsonants and *V*owels respectively. When referring to syllable structure, the symbol *G* is used to refer to *geminates* and *CC* is used to refer to consonant clusters. C_1 and C_2 refer to the first and second consonant in a consonant cluster respectively.

2.1 The Sound System of Maltese

The sound inventory presented in this dissertation is of Standard Maltese. I do not discuss dialectal forms; readers are referred to Camilleri and Vanhove (1994), Chetcuti (2005), Azzopardi-Alexander (2011) and references therein with respect to the vowel systems of (some) dialects of Maltese. Neither do I discuss any historical phonological changes, as they are beyond the scope of this dissertation; readers are referred to Borg (1978), Borg (1997), Brincat (2014) and references therein.

2.1.1 The Vowel System of Maltese

Azzopardi (1981) and Azzopardi-Alexander (2002) present a set of eleven vowels for Maltese, which are both qualitatively and quantitatively distinct from each other. In Maltese, vowel length is phonemic and the inventory of Maltese vowels consists of 5 short vowels and 6 long vowels. The vowel chart for Maltese is presented in Figure 2.1.

Figure 2.1: The vowel chart for Maltese (cf. Azzopardi 1981:147)

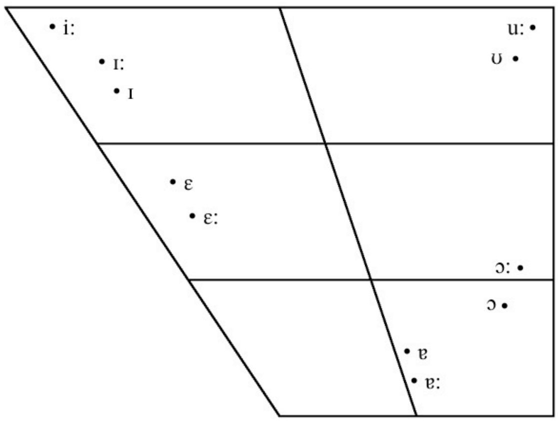


Table 2.1 lists the minimal pairs for all the vowels in Maltese. There is a three-way distinction between /ɪ/, /ɪ:/ and /i:/, where /ɪ/ and /i/ are qualitatively different from each other, whereas the distinction between /ɪ/ and /ɪ:/ is based mainly on length.

Table 2.1: Monothongs in Maltese: examples from minimal pairs

/ɪ/- /iː/ - /ɪː/	[mɪtt] *mitt* ‘hundred’	[miːt] *mit* ‘myth’	[mɪːt] *miet* ‘he died’
/ɛ/ - /ɛː/	[tɛmm] *temm* ‘he ended’	[tɛːm] *tegħem* ‘he tasted’	
/ɐ/ - /ɐː/	[rɐtt] *radd* ‘he gave back’	[rɐːt] *rat* ‘she saw’	
/ɔ/ - /ɔː/	[bɔtt] *bott* ‘bottle’	[bɔːt] *bogħod* ‘far away’	
/ʊ/ -/uː/	[kʊll] *kull* ‘every’	[kuːl] *kul* ‘eat’	

In Azzopardi’s (1981) analysis, the auditory quality of diphthongs is described as consisting one of the vowel elements, i.e. /ɪ ɛ ɐ ɔ/ and a transition to one of the glides (i.e., /j/ or /w/). The possible diphthongs in Maltese are listed in Table 2.2.

Table 2.2: List of diphthongs and examples

Diphthongs[4]	**Example**
[ɛɪ] or [ɛj]	[fɛɪn] or [fɛjn] *fejn* ‘where’
[ɛʊ] or [ɛw]	[sɛʊ] or [sɛw] *sew* ‘right’
[ɐɪ] or [ɐj]	[zɐɪr] or [zɐjr] *zgħir* ‘small’[5]
[ɐʊ] or [ɐw]	[tɐʊ] or [tɐw] *taw* ‘they gave’
[ɔɪ] or [ɔj]	[vɔɪt] or [vɔjt] *vojt* ‘empty’
[ɔʊ] or [ɔw]	[(ʔ)ɔʊm] or [(ʔ)ɔwm] *għomt* ‘swim’

2.1.2 The Consonant System of Maltese

The consonant inventory of Maltese is presented in Figure 2.2. A brief description of the phonetic realization of the consonants in Maltese is given below. This is mainly based on Azzopardi 1981 and Borg & Azzopardi-Alexander

[4] Borg and Azzopardi-Alexander (1997) and Mifsud (2008) give the diphthong [ɪʊ] or [ɪw] as one of the possible diphthongs in Maltese. However, Mifsud (2008:149) claims that [ɪʊ] is ‘very rare’. Prof. Marie Alexander (p.c. November 2015) provided me with the example: [lɪwjɐ] *liwja* ‘a bend’.

[5] These forms can also alternate with [zɛɪr] or [zɛjr].

1997. Arguably, /ʒ/ and /dʒ/ do not have full phonemic status (cf. Borg and Azzopardi-Alexander 1997 and Mifsud (2008).

Figure 2.2: Consonant inventory of Maltese (c.f. Borg and Azzopardi-Alexander 1997 and Mifsud 2008)

	Bilabial	Labiodental	Dental	Alveolar	Postalveolar	Palatal	Velar	Uvular	Pharyngeal	Glottal
Plosive	p b			t d			k g			ʔ
Nasal	m			n						
Fricative		f v		s z	ʃ ʒ					h
Affricate				ts dz	tʃ dʒ					
Approximant	w			ɹ		j				
Lateral				l						

Maltese has word-final devoicing, where voiced obstruents are realized as voiceless obstruents in word-final position. For instance, /lɐ:b/ surfaces as [lɐ:p] *lagħab* 'he played', /dʒi:d/ surfaces as [dʒi:t] *ġid* 'wealth'. Furthermore, voicing assimilation restricts the realization of consonants in consonants clusters, which is dealt with separately in §2.3.4. All consonants in the inventory, except for /ʒ/, can be geminated, however, since gemination is at the core of this dissertation, the phonetics and phonology of gemination in Maltese is discussed separately in Chapter 3.

Voiceless oral stops as singletons tend to be aspirated in Maltese. According to Azzopardi (1981), /p/ is the least aspirated stop and /k/ is the most aspirated stop, with /t/ being slightly more aspirated than /p/ but less aspirated than /k/. The voiceless stops /p t k/ and the glottal stop /ʔ/ are always audibly released. Unlike their voiceless counterparts, voiced stops are never aspirated. Furthermore, /p t k/ are aspirated when they are part of consonant clusters, unless they are preceded by /s/ or /ʃ/. In addition, two voiceless stops in a consonant cluster are usually realized as aspirated: /ktɪ:p/ → [kʰtʰɪ:pʰ] *ktieb* 'book', /ptɐlɐ/ → [pʰtʰɐ:lɐ] *btala* 'holiday'. The place of articulation of the glottal stop can vary in a number of dialects in Malta and Gozo (Borg and Azzopardi-Alexander 1997).

Borg and Azzopardi-Alexander (1997) claim that the place of articulation of the voiceless glottal fricative /h/ varies across speakers and can be realized also as a voiceless pharyngeal fricative, i.e. /ħ/. Furthermore, the duration of fricatives is longer compared to that other consonants, expect for affricates. Nasals go through a process of assimilation as they are realized homorganically with the following stop e.g. the nasal /n/ can be realized as [m] before stops: e.g. /ʔɐn.piː.nɐ/ → [ʔɐm.pɪː.nɐ] *qampiena* 'bell'. In Standard Maltese, /r/ is always realized as an approximant [ɹ] or a tap [ɾ] and not as a trill (Azzopardi-Alexander p.c. March 2015). The glides /j/ and /w/ are seem to be always realized as voiced (Azzopardi 1981).

2.2 Maltese Syllable Structure

Before describing the possible syllable structures in Maltese, it is important to highlight that Maltese monosyllables are restricted by complimentary quantity. This means that in monosyllabic words (c.f. Table 2.3), short vowels are either followed by a geminate (G) or by a consonant cluster (CC); and long vowels are followed by a single consonant, but never by a geminate (Azzopardi-Alexander 2002). This does not mean that open syllables in Maltese do not occur; open syllables are possible and examples are listed in Table 2.4.

Table 2.3: Complimentary quantity in Maltese

CVG	[hɐpp] *ħabb* 'he loved'
CVCC	[tɐlp] *talb* 'prayer'
CV:C	[kɐ:p] *kap* 'boss'

Therefore, in Maltese the following syllable types: V:G and V:CC do not occur due to this complimentary quantity restriction, and, as a result, are not found in syllable structures with added onsets or codas.

Azzopardi (1981) and Borg and Azzopardi-Alexander (1997) present the possible syllable types in Maltese. They argue that the minimal syllable requirement is a vowel. The maximum number of onset consonants is three and the maximum number of coda consonants is two[6]. Thus, a maximal Maltese syllable could have this shape: (C)(C)(C)V(C)(C).

A clearer picture of the possible syllable structure of Maltese is presented in Camilleri (2014), where she discusses syllable structures that occur as monosyllables and within word forms. I extend Camilleri's (2014) list of possible syllable structures, where I add other structures to that list, in order to come up with an exhaustive list (in Table 2.4) of the possible syllable structure (both as monosyllables and within word forms). Therefore, the possible syllable structures listed in Table 2.4 is built on Azzopardi (1981), Borg and Azzopardi-Alexander (1997) and Camilleri (2014). What is presented in this chapter is a first attempt at fully capturing the possible syllabic structures in Maltese. The description in Table 2.4 is split into four: 1) vowel initial syllable structures: *V-initial*, 2) one consonant onset syllable structure: *C-initial*, 3) two consonant onset syllable structure: *CC-initial* and 4) three consonant onset syllable structure: *CCC-initial*. The <-> in Table 2.4 refers to forms that do not occur as either monosyllables or within-word forms.

[6] Three consonant coda clusters such as /-ltʃ/ are possible in Maltese, and are discussed in Section 2.3.7.

Table 2.4: Possible syllable structures in Maltese

Initial	**Syllable Type**	**Monosyllable**		**Within-word forms**	
V	V	[ʊ]	*hu* 'he'	[**ʊ**.hut]	*uħud* 'some'
	VG	[ɔmm]	*omm* 'mother'	-	
	VCC	[ɛlf]	*elf* 'thousand'	-	
	VCCC	[ɪntʃ]	*intx* 'aren't you'	-	
	V:C	[ɐ:f]	*af* 'know'	[**ɐ:f**.sɐ]	*għafsa* 'a squeeze'
	V: (e.g. V:CVC)	-		[**ɛ:**.mɛs]	*għemes* 'he winked'
	VC (e.g. VC.CVC)	-		[**ɔr**.bɔt]	*orbot* 'tie (imp.)'
C	CV	[lɛ]	*le* 'no'	[**lɛ**.fɐʔ]	*lefaq* 'he sobbed'
	CV:	[dʒɪ:]	*ġie* 'he came'	[**dʒɪ:**.li]	*ġieli* 'sometimes'
	CVW	[rɐw]	*raw* 'they saw'	[**rɐw**.kɔm]	*rawkom* 'they saw you'
	CVC	-		[**hɐz**.bɛt]	*ħasbet* 'she thought'
	CV:C	[tɐ:f]	*taf* 'she knows'	[**tɐ:f**.nɐ]	*tafna* 'she knows us'
	CVG	[hɐpp]	*ħabb* 'he loved'	[tɪn.**hɐpp**]	*tinħabb* 'to be loved'
	CVGC	[zɐmmʃ]	*żammx* 'he didn't hold'	[ɪn.**zɐmmʃ**]	*inżammx* 'it wasn't held'
	CVCC	[bɐrt]	*bard* 'cold'	[kɐz.**bɐrt**]	*kasbart* 'I disgraced'
	CVCCC	[mɔrtʃ]	*mortx* 'didn't go'	-	

CC	CCV	[blɐ]	*bla* 'without'	[**stɐ**.hɐ]	*staħa* 'he was shy'
	CCV:	[kjuː]	*kju* 'queue'	[**kpɪː**.pɛl]	*kpiepel* 'hats'
	CCVW	[tfɛw]	*tfew* 'they switched sth off'	[**tfɛw**.kɔm]	*tfewkom* 'they over-shone you'
	CCVC	-		[**ftɐh**.tʊ]	*ftaħtu* 'I opened it'
	CCV:C	[frɐːk]	*frak* 'crumbs'	[**kniːs**.jɐ]	*knisja* 'church'
	CCVG	[frɔtt]	*frott* 'fruit'	[ʊ.zuː.**frʊtt**]	*użufrutt* 'usufruct'
	CCVGC	[ʔbɐttʃ]	*qbatx* 'didn't catch'	[ɪn.**ʔbɐttʃ**]	*inqbattx* 'I didn't get caught'
	CCVCC	[frɪsk]	*frisk* 'fresh'	-	
	CCVCCC	[hsɪltʃ]	*ħsiltx* 'didn't wash'	[ɪn.**hsɪltʃ**]	*inħsiltx* 'I didn't shower'
CCC	CCCV:	[strɔː]	*straw* 'straw'	[**zbrɐː**.nɐ]	*żbrana* 'he exploded'
	CCCVW	[ʃtrɐw]	*xtraw* 'they bought'	[**ʃtrɐw**.nɐ]	*xtrawna* 'they bought us'
	CCCVC	-		[**strɐm**.bɐ]	*stramba* 'odd (fem.)'
	CCCV:C	[sptɐːr]	*sptar* 'hospital'	-	
	CCCVCC	[strɐmp]	*stramb* 'odd (m)'	-	
	CCCVG	[ftrɐkk]	*f'trakk* 'in a truck'	-	

Focusing on the structures: *CVW, CCVW* and *CCCVW,* Camilleri (2014) claims that the vowel before syllable- or word-final glides (/w j/) is always a short vowel. Therefore, following Camilleri's (2014) description, this creates the possible syllable structures: *CVC, CCVC, CCCVC*, where the coda consonant is always a glide. I do not fully commit to Camilleri's (2014) claim because, sequences such as [ɐw], [ɛw], [ɐj] and so on, are what Azzopardi (1981) and Borg and Azzopardi-Alexander (1997) consider as diphthongs. Therefore, the rhyme of the syllable is a vowel plus a transition to another vowel or a glide (cf. Azzopardi 1981). Bearing this in mind, it is not clear whether the vowel before is short or not. Since, there are no empirical studies that show the phonetic realizations of diphthongs in Maltese, I consider these structures to be of the type: *C(C)(C)VW*, where *W* stands for the glides /w j/.

The list of possible syllable structures presented in Table 2.4 differ from those proposed by Camilleri (2014). Camilleri (2014) lists the syllable structure *CCV:* as occurring only as a within-word form but not as a monosyllable. Camilleri (2014) illustrated this type through the word /kni:sja/ *knisja* ‘church’. I disagree with this description as following the syllabification process in Maltese (described in Azzopardi 1981 and in §2.6), the /s/ can be seen to serve as a coda to the previous syllable (and not as an onset to the following syllable). The syllable structure of the word /kni:sja/ *knisja* is not *CCV:.CCV* but *CCV:C.CV*. In the list in Table 2.4, I provide the example /kju:/ *kju* ‘queue’ (another possible example is /blu:/ *blu* ‘blue’), which show that that the structure *CCV:* can also occur as monosyllables.[7]

Two structures are not reported by Camilleri (2014). Firstly, the structure *CCCV:* in /strɔ:/ *straw* ‘straw’ occurs both as a monosyllable and within-words. Secondly, a long vowel, *V:*, can occur as a syllable within words, e.g. /ɛ:/ in /**ɛ:**.mɛs/ *għemes* ‘he winked’ or /ɐ:/ in /**ɐ:**.fɐs/ *għafas* ‘ he pressed’. In (C)CV*G*C, the C following the geminate can only be the /ʃ/ for negation as in the examples: [ɪn.zɐ*mm*ʃ] *inżammx* ‘it was not held’ and [ɪn.ʔbɐ*tt*ʃ] *inqbattx* ‘I didn’t get caught’ or /s, z/ for English-origin plurals e.g. /klɐ*pp*s/ *clubs* ‘clubs’. Furthermore, the syllable type C(C)VCCC as in the examples (from Table 2.4) [mɔrtʃ] *mortx* ‘I didn’t go’ and [hsɪltʃ] *ħsiltx* ‘I didn’t wash’ (and other words which include these syllables) are limited to the 1st person negative inflected form.

In the following subsections, I describe the phonotactic constraints of each syllable structure group from Table 2.4 in detail. Specifically, I address both phonetic and phonological issues of each syllable structures group. The description of the permissible onset and coda consonants is achieved through the principles of sonority. In this work, I adopt the sonority scale in Table 2.5, based on Parker (2011). Furthermore, I also adopt Selkirk’s (1984) Sonority Sequencing Principle, which accounts for a rise to occur between a left-margin constituent and the syllable peak.

[7] Nonetheless, these are open empirical questions, which should be measured in production studies.

Table 2.5: Sonority scale for Maltese (based on Parker 2011)

High sonority	Low vowels	**/ɐ ɐː/**
	Mid vowels	**/ɪ ʊ ɛ ɛː ɔ ɔː/**
	High vowels	**/i iː uː/**
	Glides	**/j w/**
	Laterals	**/l r/**
	Nasals	**/m n/**
	Voiced fricatives	**/v z/**
	Voiced affricates	**/dʒ/**
	Voiced stops	**/b d g/**
	Voiceless fricatives	**/f s ʃ h/**
	Voiceless affricates	**/tʃ ts/**
Low sonority	Voiceless stops	**/p t k ʔ/**

2.2.1 The nucleus

All vowels in Maltese, both monophthongs and diphthongs, can serve as a syllable nucleus. As a matter of fact, the language allows vowels on their own to occur as a permissible syllable. Even though this is restricted to a few words, which are typically function words and often unstressed, such as /ɪ/ *hi* 'she', /ʊ/ *hu* 'he' or *u* 'and', some exclamations such as /ɔː/ 'oh', but also, less frequently, content words such as /ɐː/ 'confusion'. However, it is argued that syllable-initial vowels can be preceded by an epenthetic glottal stop (Borg and Azzopardi-Alexander 1997). This is discussed in §2.2.2.

2.2.2 Vowel-initial syllable structures

It is debatable whether Maltese allows onsetless syllables. The phonetic realization of onsetless syllables shows that vowels are variably preceded by an epenthetic glottal stop, which might constitute a syllable onset, e.g. /ʊ/ → [ʔʊ] *hu* 'he' (Azzopardi 1981). As a matter of fact, Borg and Azzopardi-Alexander (1997) claim that this insertion is more likely to happen in utterance initial or in post-pause position. This might suggest that the preferred syllable structure in

Maltese requires onsets (i.e. CV), which is consistent with spoken Arabic dialects, dialects of English and German. To illustrate, syllables in Arabic always require an onset. If syllables lack an onset, a glottal stop is inserted (cf. Standard Arabic, Egyptian Arabic: Gadoua 2000; Cairene Arabic: Wiltshire 1998; Youssef 2013). The preceding context triggers the insertion of a glottal stop: Wiltshire (1998) argued that when the definite article is in phrase-initial position an epenthetic glottal stop is always inserted, as in [ʔil.mu.dar.ris] 'the teacher'. This observation is also put forward by Youssef (2013), who claimed that in Cairene Arabic, the definite article /il/ is always preceded by an epenthetic glottal stop: [ʔil]. Furthermore, studies on American English (Dilley et al. 1996; Redi & Shattuck-Huffnagel 2001) showed that word-initial vowels are glottalised at the beginning of an intonational phrase. Moreover, Alber (2001) showed that glottal stop insertion is common at the beginning of words and at the beginning of stressed syllables in Standard High German.

Historically, Maltese had a voiced pharyngeal approximant [ʕ], which is no longer present in current Maltese. This is represented in the orthography by the digraph <għ>. Borg (1997) and Brame (1972) argue that vowels adjacent to orthorgraphic <għ> are lengthened, whereas Puech (1979) argues that this vowel duration is context dependent. Hume et al. (2009) investigated this observation by recording two native speakers of Maltese. They investigated whether the vowels adjacent to <għ> are lengthened in a number of positions in a word. Focusing on absolute phrase initial position, Hume et al. (2009) argued that there is increased vowel duration in the <għ> context in monosyllabic words; e.g., in a minimal pair such as [ɐːtt] *għadd* 'he counted' and [ɐtt] *att* 'act', they show that the duration of the vowel /ɐ/ is longer in the <għ> context. Nonetheless, even though they had a number of vowel-initial syllables in their corpus, Hume et al. (2009) did not report whether there were any glottal stop insertions before the vowel.

To sum up, vowel-initial syllables in Maltese might actually be phonetically realized as CV, where the C is an epenthetic glottal stop. In which case, if this is true, there are no vowel-initial syllables. If this is the case, the claim that the minimum requirement for a syllable is a vowel (Borg and Azzopardi-Alexander 1997) needs to be reconsidered. This is because the epenthetic glottal stop serves as an onset to a vowel-initial syllable. Words that have an <għ> or an orthographic <h> in absolute initial position tend to have longer adjacent vowels. However, only the durations of vowels adjacent to <għ> have been investigated empirically (Hume et al. 2009).

2.2.3 Permissible onsets in Maltese

Almost all consonants in the inventory of Maltese (cf. Figure 2.3) constitute permissible single onsets; examples are listed in Table 2.6 below. The status of the phone /ʒ/ in Maltese is unclear (cf. Borg and Azzopardi 1997). It occurs in some loan words such as [tɛlɛvɪʒɪn] *televixin* 'television', where the voiced post-alveolar fricative constitutes an onset to the final syllable. Furthermore, it can occur as part of onset clusters such as [ʒbiːɐ][8] *xbiha* 'image', however, there are no words in which have [ʒ] as a single onset consonant. In all of the examples presented in (1), there are no sonority violations in the onset consonant. The structure conforms to SSP, since a single consonant is always less sonorous than a vowel as the nucleus.

[8] This [ʒ] is only voiced because it is C_1 in a CC onset in which C_2 is voiced, thus triggering the voicing harmony, which operates in Maltese onset clusters and is discussed later on this section.

Table 2.6: Simple onsets in Maltese

Stops	[pɐːɹ] *par* 'pair' [bɐːɹ] *bar* 'bar' [tɐːɹ] *tar* 'he flew' [dɐːɹ] *dar/dahar* 'back/house' [kɐːp] *kap 'head of an institution'* [gɔst] *ġost* 'fun' [ʔɐːm] *qam* 'he woke up'
Fricatives	[fɐːɹ] *far* 'it overflowed' [vɐːɹɐ] *vara* 'statue' [sɐːɹ] *sar* 'it became' [zɐːɹ] *żar* 'he visited' [ʃɐːɹ] *xahar/xagħar* 'month/hair' [hɐll] *ħall* 'vinegar/ he undid (a knot)'
Affricates	[tʃɐːɹ] *ċar* 'clear' [dʒɐːɹ] *ġar* 'neighbour' [tsɔkk] *zokk* 'branch' [dzɔːnɐ] *żona* 'zone'[9]
Nasals	[mɐːɹ] *mar* 'he went' [nɐːɹ] *nar* 'fire'
Glides	[wɐʔt] *waqt* 'during' [juːm] *jum* 'day'
Laterals	[lɐːt] *lat* 'point of view' [rɐːt] *rat* 'she saw'

2.2.4 Permissible onset clusters in Maltese

It is generally claimed that the larger the distance in sonority between the first consonant (C_1) and the second consonant (C_2) in a consonant cluster, the more well-formed the onset cluster is (Topintzi 2011). Nonetheless, clusters having the same or similar sonority are allowed to occur in sequence in a number of

[9] For some speakers this is pronounced as [zɔːnɐ].

languages such as Russian and Bulgarian, but not in others, such as Spanish. This is referred to as the *Minimum Sonority Distance* principle (cf. Selkirk 1984, Levin 1985, Parker 2011). In languages such as Russian, Bulgarian and Leti, onset clusters containing consonants which are very close on the sonority scale, e.g. /kn/ in Russian /kniga/ 'book' are allowed. In contrast, in Spanish, only onset clusters which are made up of an obstruent and liquid, e.g. /kr/ in /krus/ 'cross' (Baertsch 2002) are allowed. Therefore, in languages like Spanish, the occurring onset clusters in such languages have a larger distance in sonority between C_1 (e.g., /k/) and C_2 (e.g., /r/) and low distance sonority clusters are not allowed. In addition, Parker (2011:1168) claims that "if a language permits clusters with a lower sonority distance, it allows clusters of all higher distances as well" but not the other way around.

Maltese, is one of these languages that, allows clusters with minimum sonority distance. Clusters that have minimum sonority distance give rise to plateaus. Sonority plateaus arise when there is no difference in sonority between the members of a consonant cluster (such as in Maltese /tp/ in /tpɛjjɛp/ *tpejjep* 'he smoked' or /sf/ in /sfɔrts/ *sforz* 'effort'). The SSP states that there must be one peak from the onset to the syllable nucleus, thus, plateaus in the onset violate the SSP (e.g., Selkirk 1984, Clements 1990, Zec 2007). A syllable with an onset cluster such as /kl/ in /klɪ:m/ *kliem* 'kliem' or /pr/ in /prɛtsts/ *prezz* 'price' has a higher sonority distance, and this leads to a rising peak from the onset to the syllable nucleus. In comparison, consonant clusters such /kt/ in /ktɪ:b/ *ktieb* 'book' or /dv/ in /dvɐljɐ/ *dvalja* 'table cloth' lead to a sonority plateau and, thus, a possible violation.

In addition to allowing onset consonant clusters with very 'flat sonority' (Zec 2007), in Maltese, there is another constraint on word-initial tautosyllabic consonant clusters. They are restricted by a voicing harmony rule which operates regressively. Therefore, consonant clusters are both voiced or both voiceless: e.g. [bdɛw] *bdew* 'we started'; [pkɪ:t] *bkiet* 'she cried'.

To give an example of the range of possible clusters from low sonority distance to high sonority distance, I show the spectrum of possible consonant clusters beginning with /p/ in Table 2.7. The permissible clusters start from those that have a minimum sonority distance (e.g. /pt/, /pk/), which lead to a sonority plateau, which are followed by clusters that have a higher sonority distance (e.g. /pr/ and /pj/).

Table 2.7: Permissible /p/-initial clusters

MSD	**Cluster**	**Example**	**Sonority**
Low	/pt/	[ptɐ:.lɐ] *btala* ‘holiday’	**Plateau**
	/pk/	[pkɛw] *bkew* ‘they cried’	
	/pʔ/	[pʔɐjt] *bqajt* ‘I stayed’	
	/ptʃ/	[ptʃɛj.jɛtʃ] *bċejjeċ* ‘pieces’	**Increase**
	/pts/	[ptsɪ:.tsɛn] *bżieżen* ‘bread rolls’	
	/ps/	[psɐrt] *bsart* ‘I guessed’	
	/pf/[10]	[pfɔr.mɐ] *b’forma* ‘with a shape’	
	/pʃ/	[pʃɐ:.rɐ] *bxara* ‘announcement’	
	/ph/	[phɐ:l] *bħal* ‘like’	
	/pn/	[pnɪ:.tsɛl] *pnietżel* ‘brushes’	
	/pl/	[plɐt:] *platt* ‘plate’	
	/pr/	[prɛts:] *prezz* ‘price’	
	/pw/	[pwɪ:.nɪ] *pwieni* ‘pains’	
High	/pj/	[pjɐ:n] *pjan* ‘plan’	

(1) lists some examples of minimum distance sonority clusters of voiced consonant clusters:

(1) Voiced consonant clusters

/bd/ → /bdi:l/ *bdil* ‘change’

/dg/ → /dgɔrr/ *gorr* ‘you complain’

/zb/ → /zbi:p/ *żbieb* ‘raisins’

[10] Cluster /pf/ appears only in the case of the preposition *b’* before /f/.

In the case of higher sonority distance onset clusters, Maltese allows: O+N, O+L O+G, as in (2).

(2) Examples of higher sonority distance clusters:

O+ N: /tn/ in /tnɛjn/ *tnejn* 'two'

/zm/ in /zmɪ:n/ *żmien* 'time'

O + L: /dl/ in /dlɐ:m/ *dlam* 'darkness'

/fr/ in /frɐ:r/ *Frar* 'February'

O + W: /ʔw/ in /ʔwɪ:l/ *qwil* 'idioms'

/vj/ in /vjɐtʃtʃ/ *vjaġġ* 'journey'

The voicing harmony rule is not strictly respected in clusters beginning with /ʔ/ and /h/. When these consonants occur as C_1 in a CC consonant cluster, voicing harmony is violated when C_2 is a voiced obstruent e.g. /ʔb/ in /ʔbi:l/ *qbil* 'agreement' and /hd/ in /hdu:t/ *ħdud* 'Sundays'. Even though the voicing harmony is violated, sonority is not. Rather, this leads to a sonority plateau. In the opposite case, when a voiced obstruent is in C_1 position and /ʔ/or /h/ is in C_2: e.g. /bʔ/ in /bʔɐjt/ *bqajt* 'I stayed', and /dh/ in /dhu:l/ *dħul* 'entrances', such clusters lead to a sonority reversal. Borg and Azzopardi-Alexander (1997) claim that the frequency of consonant cluster onsets with /ʔ/ and /h/ + voiced obstruent (e.g. [hd]) is lower than that of CC onsets of /ʔ/ and /h/ + voiceless obstruent (e.g. [ht]). Furthermore, /ʔ/ and /h/ also cluster with consonants further up in the sonority scale as in (3):

(3) Consonant clusters with /ʔ/ and /h/ as C_1

/ʔl/ in /ʔlu:p/ 'qlub' *hearts*

/ʔr/ in /ʔrɐ:r/ 'qrar' confession

/hm/ in /hmɐ:r/ 'ħmar' *donkey*

/hl/ in /hlɐ:s/ 'ħlas' *payment*

2.2.5 Sibilant Onset Clusters

Maltese allows sibilant onset clusters. The voicing harmony rule still applies in sibilant clusters as in (4).

(4) Sibilant onset clusters: voicing harmony

/sk/ in /skuːr/ *skur* 'dark'

/sp/ in /spɪss/ *spiss* 'often'

/ʃt/ in /ʃtɐːʔ/ *xtaq* 'he wished'

/ʃk/ in /ʃkɪːl/ *xkiel* 'obstacle'

/zb/ in /zbɐll/ *żball* 'mistake'

/zv/ in /zvɔːk/ *zvog* 'vent'

The clusters in (4), just like in English and Italian, pose a challenge to sonority since the sibilant is more sonorous than the stop (in first five examples in (4)) and leads to a sonority plateau in /zv/.

Furthermore, Maltese also permits sibilant clusters which have a high sonority distance and do not violate sonority as in (5)

(5) Sibilant onset clusters: high sonority distance

/sr/ in /sriːp/ *sriep* 'snakes'

/zr/ in /zrɐːr/ *żrar* 'coarse aggregate used in concrete'

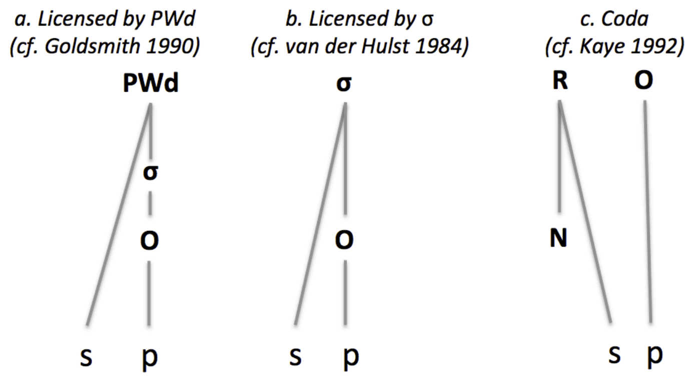
/ʃm/ in /ʃmuːn/ *Xmun* 'Simon'

/ʃl/ in /ʃlɔkk/ *Xlokk* 'south east'

/zm/ in /zmɛrtʃ/ *żmerċ* 'awry'

The representation of s-clusters in the literature has received a lot of attention. This is because sibilant-stop (e.g. /st/, /ʃk/) and sibilant-fricative (/sf/, /zv/) initial clusters pose a challenge to syllabification since they violate the Sonority Sequencing Principle because the sibilant is more sonorous than the stop/fricative. Many proposals have been suggested to deal with the syllabification of such sibilant clusters. For instance, the sibilant can be represented as an appendix linked to a node higher than the syllable, i.e., the prosodic word, henceforth PWd, as in Figure 2.3a (cf. Goldsmith 1990). On the other hand, van der Hulst (1984) argues that the sibilant is directly linked to the syllable node as in Figure 2.3b. In Government Phonology, word-initial and word-internal sibilant clusters are heterosyllabic. This claim suggests that the sibilant is part of the previous syllable and is linked to the coda of that previous syllable, this coda consonant is preceded by an empty nucleus (as in Figure 2.3c) which occurs through what has been referred to as magic licensing (cf. Kaye 1992, Goad 2011, 2012).

Figure 2.3: Representation of sClusters (adapted from Goad 2011)



Another proposal for the syllabification of sibilant-obstruent clusters is to look at the coordination of articulatory gestures (c.f. Browman and Goldstein 1992). Empirical evidence has shown that in languages with branching onsets, such as English, sibiliant-obstruent clusters behave quite similarly to other consonant clusters (Browman and Goldstein 2000; Hall 2010), where a cluster like /sp/ is both a word onset and a syllable onset cluster. On the other hand, in Italian, obstruent-liquid clusters (such as /pr/) and sibilant-obstruent clusters (e.g. /sp/) have different coordination patterns and, therefore, Hermes et al. (2013) conclude that Italian employs two syllabification strategies, where obstruent-liquid clusters are analyzed as tautosyllabic clusters, and sibilant-obstruent clusters are analyzed as heterosyllabic clusters. In a preliminary study on Maltese, Hermes et al. (2014) concluded that both sibilant-initial clusters such as /sp/ and /sf/ and obstruent-initial clusters (such as /pr/) involve a simple onset coordination, which suggests that both cluster types are syllabified as heterosyllabic. Results from Moroccan Arabic (Shaw et al. 2011) and Tashlhiyt Berber (Hermes et al. 2011) also favour a simple onset coordination, which also suggests that such clusters are syllabified as heterosyllabic. Even though this requires more empirical evidence, the syllabification of onsets clusters in Maltese, regardless of the manner of the first consonant in a consonant clusters, may be syllabified as not belonging to the same syllable.

To sum up, it is possible that there is not a universal approach to syllabification: in some languages, like English, sibilant clusters pattern like non-sibilant clusters and are considered as tautosyllabic, but in Italian, sibilant-obstruent clusters, unlike obstruent-liquid clusters, are heterosyllabic. In languages such as Moroccan Arabic, Tashlhiyt Berber and possibly Maltese, sibilant-initial clusters and obstruent-initial clusters are heterosyllabic.

2.2.6 Sonorant-initial clusters

Maltese has consonant clusters that have a sonorant (/l m n r/) as C_1. Maltese has combinations of sonorant + stop (e.g. /lp/, /md/, /nt/, /rk/), sonorant + fricative (e.g. /ls/, /ms/, /nz/, /rv/), sonorant + glottal (e.g. /mʔ/ and /nh/). However, these clusters violate sonority, as C_1 is more sonorous than C_2. Also, such clusters are optimal examples of sonority reversals, where C_1 is more sonorous than C_2. In order to avoid this violation one of two strategies can be employed. First, Azzopardi (1981) proposes that the realization of sonorants as C_1 in a consonant cluster could be syllabic. Thus, /mʔɐːr/ surfaces as [m̩.ʔɐːr] *mqar* '*at least*'. This realization does not violate sonority because a syllabic consonant constitutes its own syllable nucleus. The other strategy is to insert a vocalic element of [ɪ]-like quality before the sonorant consonant: [ɪm.ʔɐːr]. In this case, the vowel [ɪ] serves as a syllable nucleus, which is followed by the sonorant [m], which serves as coda to the first syllable. In addition, it is possible for a glottal stop to be inserted before the epenthetic vowel. If this epenthetic glottal stop were represented in the phonological structure, then this would constitute a syllable onset. More examples of sonorant-initial clusters are presented in (6).

(6) Realization of sonorant-initial clusters

/lp/ → [ɪl.pu:p] or [l̩.pu:p] *lpup* 'wolves'

/md/ → [ɪm.di:.nɐ] or [m̩. di:.nɐ] *Mdina* 'Mdina (name of town)'

/nz/ → [ɪn.zi:t] or [n̩.zi:t] *nżied* 'I add'

/rv/ → [ɪr.vɛll] or [r̩.vɛll] *rvell* 'revolution'

/mh/ → [ɪm.hɐ:r] or [m̩.hɐ:r] *mħar* 'clams'

Thus, sonorant-initial clusters in Maltese are never tautosyllabic, but rather are always heterosyllabic.

2.2.7 CCC-initial clusters

As shown in Table 2.4, Maltese also allows for tri-consonantal word-initial clusters (abbreviated to CCC-initial). Borg and Azzopardi-Alexander (1997) show that the combinations of which consonants are allowed is very restricted. C_1 is usually a fricative (/s, ʃ, z/) or a bilabial stop (i.e., /p, b/). C_2 can be either an oral stop (i.e., /p, b, t, d, k, g/) or the fricative (/f/). C_3 tends to be occupied by a sonorant but can be filled by any other consonants. It's important to note that the voicing harmony still applies in CCC-initial clusters. Furthermore, the morphological prefixes /b/ 'with', /ʃ/ 'what' and /f/ 'in' can contribute to create CCC-initial onsets. In Table 2.4, I provide the example [ftrɐkk] *f'trakk* 'in a truck', where the first consonant [f] is a morphological prefix, and its addition leads to a tri-consonantal clusters [ftr]. Examples of tri-consonantal clusters in Maltese are found in (7).

(7) CCC-initial

[stʔɐrr] *stqarr* 'he confessed'

[zbrɔffɐ] *zbroffa* 'he exploded'

[ʃpru:n] *xprun* 'a spur'

Little has been said about the syllabification of CCC-clusters in Maltese. However, they are usually considered as a complex onset.

2.2.8 The Coda

Before describing which consonants can occur in coda position, it is beneficial to point out that syllables without codas can occur in Maltese, as in (8).

(8) (C)V syllables

/ʊ/ *hu* 'he'

/tɐː/ *ta* 'he gave'

/bluː/ *blu* 'blue'

Maltese allows for both simplex and complex codas. As simplex codas, all consonants in the inventory are allowed, expect for voiced obstruents which are realized as voiceless obstruents by word-final devoicing (cf. (9) below).

(9) Simplex Coda Consonants

/lɐːb/ → [lɐːp] *lagħab* 'he played'

/vɔːt/ *vot* 'vote'

/tɐːf/ *taf* 'she knows'

/truːʃ/ *trux* 'deaf'

/mɐːr/ *mar* 'he went'

/fɜːm/ *fehem* 'he understood'

To exemplify word-final devoicing in Maltese, I will use the first verbal form of the root /b-r-d/ is [bɪrɛt] *bired* 'to become cool', where the final consonant in the root is the underlying voiced alveolar plosive /d/ and this is realized as its voiceless alveolar counterpart [t]. In other inflected or derived forms, where the root consonant /d/ is not in final position, it surfaces as a voiced alveolar plosive: [bɪr.dɛt] *birdet* 'she become cold'. In the latter example, the voiced alveolar plosive serves as an onset to the following syllable and therefore is not devoiced. In word-final clusters, devoicing still applies, the derived noun from [bɪrɛt] *bired* 'to become cool' is [bɐrt] *bard* 'cold'.

In terms of coda consonant clusters, Borg and Azzopardi (1997) argue that maximally two consonants can occur in coda position, unless the negative suffix /ʃ/ or the perfect aspect suffix /t/ are added to verbs. In this case, CCC codas are also possible. Borg and Azzopardi (1997: 310), following Azzopardi (1981), provide the following list of "actually-occurring" obstruent-obstruent coda clusters.

(10)	/pt/	/ʔlɪpt/ *qlibt* 'I switched'
	/ps/	/hɐps/ *ħabs* 'prison'
	/pʃ/	/(ma) lɐpʃ/ *(ma) lagħabx* 'he didn't play'
	/ph/	/ʃɛph/ *xebh* 'resemblance'
(11)	/kt/	/dlɪkt/ *dlikt* 'I spread'
	/ks/	/ɐːks/ *għaks* 'oppression'
	/kʃ/	/(ma) tɐkʃ/ *(ma) takx* 'he didn't give you'
(12)	/st/	/hlɪst/ *ħlist* 'I got rid of'
	/sk/	/bɔsk/ *bosk* 'forest'
	/sʃ/	/(ma) tʔisʃ/ *(ma) tqisx* 'you don't acknowledge'
	/sʔ/	/wɪsʔ/ *wisq* 'too much'
(13)	/ft/	/zɪft/ *zift* 'tar'
	/fs/	/nɪfs/ *nifs* 'breath'
	/fʃ/	/(ma) tɐfʃ/ *(ma) tafx* 'you don't know'
(14)	/ʃt/	/ɛːʃt/ *għext* 'I lived'
	/ʃk/	/brɔʃk/ *broxk* 'scrubbing brush'
(15)	/tʃt/	/pɐtʃpatʃt/ *paċpaċt* 'I spoke/gossiped'

(16) /ʔt/ /dɔʔt/ *doqt* 'I tasted'

/ʔs/ /dɐʔs/ *daqs* 'size'

/ʔʃ/ /ma ʃtɐʔʃ/ *(ma) xtaqtx* 'he didn't wished'

(17) /ht/ tɐht/ *taħt* 'under'

/hʃ/ /(ma) tɐ(:)hʃ/ *(ma) tahx* 'he didn't give him'

/hʔ/ /dɐhʔ/ *daħq* 'laughter'

Therefore, consonant clusters in coda position, just like onset consonant clusters, allow for a sonority plateau to occur. Maltese also allows clusters that classify under sonority reversal clusters, these include stop + fricative combinations such as /ps/and /pʃ/.

Moreover, coda consonant clusters, which do not lead to a plateau, are also permissible in Maltese. The sonorants /l m n r w j/ can cluster with voiceless obstruents, see (18) below. In the case of the glides /w j/, the can also cluster with some of the sonorants (cf. (19) below).

(18) /mp/ /kɐmp/ *kamp* 'camp'

/mt/ /hlɔmt/ *ħlomt* 'I dreamt'

/mʃ/ /ʃɛmʃ/ *xemx* 'sun'

/mh/ /ʔɐmh/ *qamħ* 'wheat'

(19) /jl/ /lɛjl/ *lejl* 'night'

/wn/ /ɐwn/ *hawn* 'here'

/wl/ /ʔɐwl/ *qawl* 'idiom'

2.3 Epenthesis in Maltese

One type of epenthetic vowel, prothetic vowels, can be found at the beginning of words in Maltese. The phonological conditions for this vocalic insertion are presented here. Note that prescriptive grammars identify a set of epenthetic vowels which occur within the word, they are referred to as 'euphonic vowels'.

However, this set of epenthetic vowels is not discussed in any of the traditional grammars, such as Sutcliffe 1936, Aquilina 1965, and Borg and Azzopardi 1997.[11]

The prothetic vowel in Maltese tends to be a vowel of [ɪ]-like quality.[12] This vowel can occur in the following contexts:

1) **before the definite article**

   a) [ɪl-kɛlp] *il-kelb* ‘the dog’ at the beginning of a phonological phrase or after a word ending in a consonant, e.g. [hɐdɛt ɪl-kɛlp] *ħadet il-kelb* ‘she took the dog’
   b) when it regressively assimilates in [+coronal] sounds[13] [ɪʃ-ʃɛmʃ] *ix-xemx* ‘the sun’, [ɪt-tɔrt] *it-tort* ‘the blame’, [ɪs-su:ʔ] *is-suq* ‘the market’, [ɪz-zrɪntʃ] *iż-żrinġ* ‘the frog’.

The definite article before certain onset clusters can alternate from /ɪl-/ to /l-ɪ/. This is common before nouns beginning with a sibilant cluster. According to Aquilina (1965), this occurs when the noun is a loan word, which begins with an /s/. In non-Semitic nouns, such as [l-ɪsfɪdɐ] *l-isfida* ‘the challenge’ or [l-ɪskɔlɐ] *l-iskola* ‘the school’, the article alternates to /l-ɪ/. However, unlike Aquilina (1965), I claim that the article alternation might also occur before Semitic words too such as in (20)[14]:

(20) Article alternation before s-clusters

[l-ɪskɪ:kɛn] *l-iskieken* ‘the knives’,
[l-ɪsbʊhɪjɐ] *l-isbuħija* ‘the beauty’
[l-ɪsʔɐ:ʔ] *l-isqaq* ‘the pathways’.

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[11] Readers are referred to *Grammatika Maltija* (Bro. Henry Fenech, 1980) for a discussion on euphonic vowels.
[12] The epenthetic vowel can also be /ɛ/ e.g. as in [ɛrdʒɐjt] *erġajt* ‘I repeated’ and [ɛrwɪ:h] *erwieħ* ‘souls’.
[13] Readers can read more about the definite article in Maltese in Chapter 3 §3.6.3.2.
[14] I would like to acknowledge that these observations might be subject to across speaker variation.

The article alternation does not, as Aquilina (1965) claims, only happen in /s/-initial consonant clusters, but also with initial clusters, which have the sibilants /ʃ/ and /z/ in C_1 position[15], as in (21-23). I claim that the article alternation from /ɪl/ to [l-ɪ] occurs before sibilant-initial clusters and not just /s/-initial clusters. Even though it is not entirely clear what triggers this article alternation, it is possible that the origin of the word plays a role. Almost all non-Semitic nouns which start with a sibilant-initial clusters undergo this article alternation. Before Semitic nouns, this alternation can happen before sibilant-initial clusters. However, when this article alternation occurs before Semitic nouns needs to be investigated further, nonetheless, it might be subject to across speaker variation. Also, note that some of the examples (i.e. 21-23) can alternate with the assimilated version of the article: for instance, [l-ɪsbʊhɪjɐ] *l-isbuħija* and [ɪs-sbʊhɪjɐ] *is-sbuħija* 'the beauty'.

(21) Article alternation: /s/-clusters

/st/ → [l-ɪstɐtwɐ] *l-istatwa* 'the statue'
/sp/ → [l-ɪspɔrt] *l-isport* 'the sports'
/sf/ → [l-ɪsfɛrɐ] *l-isfera* 'the sphere'

(22) Article alternation: /ʃ/-clusters

/ʃk/ → [l-ɪʃku:pɐ] *l-ixkupa* 'the broom'
/ʃpr/ → [l-ɪʃpru:n] *l-ixprun* 'the spur'
/ʃm/ → [l-ɪʃmɐjjɐr] *l-ixmara* 'the river'

(23) Article alternation: /z/-clusters

/zb/ → [l-ɪzbɐll] *l-iżball* 'the mistake'
/zv/ → [l-ɪzvɛtsjɐ] *l-Iżvezja* '(the) Sweden'
/zm/ → [l-ɪzmɐgɐt] *l-iżmagat* 'the not-so-right one'

However, compare [l-ɪzbɐll] *l-iżball* 'the mistake' to [ɪz-zbɪ:p] *iż-żbib* 'the raisins'. The only difference between such clusters is the fact that the former is of non-

[15] Clusters with the affricate /tʃ/ can also alternate the article, e.g. [l-ɪtʃfnɐ] *l-iġfna* 'the ships', but note [ɪtʃ-tʃpɐ:r] *iċ-ċpar* 'the fog'. This example goes to show that a Semitic word [l-ɪtʃfnɐ] *l-iġfna* undergoes article alternation, but a non-Semitic word [ɪtʃ-tʃpɐ:r] *iċ-ċpar* does not.

Semitic (Italian) origin and the latter is of Semitic origin. There is a difference in their syllable structure: CCVG and CCV:C, however, in 21-23, the article alternation is not limited to a particular syllable structure.

More exceptions exist: [l-ɪbli:t] *l-ibliet* 'the cities', [l-ɪfrɐn] *l-ifran* 'the ovens'. These forms co-exist with [ɪl-bli:t] *il-bliet* 'the cities' and [ɪl-frɐn] *il-fran* 'the ovens'. These can be compared with other forms: such as [ɪl-bdi:wɐ] *il-bdiewa* 'the farmers' and [ɪl-fdɐl] *il-fdal* 'the leftovers', which do not alternate to /l-ɪ/. Note all of these words come from Semitic.

2) **before sonorant-initial consonant clusters**

As discussed in §2.3.6, sonorant-initial clusters can be preceded by the epenthetic vowel: the consonant cluster /rh/ in [ɪr.hɐm] *irħam* 'a slab of marble' triggers an epenthetic vowel, but obstruent-initial clusters, such as /tl/ in [tlu:ʔ] *tluq* 'departure' do not. When sonorant-initial clusters appear in nouns, the article is /l-i/ (as in (24) below). This rule applies to all nouns, regardless of their origin.

(24) Definite article before sonorant-initial nouns

/rm/ in [l-ɪrmi:t] *l-irmiet* 'the ashes'

/mt/ in [l-ɪmtɐrfɐ] *l-Imtarfa* 'Mtarfa (town name)'

It is not clear whether sonorant-initial clusters trigger the article alternation or whether they are treated as vowel-initial words and therefore take the /l/-article like vowel-initial words e.g. [l-ɔmm] *l-omm* 'the mother', [l-ɐ:n] *l-għan* 'the aim', [l-ʊlɪ:t] *l-ulied* 'the children'.

3) **before word-initial geminates** at the beginning of a phonological phrase (pp) or after a word ending in a consonant as in (25). Word-initial geminates in Maltese are discussed in detail in Chapters 3 §3.6 and empirical evidence for word-initial geminates in Maltese is given in Chapters 5 and 6.

(25) Word-initial geminates

$_{pp}$[ɪddu:r] *iddur* ‘you/she turn(s) round’

[mɐrrɛt ɪddu:r] *marret iddur* ‘she went around’

[rɪtɐ ddu:r] *Rita ddur* ‘Rita turns’

2.4 Syllabification in Maltese

According to Borg and Azzopardi-Alexander (1997) polysyllabic words which have one consonant in medial position, e.g. *CVCVC* are syllabified as *CV.CVC*, where the medial consonant constitutes a syllable onset to the following syllable, as in (26). This follows the Maximum Onset Principle (MOP) where a consonant flanked between two vowels is more likely to syllabify as an onset rather than a coda (c.f. Kahn 1976).

(26) Syllable division of one medial consonant

[kɪ.s̲ɛr] *kiser* ‘he broke’

[mɪ:.t̲ʊ] *mietu* ‘they died’

[lɐ:.p̲ɛs] *lapes* ‘pencil’

[tɪ.f̲ɛl] *tifel* ‘a boy’

In polysyllabic words of structures like *CVCCV* or *CVCCVC*, medial consonant sequences are not consonant clusters as they tend to be syllabified as the coda to the preceding syllable and the onset of the following syllable (cf. Azzopardi 1981). Therefore, *CVCCV* is syllabified as two syllables: *CVC.CV*, see (27) for examples.

(27) Syllable division of medial consonant sequences

[hɔl̲.m̲ɐ] *ħolma* ‘dream’

[tɐh̲.f̲ɛr] *taħfer* ‘forgiveness’

[ʃɔr̲.t̲ɐ] *xorta* ‘sameness’

[tɔʔ̲.b̲ɐ] *toqba* ‘hole’

The same syllable division applies to word-medial geminates as shown in (28).

(28) Syllable division of word-medial geminates

[hɐf̠.f̠ɛr] *ħaffer* ‘he dug’

[rɐt̠.t̠ɐp] *rattab* ‘he softened’

[tɛl̠.l̠ɛf] *tellef* ‘he disrupted’

[ʔɐt̠ʃ̠.t̠ʃ̠ɐt] *qaċċat* ‘he removed’

Word-initial geminates occur due to morphophonological processes (as will be described in Chapter 3 §3.6.3), however, they are disallowed phonologically. In §2.5 above, I showed how word-initial geminates tend to be preceded by the epenthetic vowel. Therefore, I proses that word-initial geminates in Maltese, like word-medial geminates, are ambisyllabic, where the first part of the geminate serves as a coda to the previous syllable and the second part of the geminate serves as an onset to the following syllable. Therefore, underlying word-initial geminates surface as word-medial geminates and are syllabified in the same way as word-medial geminates, see (29).

(29) Syllable division for word-initial geminates

/ppɐkkja/ → [ɪp.pɐk.kjɐ] *ippakkja* ‘he packed’

/ddɛffɛs/ → [ɪd.dɛf.fɛs] *iddeffes* ‘he poked his nose in s.o. else’s affairs’

/ssɛbbɐh/ → [ɪs.sɛb.bɐh] *issebbaħ* ‘he was beautified’

As it is made clearer in §2.6.2, I argue that vowel epenthesis before word-initial geminates allows the syllabification of stray consonants (Itô 1986; 1989). Furthermore, in §2.6.1, I describe how word-initial geminates and sonorant-initial clusters are syllabified.

On the other hand, word-final geminates are syllabified as coda consonants, as in (30).

(30) Syllable division for word-final geminates

[(ʔ)ɪn.dɔʔʔ] *indoqq* ‘I play’

[ʊ.kɔll] *ukoll* ‘as well’

[kɐp.rɪtʃtʃ] *kapriċċ* ‘whim’

Azzopardi (1981) suggested that word-medial sequences can be syllabified as either an onset sequence of the following syllable or as a coda sequence of the preceding syllable, as in (31).

(31) Other ‘possible’ syllabification

CVCCV → CV.CCV

CVCCV → CVCC.V

Examples are difficult to come up with, and indeed Azzopardi (1981) does not provide any. However, word-medial consonants could conceivably be syllabified as in (32), where the sequence could either serve as a onset clusters or as a coda cluster.

(32) Other ‘possible’ syllabification[16]

/fɛstɐ/ → [fɛ.stɐ] *festa* ‘feast’

/fɛstɐ/ → [fɛst.ɐ] *festa ‘feast’*

Both syllabified forms in (32) constitute permissible syllables in Maltese: as shown in §2.3, Maltese allows for CV syllables and words and also s-initial syllables. In addition in the case of [fɛst.ɐ] *festa* ‘feast’, CVCC syllables are also allowed, and V only syllables are also allowed (but only in polysyllabic words cf. Table 2.4). Therefore, the syllabification of /fɛstɐ/ *festa* ‘feast’ in (32) does not violate the phontactic constraints of Maltese. However, the preferred syllabified

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[16] I claim that the syllabification of such word-medial clusters follow the alogrithm I proposed earlier, where the first consonant serves as a coda to the previous sylalble and the second consonant serves as an onset to the following syllable, i.e., /fɛstɐ/is [fɛs.tɐ] *festa* ‘feast’. Even though the examples in (32) are theoretically possible, I believe they are difficult to find in the language.

form is when the medial consonantal sequence serves as a coda to the previous syllable and an onset to the following syllable, as in: [fɛs.tɐ] *festa* ‘feast’.

In the case of three-consonant sequences in word-medial position, Azzopardi (1981) proposes that the preferred syllabification of such sequences is of a consonant as a coda to the preceding syllable and a consonant cluster to the following syllable, as in (33).

(33) Syllabification of medial clusters (1)

[mɐh.frɐ] *maħfra* ‘forgiveness’

[mɪ.nɪs.trʊ] *ministru* ‘minister’

It is also possible for such clusters to be syllabified in such a way that the first two consonants constitute a consonant cluster in coda position, and the third consonant constitutes a simple onset in coda position, as in (34).

(34) Syllabification of medial clusters (2)

[jɐʔs.mʊ] *jaqsmu* ‘they divide/share’

[hlɪst.kɔm] *ħlistkom* ‘I freed you (pl.)’

There might be a correlation between syllable boundary and morpheme boundary in examples like [hlɪst.kɔm] *ħlistkom* ‘I freed you (pl.)’, where the coda consonant cluster [st] belongs to the verb and the initial [k] is part of the clitic. Yet, this is not the case in [jɐʔs.mʊ][17] *jaqsmu* ‘they divide/share’, where the suffix -ʊ is not placed in a syllable of it own. It is possible that in cases where the morpheme has a CVC structure (such as /**k**ɔm/ ‘you (pl.)’), such morphemes could constitute separate syllables. This suggests that morpheme boundaries are respected more than syllable boundaries, and as a result, this would lead to a division of a sequence of three consonants to CC.C.

[17] A counter example of this is the third person feminine singular clitic [ɐ], as in [jɐʔ.sɐm.ɐ] *jaqsamha* ‘he breaks her’, the morpheme constitutes a syllable on its own.

2.4.1. Syllabification of sonorant-initial clusters and word-initial geminates

As described in §2.4, sonorant-initial clusters and word-initial geminates in Maltese trigger an epenthetic vowel in syllable-initial position (Azzopardi 1981; Borg and Azzopardi-Alexander 1997), as in (35).

(35) Insertion before sonorant-initial clusters and word-initial geminates

/mhɐːr/ → [ɪ̠mħɐːr] *imħar* 'clams'

/ʃʃɛjjɛr/ → [ɪ̠ʃʃɛjjɛr] *ixxejjer* 'you/she wave(s)'

Here, I discuss the role of the epenthetic vowel in the syllabification of sonorant-initial clusters and word-initial geminates. There seems to be a cross-linguistic consensus on the function of epenthetic vowels: they serve to repair input forms which do not meet a language's structural requirements (Hall 2011). Hall (2011) describes three ways in which epenthetic vowels surface. First, following Itô (1986, 1989), epenthesis allows the syllabification of stray consonants. Second, following Broselow (1982), epenthesis is triggered by a particular sequence of consonants. Finally, following Côté (2000), epenthesis is triggered by the need to make consonants perceptible. The case of epenthesis in word-initial position in Maltese falls into all three categories. Here, I will describe how the epenthetic vowel in Maltese syllabifies stray consonants.

First, the location of the epenthetic vowel before sonorant-initial and word-initial geminates in Maltese is fixed: the epenthetic vowel always precedes a sonorant–initial consonant cluster (e.g., /nt/, /lt/, /ms/)[18] or word-initial geminate (e.g., /dd/, /vv/, /ss/). As the examples in Table 2.8 show, the epenthetic vowel is fixed both in position and also in quality as it is of /ɪ/-like quality.

[18] Unless such the sonorants are treated as syllabic.

Table 2.8: Epenthetic vowel before sonorant-initial consonant clusters and word-initial geminates

Sonorant initial consonant clusters	**Word-initial Geminates**
/n̠f̠ɐʔt/ → [ɪn̠.f̠ɐʔt] *infaqt* 'I spent'	/d̠d̠ɐhhal/ → [ɪd̠.d̠ɐh.hal] *iddaħħal* 'to be inserted'
/r̠b̠ɐht/ → [ɪr̠.b̠ɐht] *irbaħt* 'I won'	/v̠v̠ɔtɐ/ → [ɪv̠.v̠ɔː.ta] *ivvota* 'to vote'

Word-initial geminates and sonorant-initial clusters only trigger epenthesis, obstruent-initial cluster do not trigger epenthesis. Obstruent + obstruent (e.g. /pt, bd, sf/) or obstruent + sonorant (e.g. /tl, km/) do not trigger epenthesis before the first consonant or between the two consonants. This is in contrast to other dialects of Arabic, which break up word-initial clusters by inserting an epenthetic vowel between C_1 and C_2 in the cluster (cf. Watson 2007; Kiparsky 2003).

Following the principle of Prosodic Licensing, which "requires all phonological units [to] belong to higher prosodic structure" (Itô 1986:3), epenthesis allows the syllabification of stray consonants. Furthermore, the principle of Prosodic Licensing ensures that each segment in the phonological string is syllabified. Therefore, for syllabification to take place, segments must belong to higher prosodic structures, e.g. syllables. Any segments that are not linked to syllables are repaired in order to satisfy Prosodic Licensing. Epenthesis can be explained through the syllabification of stray consonants as posited by Itô (1986, 1989). Following, Itô's (1986, 1989) directionality of syllabification, I postulate that syllabification takes places from right-to-left. The process of syllabification in Maltese allows for Stray Epenthesis (Itô 1986), where stray consonants are syllabified because a vowel is inserted. Maltese, unlike Korean or Attic Greek, does not allow for Stray Erasure, where stray consonants are deleted from the phonological string.

Therefore, the sonorant in sonorant-initial consonant clusters and the first part of the geminates in word-initial geminate, trigger Stray Epenthesis. These segments are not deleted but are epenthesized as all segments in a phonological string have to be syllabified. Following Stray Epenthesis, the sonorant in the consonant clusters (e.g. /lt/ in (36)) and the first part of the geminate (e.g. /vv/ in (37)) become the coda of a preceding syllable. The epenthetic vowel fills in the nucleus of the preceding syllable (cf. (37) below).

(36) Right-to-left syllabification of sonorant-initial clusters

/ltɪːm/ *ltiem* 'orphan'

.tɪːm

*l.tɪːm

ɪl.tɪːm

(37) Right-to-left syllabification of word-initial geminates

[ɪffɪrmɐ] *ffirma* 'to sign'

.mɐ

fɪr.mɐ

*f.fɪr.mɐ

ɪf.fɪr.mɐ

In addition, any of the morphological prefixes that can be added to the verb serve as an onset to this added syllable (cf. Figure 2.4). For instance, the first person imperfect prefix 'n' can only be added before the epenthetic vowel, thus a form like *nffirma is banned (cf. 38). As a result, there is a syllable with an epenthetic vowel as nucleus and a morphological prefix as an onset.

(38) Syllabification of imperfect prefix /n/ 'n'

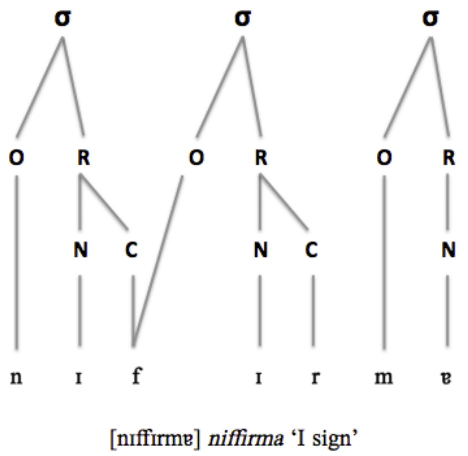
[n-ffɪrmɐ] *niffirma* 'I sign'

.mɐ

fɪr.mɐ

nɪf.fɪr.mɐ

Figure 2.4: Syllabification of the inflected verb form [nɪffɪrmɐ] 'I sign'[19]



Following Nespor and Vogel (1986) I take this to be the domain of the prosodic word as it consists of a stem (i.e. the verb) and a prefix which is added on as a result of morphological inflection (as in the case of *niffirma* in (39)) or derivation. This is also reinforced by Selkirk's (1995) proposal that the left and the right edges of words coincide with the left and right edges of the prosodic word, which was subsequently adopted for Maltese by Kiparsky (2011) and Wolf (2011). As a result, word-initial geminates, which result due to a morpho-phonological process, constitute their own prosodic word (PWd), as in (39).

(39) Prosodic Word (PWd)
[ɪffɪrmɐ]**PWd** *ffirma* 'to sign'
[nɪffɪrmɐ]**PWd** *niffrima* 'I sign'

Furthermore, the application of Stray Epenthesis applies in phonological-initial position and when the previous word ends in a consonant (as in (40).)

(40) Syllabification of word-initial geminate /vv/
[luːk.ɪv.vɔː.tɐ] *Luke (i)vvota* 'Luke voted'

[19] Throught the dissertation, in the representation of geminates, geminates are associated to the coda and onset slots; and, it is assumed that these double associations represent the geminates. Such a representation is widespread within the gemination literature, and I follow Davis (2011) with respect to conventions for geminate representations.

In cases where the word before sonorant-initial and word-initial geminates ends in a vowel, a number of strategies can occur. Hoberman and Aronoff (2003) claim that the prothetic vowel before word-initial geminates does not occur when the preceding word ends in a vowel. I claim that in such cases, there are cases of across morpheme and across word-boundary syllabification. When the previous words ends in a vowel, the stray consonant serves as a coda to that syllable: which results in across word syllabification, as in (41).

(41) Across word syllabification: word-initial geminates

[ɐn.dɐd.dɐh.hɐl.] *għandha ddaħħal* 'she has to enter'

Another strategy is for Stray Epenthesis to occur and result in an inserted vowel before the word-initial geminate, as in (42).

(42) Across word syllabification: word-initial geminates

[ɐn.dɐ.ɹd.dɐh.hɐl.] *għanhda ddaħħal* 'she has to enter'

On the other hand, unlike sonorant-initial clusters or word-initial geminates, Stray Epenthesis does not operate with obstruent-initial consonant clusters. Obstruent-initial consonant clusters are tautosyllabic and the first consonant is not syllabified as the coda of a previous vowel-final word, as in (43).

(43) Onset clusters

[hɐf.nɐ.ptɪː.hɪ] *ħafna btieħi* 'a lot of inner courtyards'

2.5 Summary

In this chapter, I presented an overview of some of the key phenomena related to the phonetics and phonology of Maltese. More concretely, I outlined the possible syllable structures that can occur as monosyllables and within-words in Maltese. This was a much-needed description for the phonology of Maltese. As a matter of fact, this can be fed into a comparison of the possible syllable structures of Arabic, Italian and English. Therefore, I propose that a possible future study is a comparative study of syllable structures in Maltese and of the languages Maltese originates from.

This chapter also showed that the possibilities of onset clusters in Maltese are not very restricted. Specifically, Maltese allows for both low sonority distance (e.g. /pt/) and high sonority onset clusters (e.g. /tl/). Moreover, in the low sonority distance onset clusters, Maltese permits sonority reversals and sonority plateaus. Therefore, even though the sonority framework was used to describe the possible clusters in Maltese - this is not without any problems..

In comparing word-initial clusters and word-initial geminates, I have shown that word-initial geminates (e.g., /pp/) behave similarly to sonorant-initial clusters (e.g., /lt/), where they tend to be preceded by an epenthetic vowel. I argued that sonorant-initial clusters and word-initial geminates in Maltese are banned in the phonology and the presence of a preceding vocalic insertions leads to a process of resyllabification. Thereefore, sonorant-initial clusters are not phonological onsets. The presence (and absence) of a vocalic insertion before word-initial geminates in Maltese is investigated in two production studies in this dissertation. I investigated the context in which vocalic insertions appear and their implications to the phonological representation of word-initial geminates.

In the discussions that follows I give a cross linguistic overview of gemination by outlining key findings of empirical studies on word-medial, word-initial and word-final geminates. Furthermore, I compare the phonological representations of geminates in the different positions. This overview leads to a review of gemination in Maltese, focusing primarily on how geminates in Maltese arise.

Chapter 3: Gemination in a cross-linguistic perspective

The aims of this chapter are twofold. First, in §§3.1-3.3, I give an overview of gemination by looking at their acoustic correlates in word-medial, word-initial and word-final position. Since geminates are more commonly found in word-medial position and since there are numerous studies on such geminates, I start off by sketching out the acoustic correlates in word-medial position. The overview of the acoustic correlates of gemination in different word positions leads to the discussion of the representation of gemination (in §3.4). The second aim of this chapter is to discuss the main tenants of these representations. In §3.5, I compare the acoustic correlates and the representation of lexical and surface geminates. A general overview of gemination in cross-linguistic distinct languages leads to a discussion of gemination in Maltese in §3.6. In this discussion, I illustrate which sounds can be geminated and how gemination arises in Maltese.

3.1 The acoustic correlates of word-medial geminates

The literature shows that geminates flanked between two-vowels, in word-medial position, are more commonly found than geminates in word-initial or word-final position (cf. Thurgood 1993; Davis 2011; Pajak 2013).

3.1.1 Constriction duration

Constriction duration is the most robust correlate for gemination. Geminates, by definition, are longer than singletons; however, the singleton-to-geminate duration ratio depends on the manner of articulation and also the language under investigation. A collection of singleton-to-geminate duration ratios from seven typologically different languages, which are listed in (1), is presented in Table 3.1.

(1) Language Families[20]

- Indo-European (Cypriot Greek, Swedish, Bengali, Swiss German, Italian)
- Afro-Asiatic (Lebanese Arabic, Libyan Arabic, Iraqi Arabic, Tashlhiyt Berber)
- Altaic (Turkish)
- Austronesian (Buginese, Madurese, Toba Batak)
- Uralic (Estonian, Finnish, Hungarian)
- Japanese (Japanese)
- Indo-Aryan (Punjabi)

The constriction duration ratios are based on empirical studies of these languages. The list is not exhaustive as some manners of articulation have either not been investigated in that language, or else the language does not have geminates in that manner of articulation.

One observation that can be made from Table 3.1 is that the duration ratios of some manners of articulation are less robust than others. For instance, the duration ratio of stops varies greatly from language to language: Madurese has the lowest duration ratio 1:1.5 and Swiss German has the highest duration ratio 1:3. In both languages, voiceless stops were investigated, and, therefore, the reason for the difference in the duration ratios in both languages cannot be due to voicing.[21] Fricatives, like stops, also show a lot of variation across languages: the lowest duration ratio is 1:1.2 in Madurese, and the highest is Lebanese Arabic at 1:1.85. In addition, lateral duration ratios also show variation i.e. 1:1.8-1:2.6, but the range is less. However, unlike stops and fricatives, laterals have been investigated less.

[20] Language families are given according to WALS (Dryer and Haspelmath 2013)

[21] Also the duration ratio for voiced and voiceless stops seems to be fairly similar, e.g. in Tashlhiyt Berber the duration ratio is 1:2.5 for both voiced and voiceless stops (cf. Ridouane 2007).

Table 3.1: Singleton-to-gemination duration ratios in word-medial position across languages

Language	Stops	Fricatives	Laterals	Nasals	Rhotics	Approximants	Glides
Bengali (Lahiri and Hankamer 1988)	1:1.93	-	-	-	-	-	-
Buginese (Cohn et al. 1999)	1:1.7	1:1.4	1:1.8	1:1.6	1:3.8	-	1:1.8
Cypriot Greek (Arvaniti and Tserdanelis 2000)	1:1.6	1:1.5	1:2	1:1.96	1:2.5	-	-
Finnish (Ayoma 2002)	-	-	-	1:2.9	-	-	-
Hungarian (Ham 2001)	1:2.6	-	-	-	-	-	-
Iraqi Arabic (Hassan 2002)	1:1.8	-	1:2.3	1:2.4	-	-	-
Italian (Payne 2005)	1:1.8	1:1.5	1:2.3	1:2.1	-	-	-
Japanese (Kawahara 2015)	1:2.4	1:1.8	-	1:2.2	-	-	-
Lebanese Arabic (Khattab and Al-Tamimi 2014)	1:2.44	1:1.85	1:2.6	1:2.60	1:5.04	1:1.96	-
Libyan Arabic (Issa 2015)	-	-	1:2.2	1:2.36	-	-	-
Madurese (Cohn et al. 1999)	1:1.5	1:1.2	1:1.8	1:1.6	1:5.7	-	1:1.5
Swedish (Hassan 2002)	1:1.87	1:1.8	1:2	1:1.79	1:2	-	-
Swiss German (Kraehenmann 2011)	1:3	-	-	-	-	-	-
Tashlhyt Berber (Ridounae 2007)	1:2.5	1:1.6	-	-	-	-	-
Toba Batak (Cohn et al. 1999)	1:2.4	1:1.7	1:2.0	1:2.0	-	-	-
Turkish (Lahiri and Hankamer 1988)	1:2.9	-	-	-	-	-	-

3.1.2 Voice onset time (VOT) for word-medial stops

Kawahara (2015:48) suggests that VOT might be longer in word-medial geminate stops than in word-medial singleton stops as "longer closure would result in higher pressure build-up behind the stop occlusion." This seems to be the case for word-medial geminates in Cypriot Greek, where VOT is longer in geminates than in singletons (Arvaniti and Tserdanelis 2000). Contrastively, in Turkish, VOT is shorter in word-medial geminates than in word-medial singletons (Lahiri and Hankamer 1988). Furthermore, in many languages, such as Bengali (Lahiri and Hankamer 1988), Buginese, Madurese and Toba Batak (Cohn et al. 1999); Swiss German (Kraehenmann 2001); Levantine Arabic (Ham 2001); Hungarian (Ham 2001), Tashlhiyt Berber (Ridouane 2007) and Japanese (Kawahara 2015), the duration of VOT in word-medial geminate and singleton stops is comparable (cf. Table 3.2). Doty et al. (2007) report that VOT is statistically significantly shorter in geminate stops than in singletons in Finnish. However, the difference in VOT is 3ms (i.e., VOT in geminates is 19ms and VOT in singletons is 22ms). Despite the statistical significance, they argue that this difference does not serve as a correlate and is not perceptually salient. For this reason it is placed in the *no difference* column in Table 3.2.

Table 3.2: VOT for word-medial stops in different languages[22]

VOT longer in geminates	Cypriot Greek
VOT shorter in geminates	Turkish
No difference	Bengali, Buginese, Finnish, Hungarian, Japanese, Levantine Arabic, Madurese, Swiss German, Tashlhiyt Berber, Toba Batak

[22] References for these studies are as follows: *Cypriot Greek* (Arvaniti and Tserdanelis 2000), Turkish (Lahiri and Hankamer 1988), *Bengali* (Lahiri and Hankamer 1988), *Buginese, Madurese and Toba Batak* (Cohn et al. 1999); *Swiss German* (Kraehenmann 2001); *Levantine Arabic* (Ham 2001); *Hungarian* (Ham 2001), *Tashilhyt Berber* (Ridouane 2007); *Japanese* (Kawahara 2015), *Finnish* (Doty et al. 2007).

3.1.3 The vowel preceding word-medial geminates/singletons

Another correlate for gemination, in some languages but not in others, is the duration of the preceding vowel. Maddieson (1985:212) claimed that vowels before geminates tend to be shorter than vowels before singletons, and claimed that vowels before geminates are both phonologically and phonetically short. However, it is not always the case that the vowel before geminates is shorter than that before singletons. In addition, there are languages such as Lebanese Arabic and Finnish that allow both phonologically short and long vowels before both geminates and singletons. Vowel shortening before geminates is reported in Bengali (Lahiri and Hankamer 1988), Buginese, Madurese, Toba Batak (Cohn et al. 1999), Italian (Esposito and Di Benedetto 1999), Iraqi Arabic (Hassan 2002), Tashilhyt Berber (Ridouane 2007) and Libyan Arabic (Issa 2015).

The empirical data show that the duration of the vowel before geminates seems to be language-specific, as there are numerous exceptions to Maddieson's (1985) claim. No durational differences between the preceding vowel in singletons and geminates are reported for Turkish (Lahiri and Hankamer 1988), Estonian (Engstrand and Krull 1994)[23], Hungarian (Ham 2001) and Punjabi (Hussain 2015).

The duration of the preceding vowel links to the role of production and perception. This is because, just like VOT, small differences in the production of the preceding vowel are found before geminates and singletons, but this small difference might not serve as an important cue in perception. For instance, in Cypriot Greek, Arvaniti and Tserdanelis (2000) reported that the duration of the preceding vowel was not significantly different before geminates and singletons. However, they report that in the case of /k/, /m/ and /r/, the vowel preceding such geminates was on average 12ms shorter than before singletons. Nonetheless, they claim that this is a small difference and, therefore, it might not be a cue for gemination in terms of perception.

[23] Note that Lehiste (1966) reports that the vowel before geminates in Estonian is shorter than the vowel before singletons. Yet, Engstrand and Krull (1994) report that there is no vowel shortening before geminates in Estonian.

Swedish has a complementary quantity feature (Schaeffler 2005), where a phonological long vowel precedes a short consonant, and a phonological short vowel precedes a geminate as in (2).

(2) Complementary quantity in Swedish (e.g. from Hassan 2002)
CV:CV → [lo:sa] 'lock'
CVGC → [lɔssa] 'loose'

In an investigation of gemination and the preceding vowel in Swedish, Hassan (2002) reports that the phonological contrast was maintained phonetically. Therefore, the vowels before singletons were phonetically longer ($\bar{x}$ = 274 ms) than before geminates ($\bar{x}$=131 ms).

Lebanese Arabic and Finnish are two languages which allow short and long vowels to occur before both singletons and geminates, as in (3) for Lebanese Arabic.

(3) Lebanese Arabic (from Khattab and Al-Tamimi 2014:238)
Short vowel: /ħ**a**.kam/ 'referee'; /ħ**a**k.kam/ 'he treated'
Long vowel: /ħ**aa**.kam/ 'he tried'/; /ħ**aa**k.ka/ 'scratched-FEM-SG'

The duration of phonologically short vowels is comparable before geminates and singletons in both Lebanese Arabic (Khattab and Al-Tamimi 2014) and Finnish (Doty et al. 2007). Khattab and Al-Tamimi (2014) report that the average duration of vowel before singletons was 78ms, whereas the vowel before geminates was 77ms. Furthermore, Khattab and Al-Tamimi (2014) report that the duration of the phonologically long vowels before geminates is, on average, phonetically shorter ($\bar{x}$=149ms) when compared to the duration of phonologically long vowels before singletons ($\bar{x}$=166ms). Nonetheless, they argue that even though long vowels are shortened before geminates, this might not act as a correlate to gemination in perception. In the case of Finnish, Doty et al. (2007) also report that phonologically long vowels are shorter before geminates ($\bar{x}$=173ms) than when are followed by a singleton ($\bar{x}$=201ms).

3.1.4 The vowel after word-medial geminates/singletons

The vowel after word-medial geminates has been investigated much less than the vowel preceding geminates. Just like the duration of the vowel preceding geminates, there are cross-linguistic differences. The vowel after word-medial geminates in Japanese is reported to be shorter than after singletons (Han 1994, Idemaru and Guion 2008). Idemaru and Guion (2008) report that in Japanese the vowel after geminates is shorter ($\bar{x}$=63ms) than the vowel following singletons ($\bar{x}$=76ms). Moreover, Idemaru and Guion (2010) report that in a perception experiment listeners did not rely heavily on the duration of the vowel after singletons/geminates to identify the singleton/geminate contrast. Another language that reportedly has a short vowel durations after word-medial geminates is Punjabi (Hussain 2015). The vowel after geminates ($\bar{x}$=131ms) in Punjabi is 68ms shorter than the vowel after singletons ($\bar{x}$=199ms).[24] A different pattern than that of Japanese and Punjabi, has been reported for Finnish. Doty et al. (2007:2740) reported that "the duration of the following vowel showed an inverse relationship with the length of the pre-consonantal vowel". Therefore, when the preceding vowel was long, the vowel following was short and vice-versa.

3.1.5 Primary and secondary correlates to gemination[25]

The discussion of the acoustic correlates of gemination is driven by the fact that the *primary correlate*, namely constriction duration, has been measured and has been found as a correlate to gemination (in different positions in the word as ia shown in §3.2 and §3.3) in all of the studies. Geminates are phonetically characterized by longer durations than their singleton counterparts. The duration of geminates depends on the language and also the manner of

[24] Note the duration is pooled across all speakers and places of articulation reported in the study.
[25] A number of studies looked at non-durational correlates for gemination such as the amplitude of the vowel before/after geminates (e..g, Arvaniti and Tserdanelis 2000; Doty et al. 2007) and the amplitude of the release of geminate stops (e.g., Doty et al. 2007; Ridouane 2007, 2010) to mention a few. These non-durational correlates are not discussed in this dissertation since I do not report any of these for Maltese. These non-durational correlates can serve as secondary correlates and it would be worth investigating in further work.

articulation under-investigation. Affricate word-medial geminates have the lowest duration ratio (e.g. Hungarian 1:1.2), whereas rhotics have the highest duration ratios (e.g. Lebanese Arabic 1:5). This shows that the phonetic realization of geminates varies. Nonetheless, the fact that geminates are always longer than singletons, entails that constriction duration is the primary cue for gemination.

However, the effect of gemination on *secondary correlates* (e.g. VOT or the duration of the vowel before geminates/singletons) is language dependent, where it may be used as correlate in one language but not in another. There are cross-linguistic differences to whether VOT serves as a correlate to gemination. For instance, VOT is longer in geminates (e.g., Cypriot Greek), it is shorter in geminates (e.g., Turkish) and VOT is comparable in singletons and geminates (e.g., Japanese, Swiss German). Another correlate that has been investigated in a number of studies is the duration of the vowel before geminates. Maddieson (1985) claims that the vowel before geminates should have shorter duration compared to the vowel before singletons. However, the empirical evidence shows that there is in fact a three-way distinction. First, the vowel before geminates shortens as in Italian and Bengali; second, the vowel lengthens before geminates as in Japanese; third, the duration of the vowel before geminates and singletons is comparable as in Turkish and Punjabi. These facts suggest that the *secondary correlates* such as VOT, the duration of the preceding vowel (to name a few) to gemination are less consistent and robust across typologically different languages.

3.2 The acoustic correlates of word-initial geminates

Geminates in word-initial position are typologically uncommon. There are only a few attested languages that have a consonantal quantity contrast in word-initial position. Kraehenmann (2011) describes some cross-linguistic tendencies for word-initial geminates based on Muller's (2001) language appendix. However, Kraehenmann (2011) notes that Muller's (2001) appendix is not conclusive and some languages have been left out, which in turn are also left out in

Kraehenmann (2011). Maltese is one of the languages that was not included in Muller's (2001) original database. Kraehenmann (2011) presents a database of 29 languages coming from 11 different language families that have word-initial geminates. By establishing this database, she draws a number of conclusions on the phonetic features of word-initial geminates in these languages. By referring to frequency, Kraehenmann (2001) illustrates that the nasals /nn mm/ and the voiceless stops /tt kk pp/ are the most frequent phonemes in Muller's database, which are then followed by the fricatives /ss ff/, the voiced stops /dd bb/ and the liquids /ll rr/. Moreover, stops and fricatives together make up almost two-thirds of the phonemes in the database, whereas nasals make up majority of the last one-third. On the other hand, geminate glides and affricates are the least frequent. Kraehenmann (2011) also points out that if a language has word-initial geminates, the language also has medial geminates (cf. Thurgood 1993; Pajak 2013).

Empirical studies on word-initial geminates are scarce and restricted to a few languages. As a result, the phonetics of word-initial geminates has been studied thoroughly for only five languages or language varieties: Kelantan Malay (Hamzah 2010; Hamzah et al. 2011, 2012), Pattani Malay (Abramson 1986, 1987), Swiss German (Kraehenmann 2001), Cypriot Greek (Muller 2001; 2003) and Tashlhiyt Berber (Ridouane 2007, 2010). One of the pressing issues in defining the acoustic correlates of word-initial geminates is the realisation of voiceless stops. As it is made clearer in the studies presented below, word- or phrase-initial voiceless stops have no acoustic impact during the consonantal constriction compared to nasals or fricatives; and arguably this causes issues in production and perception. Specifically, on the acoustic surface there is no direct signal of relative duration in singletons and geminates. It can be argued that due to this lack of acoustic excitation, the singleton-geminate contrast in voiceless stops might be difficult to perceive (cf. Muller 2001).

3.2.1 Kelantan Malay

Kelantan Malay is a dialect of the Malay languages spoken in the Malaysian state of Kelantan, which is located in the north-eastern part of the Malay peninsula in Malaysia (Hamzah 2013). In a number of studies, Hamzah (2010) and Hamzah et al. (2011, 2012) investigate the primary and secondary correlates of word-initial geminates in Kelantan Malay. Hamzah (2010) addresses the question of whether native speakers of Kelantan Malay are able to produce the singleton-geminate duration contrast in word-initial position. This was investigated through a production experiment with 6 native speakers, who read target words embedded in carrier phrases. Target words were categorized according to the manner of articulation: voiceless stops (/p t k/), voiced stops (/b d g/) and sonorants (/m n l ŋ/), see Table 3.3 for examples.

Table 3.3: Kelantan Malay: example target words from Hamzah (2010)

Segment	**Singleton**	**Geminate**
/p/	/<u>**p**</u>itu/ 'door'	/<u>**pp**</u>itu/ 'at the door'
/b/	/<u>**b**</u>ini/ 'wife'	/<u>**bb**</u>ini/ 'married'
/n/	/<u>**n**</u>ikɔh/ 'marriage/	/<u>**nn**</u>ikɔh/ 'getting married'

All chosen tokens were disyllabic words of the type <u>C(C)</u>VCV or <u>C(C)</u>VCVC. The vowel after the initial singleton/geminate was either the low back vowel /a/ or the high front vowel /i/. In this study, Hamzah (2010:18) presents consonant duration measurements, which were measured 'from the beginning of the consonant closure to the onset of voicing- VOT was included'. Hamzah (2010) reports that a statistically significant effect of manner of articulation, where sonorants had the largest singleton-to-geminate duration ratio (1:2.59), voiceless stops had the lowest singleton-to-geminate duration ratio (1:2.12) and voiced stops had a duration ratio larger than voiceless stops but smaller than sonorants (1:2.37). This suggests that the singleton-to-geminate duration ratio varies according to the manner of articulation.

In a follow-up study, Hamzah et al. (2011) concentrated on the geminate-singleton contrast in voiceless stops and investigated the constriction duration and VOT separately. In this study, the same design as Hamzah (2010) was adopted; however, target words were presented in two contexts, namely, in isolation and intervocalically. The singleton-geminate ratio was more than double for all the voiceless stops (/p t k/). The bilabial stop had the longest duration ratio: the singleton-to-geminate duration ratio for /p/was 1:2.51; for /t/ was 1:2.93 and for /k/ was 1:2.84 (Hamzah et al. 2011). VOT was investigated as a secondary correlate to gemination. In this production study, when target words were produced in isolation, singletons had longer VOT durations than geminates for all three voiceless stops. When target words were produced sentence-medially, a similar result was found, i.e. VOT was longer for singletons than for geminates. However, in sentence-medial position, the VOT duration was significant longer for singleton stops for /p/ and /t/ but not for /k/. However, it seems that some speakers have longer VOT in velar stops than others. Hamzah et al. (2011) concludes that for Kelantan Malay the strongest correlate for word-initial gemination is closure duration, while VOT is a secondary correlate. Furthermore, Hamzah et al. (2012) report shortening of the vowel following word-initial geminates, when compared to singletons. They argue that even though the difference is present in production, it is lower than the Just Noticeable Difference (JND) (cf. Lehiste 1970) and this might not serve as a direct perceptual cue.

3.2.2 Pattani Malay

Pattani Malay is also a dialect of the Malay languages, but Pattani Malay is spoken in southeastern Thailand (Abramson 1986). It is reported that all the sounds in the Pattani Malay inventory can occur as word-initial geminates. Abramson (1987) provides evidence from one speaker in a production study. Target words, which were disyllabic, had geminates in word-initial and word-medial position. Abramson (1987) gives examples of word-initial geminates only and not of word-medial geminates, two examples of words containing word-initial geminates in Pattani Malay are shown in (4).

(4) Pattani Malay (Abramson 1987)

/**l̲**abɔ/ 'to make a profit'

/**l̲l̲**abɔ/ 'spider'

Target words were elicited in isolation and in a carrier phrase. The constriction durations were measured for all word-initial geminates, excluding voiceless stops because of their silent period in true word-/utterance-initial, which makes them immeasurable. Geminates were longer than singletons in both target positions: i.e., initial and medial. Abramson (1987) argues that constriction duration might not be a sufficient cue for voiceless geminate stops. Therefore, there might be other cues, which are manifested in order to maintain a contrast between singletons and geminates. Abramson (1987), for voiceless plosives, investigated the root-mean-square (RMS) amplitude of each syllable in the aforementioned disyllabic words. For voiceless plosives, Abramson (1987) reports that for geminates, the RMS average in the first syllable is higher than that in the second syllable. This suggests that since, in the case of voiceless plosives, there is no audible excitation in word-/utterance-initial position, another correlate, such as amplitude, is being used to convey the distinction between singletons and geminates. Ideally, more speakers should be investigated.

3.2.3 Cypriot Greek

Muller (2001) investigated the production and perception of word-initial geminates in Cypriot Greek. In her study, the target words consisted of the voiceless stops /p t k/ and the fricative /ʃ/. In the production experiment, 6 speakers (3 males, 3 females) produced target words in isolation and in a carrier phrase. Muller (2001, 2003) stated that the absolute duration of word-initial stops cannot be measured because voiceless stops are silent during their constriction duration, especially when they are in absolute initial position; i.e., at the beginning of a phonological phrase. Thus, only VOT was measured for stops, whereas for fricatives constriction duration was measured. VOT was longer in geminates than in singletons, with an average duration of 114ms for geminates and 43.3ms for singletons. This result follows what had been previously found for word-medial geminates in Cypriot Greek, where word-medial geminates had longer VOT values than singletons (Tserdanelis and Arvaniti 2001). As expected, fricatives in word-initial position followed the pattern found in word-medial position, i.e., geminates were longer than singletons. Muller (2001) concludes that with respect to the secondary correlates of gemination, there are language specific differences. In the case of Cypriot Greek voiceless stops, Muller (2001) argues that VOT is a crucial correlate as it “must be crucially relied upon when duration is difficult or impossible to discern” such as in word-initial position (Muller, 2001:36).

Muller (2001) argues that since Cypriot Greek does not have a voicing contrast, the language can use VOT as a cue to contrast another phonological distinctions. Therefore, VOT is used to distinguish singletons and geminates, because it is not used to distinguish voiced and voiceless stops in the language. It is possible that in a language such as Pattani Malay, which has voiced and voiceless stops, VOT does not function as a cue to distinguish singletons and geminates.

3.2.4 Tashlhiyt Berber

Berber is an Afro-Asiatic language spoken in large parts of Northern Africa. Tashlhiyt Berber is spoken in the southern part of Morocco. The data presented by Ridouane (2007, 2010) is based on Tashlhiyt Berber spoken in Agadir and its suburbs. Tashlhiyt Berber has geminates in word-initial, word-medial and word-final positions, and also allows for gemination to occur across word and morpheme boundaries (Ridouane 2007, 2010).

In two production experiments, Ridouane (2007) investigated the singleton/geminate contrast by looking at a number of temporal and non-temporal parameters. Since the acoustic signal is not a suitable measure to distinguish voiceless stops in utterance-initial position, Ridouane (2007) addressed this issue of voiceless stops (both singleton and geminate) in phrase-initial position by means of electropalatography. This study looked at the phonological contrast in word-initial, word-medial and word-final positions. The results for word-initial geminates are presented here.[26] In this study, target words consisted only of the dental stops /t d/ in word-initial position, which is the optimal place for the coverage area of the artificial palate and consonant contact. In the acoustic study the voiceless stops /t, k, tˤ/, voiced stops /d, g, dˤ/; the voiceless fricatives /s, ʃ/, voiced fricatives /z, ʒ/ and were used, see examples in Table 3.4 below.

Table 3.4: Tashlhiyt Berber word-initial examples from Ridouane (2007)

	Singleton	Geminate
/t/	[**t**id] 'those (fem.)'	[**tt**id] 'soap'
/d/	[**d**is] 'with him'	[**dd**iʁ] 'I went'
/s/	[**s**in] 'two'	[**ss**ir] 'lace'
/ʒ/	[**ʒ**ij̥f] 'throw'	[**ʒʒ**iʁ] 'I recovered'

Each target word was presented in a carrier phrase, where the segment before the word-initial geminate was a vowel and each target was additionally presented in absolute phrase-initial position. The acoustic data showed that geminates in word-initial position were significantly longer than singletons in the same position. The duration ratios calculated on the means of word-initial geminates presented in Ridouane (2007) were as follows: voiced stops 1:2.5; voiceless fricatives 1:1.7 and voiced fricatives 1:1.9. Furthermore, the electropalatographic results showed that voiceless stop geminates were produced with significantly longer closure duration than singletons. Thus, even though the contrast in voiceless stops was not perceptually salient, it was still implemented. In addition, the contrast was maintained when geminate voiceless stops were in phrase-initial position and when they were preceded by a pause. Thus, constriction duration is considered to be the primary correlate of gemination, even in sounds where the contrast may be less well perceived. The VOT of voiceless stops was similar in singletons ($\bar{x}$ = 42 ms) and geminates ($\bar{x}$ =

[26] Word-medial geminates in Tashlhiyt Berber are discussed in §3.1 and word-final geminates in Tashlhiyt Berber are discussed in §3.3.

43 ms). However, the VOT of voiced stops was significantly longer in geminates ($\bar{x}$ = 29 ms) than in singletons ($\bar{x}$ = 16 ms).

With regards to non-temporal parameters, Ridouane (2007) suggested that there are speaker-specific differences. For instance, Ridouane (2007) investigated the presence or absence of bursts in geminate stops. First of all, geminate stops are always produced with an identifiable burst in all word-positions and in all places of articulation. However, Ridouane (2007) showed that some speakers tended to produce the voiced dental and velar stops in word-final position with no bursts. Ridouane (2007) also showed that geminate stops can be devoiced. The results indicate that this varies across speakers, repetition and place of articulation. For example, one speaker always produced geminate stops as devoiced, while another produced geminates as devoiced 13% of the time. Ridouane (2007) argued that the picture for the secondary correlates for gemination is less clear than the primary correlate (constriction duration). Secondary correlates, which can be temporal or non-temporal acoustic parameters, vary in a number of factors and in speaker-specific behavior.

3.2.5 Swiss German

Kraehenmann (2001) investigated the production of geminate and singleton stops in the Thurgovian dialect of Swiss German, also in word-initial, word-medial and word-final position.[27] The discussion here focuses on Kraehenmann's (2001) results on word-initial singletons/geminates. Kraehenmann (2001) presented data from 3 native speakers of Thurgovian. The target words contained a voiceless stop (/p t k/) in word-initial position: as in /pohne/ 'bean' and /ppomfrit/ 'French fries'. Target words were presented in initial position and embedded in three carrier phrases: the target initial singleton/geminate stop was preceded by either a vowel, or a sonorant, or an obstruent. Results for both the constriction duration and the release of the stop (i.e. VOT) were reported in the study. First, constriction duration was considerably longer for

[27] The results for word-medial geminates are discussed in §3.1 and the results for word-final geminates are discussed in §3.3.

geminates ($\bar{x}$ = 80 ms) than singletons ($\bar{x}$ = 54 ms). Kraehenmann (2001) claimed that the duration of geminate stops was around double the duration of singleton stops, when pooling the data across all speakers and data points. However, on closer inspection, the data for word-initial geminates did not show a duration double that of singletons. As a matter of fact, Kraehenmann (2001) commented that the contrast was weakest in word-initial position and had significantly longer durations in word-medial and word-final positions. Second, the results for the duration of VOT for singleton and geminate stops were very similar, both around 24ms long. A similar result is also reported for word-medial geminates. As a result, Kraehenmann (2001:124) concluded that VOT is not "an acoustic property that distinguishes singleton and geminates" in Swiss German. The data also suggested that the phonological context also affected the presence and absence of the contrast in word-initial position. This is because when the preceding context ended in a vowel or a sonorant, the contrast was maintained. However, Kraehenmann (2001)'s data suggested that when the word-initial stop was preceded by an obstruent the contrast was neutralized, as the constriction durations of singleton and geminate stops were very similar.

3.2.6 Interim Summary

Table 3.5 summarizes the primary and secondary correlates discussed in §§3.2.1-3.2.5. By definition, geminates are long consonants, so they are realized with phonetically longer durations than their singletons counterparts. In fact, just like for word-medial geminates, constriction duration is considered the primary correlate to word-initial geminates. As already discussed for word-medial geminates in §3.1.2-3.1.4, secondary correlates for gemination in word-initial position depend on both the correlate and language under investigation.

Table 3.5: Primary and secondary correlates of word-initial geminates across languages

Language	Primary Correlate	Secondary Correlates
Kelatan Malay	Constriction duration	- **VOT** in voiceless stops is shorter in geminates than singletons - **Tonic vowel**: shorter after word-initial geminates
Pattani Malay	Constriction duration	- **RMS**: higher in the first syllable in geminates - **Amplitude:** higher in geminates - **Fundamental frequency:** higher in geminates
Cypriot Greek	Constriction duration (for fricatives only)	- **VOT** in voiceless stops is longer in geminates than singletons
Tashlhiyt Berber	Constriction duration	- **VOT** in voiced stops is longer in geminates than in singletons (but not in voiceless stops) - **Noise burst**: higher in geminates -**Release amplitude**: higher in geminates
Swiss German[28]	Closure duration (for stops only)	

3.3 The acoustic correlates of word-final geminates

In this section, I discuss a number of empirical studies on the acoustic realization of word-final geminates in typologically different languages. By doing so, I establish the primary and secondary correlates of word-final geminates in each language. In (5), the language families and the language(s) used for this description are listed.

[28] Kraehenmann (2001) also measured VOT for stops, but this did not serve as a correlate to gemination. Therefore, this is not listed in Table 3.5.

(5) Language families

Indo-European: Swiss German

Afro-Asiatic: Jordanian Arabic, Levantine Arabic, Tashlhiyt Berber, Maltese

Uralic: Hungarian

Moreover, it has been remarked that word-final geminates are less common than word-medial geminates but more common than word-initial geminates (cf. Thurgood 1993, Dmitrieva 2012, Pajak 2013).[29]

3.3.1 Swiss German

Kraehenmann (2001) investigated the production of the word-final geminate voiceless stops /pp tt kk/. The singleton-to-gemination duration ratio for word-final geminates is 1:1.97. However, VOT, like in word-medial and word-initial position, did not serve as a cue to gemination. Kraehenmann (2001) reported the following durations for VOT in singletons: 34ms and geminates: 35ms.

Kraehenmann's (2001) core finding for word-final geminates in Swiss German is related to the position of word-final geminates within the phonological string. In phrase-final position, i.e. at a phrase boundary, the contrast was maintained: therefore, geminates were longer than singletons. Word-final geminates were also placed in phrase-medial position, where a vowel, sonorant or an obstruent followed the word-final geminate. The following context affected the duration of geminates and singletons. When word-final geminates were followed by a vowel or a sonorant, there were clear differences in consonant constriction duration: geminates were significantly and consistently longer than singletons (Kraehenmann 2001), despite having different duration ratios: in the vowel context 1:1.6 and in the sonorant context 1:2.5. However, the contrast was neutralized when an obstruent followed the word-final geminate/singleton. As a

[29] I would like to point out that the literature does not give any percentages (or any lists) where one could quantify the direction of this difference.

result, the constriction durations of singletons and geminates were comparable (i.e. 69ms for singletons and 74ms for geminates).[30]

Table 3.6: Singleton-to-geminate duration ratios for word-medial and word-final positions for Swiss German (Kraehenmann 2001)

Preceded by a:	Word-medial	Word-final
Sonorant	1:3	1:2.5
Vowel	1:3	1:1.6

The comparison of the singleton-to-geminate duration ratio in word-medial and word-final position shows some differences. Firstly, when the geminate was preceded by a sonorant (/m/), there is a slight decrease in the duration ratio from word-medial to word-final. Furthermore, the duration ratio noticeably decreased (almost by half) from word-medial to word-final when the geminate was preceded by a vowel.

3.3.2 Tashlhiyt Berber

Ridouane (2007) investigated the duration of the constriction duration of final geminate obstruents in Tashlhiyt Berber. Production data showed that in final position, the contrast was maintained. Table 3.7 lists singleton-to-geminate duration ratios for word-medial and word-final position. In addition, Ridouane (2007), like Kraehenmann (2001), adopts a segmental analysis to gemination. However, Ridouane (2007) does not explicitly comment on the representation of word-final geminates, but proposes one representation for gemination in initial, medial and final position.

[30] These durations are averaged across the different preceding contexts and were taken from Kraehenmann (2001).

Table 3.7: Singleton-to-geminate duration ratios for word-medial and word-final positions in Tashlhiyt Berber (Ridouane 2007)

	Duration Ratio	
Manner	**Word-medial**	**Word-final**
Voiceless stops	1:2.5	1:2.8
Voiced stops	1:2.5	1:2.6
Voiceless fricatives	1:1.4	1:1.8
Voiced fricatives	1:1.7	1:1.9

In Table 3.7, stops have longer duration ratios than fricatives in both word positions. Furthermore, there's an increase in the duration ratio from word-medial to word-final. As a matter of fact, Ridouane (2007:128) reports that the actual durational difference between word-medial and word-final singletons/geminates reached statistical significance, where word-final singletons/geminates were longer than word-medial singletons/geminates. Moreover, this durational difference is attributed to final-domain lengthening (as in Fougeron and Keating 1997). Note that these results are different from Kraehenmann (2001), where she reports a decrease from word-medial to word-final position.

3.3.3 Hungarian

Ham (2001) reported that constriction duration for word-final stops was larger in geminates than in singletons. Furthermore, he reports that the duration ratio of voiced stops was shorter than voiceless stops. Table 3.8 lists the duration ratios of word-medial and word-final geminates in Hungarian.

Table 3.8: Singleton-to-geminate duration ratios for word-medial and word-final positions in Hungarian (Ham 2001)

Manner	**Word-medial**	**Word-final**
Voiceless stops	1:2.3	1:1.9
Voiced stops	1:2.8	1:1.8

The duration ratios are longer in word-medial position than in word-final position. Therefore, there is a decrease in duration ratio from word-medial to word-final position. This patterns with the findings for Swiss German by Kraehenmann (2001) rather than those for Tashlhiyt Berber (Ridouane 2007), where in the former the duration ratio was longer in word-medial position than in word-final position. Moreover, it seems that in word-medial position, voiceless stops have a shorter duration ratio than voiced stops. In word-final position, the opposite pattern is found, even though to a very slight degree, voiceless stops have a longer duration ratio than voiced stops.

Furthermore, Ham (2001) reports that the duration of the vowel before geminates is not shorter than the duration of the vowel before singletons, so much so that Ham (2001: 157) states: "closed syllable shortening effects are absent in both short and long vowels" in Hungarian.

3.3.4 Jordanian Arabic

Al-Tamimi et al. (2010) investigated the duration of word-final geminates in Jordanian Arabic. Word pairs, which had a VC or a VG structure, were used as target words, therefore, a short vowel preceded both singletons and geminates. The target consonants were the nasal /m, n/ and the stop /d/. Al-Tamimi et al. (2010) reported that geminates are longer than their singleton counterparts, the geminate voiced stop is 1.3 times longer than its singleton counterpart, whereas, the nasals are around 1.5 times longer than singletons. Furthermore, Al-Tamimi et al. (2010) argue that vowel before singletons is around 1.4 times longer than that before geminates. Therefore, gemination in Jordanian Arabic manifests two correlates: constriction duration and preceding vowel duration, in which the vowel before geminates is shorter than before singletons.

3.3.5 Levantine Arabic

Ham (2001) investigated word-final singletons and geminates in Levantine Arabic. The results show that the phonological contrast is present in word-final position. The target words, which included both voiced and voiceless stops, were placed in a carrier phrase before a nasal-initial word. Ham (2001) reports an average singleton-to-geminate duration ratio of 1:1.9 for voiced stops and a ratio of 1:1.5 for voiceless stops. However, the duration of the previous short vowel was similar before singletons and geminates.

3.3.6 Maltese

Hume et al. (2014) investigated word-final geminates and singletons in Maltese. In a production study, Hume et al. (2014) investigated the following manners of articulation: stops /t-tt, k-kk, ʔ-ʔʔ/, fricative /s-ss, ʃ-ʃʃ/, affricate /dʒ-dʒdʒ/, nasals: /m-mm; n-nn/, liquids /l-ll, r-rr/. Target words included the target consonants in world-final position, and the target words were embedded in a carrier phrase. Hume et al. (2014) measured consonant duration, aspiration duration and the duration of the preceding vowel. They expected that the vowel before geminates would have shorter durations than the vowel before the singleton. They argued that this is a difference between a superheavy and a heavy syllable. However, this is also because of the phonological requirements on monosyllabic words in Maltese (as outlined in Chapter 2 §2.3). Hume et al. (2014) reported that constriction duration was a strong correlate for gemination (cf. Table 3.9), but aspiration duration did not serve as a correlate to distinguish singletons and geminates.

Table 3.9: Mean duration of word-final singletons and geminates in Maltese (Hume et al. 2014)

Manner	Singleton	Geminate
Stops	130ms	185ms
Fricatives	180ms	240ms
Affricates	175ms	190ms
Nasals	85ms	160ms
Liquids	75ms	143ms

As Hume et al. (2014) predicted, in monosyllables, the duration of the vowel preceding singleton consonants was longer than the vowel preceding geminate consonants. The vowel before singletons seems to be around 30ms longer than before geminates. However, in disyllabic words the vowel before singletons was only slightly longer than geminates (e.g. 155ms for singletons and 145ms for geminates). Whether this difference is a salient cue in the perception of such contrasts is still an unanswered question.

3.3.7 Summary: Correlates for word-final geminates

As expected, constriction duration is the primary correlate for word-final geminates. It is interesting to note that in some languages, such as Swiss German and Hungarian, the singleton-to-geminate duration ratio in word-final position is smaller than in word-medial position. In contrast, Tashlhiyt Berber shows the opposite pattern: longer singleton-to-geminate duration ratios in word-final position than in word-medial position. Fewer secondary correlates have been investigated, but the few that have, show that there language specific differences. For instance, VOT is not a correlate for word-final geminates (neither is it for word-initial and word-medial geminates). Moreover, the duration of the vowel before word-final geminates is reported to be shorter than in singletons in Jordanian Arabic but not in Hungarian.

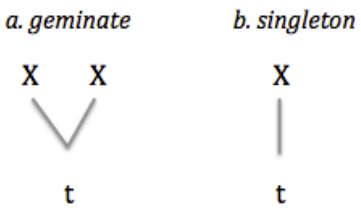
3.4 The representation of geminates

"The issue of the representation of geminate consonants has been a controversial matter and will most likely remain so in future investigations" (Davis 2011:892). The literature on the representation of geminates is divided into two separate approaches; namely, *a segmental length approach* in §3.4.1 (cf. Leben 1980; Levin 1985 and Ringen and Vago 2011) and *a syllable weight analysis* based on moraic theory in §3.4.2 (cf. Hayes 1989; Davis 1999, 2011).

3.4.1 A segmental approach

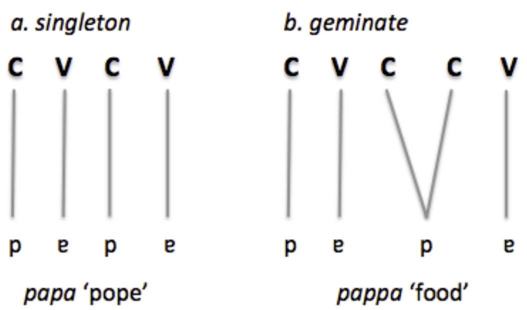
Leben (1980) proposed an autosegmental approach to the representation of geminates. In an autosegmental approach, as in Figure 3.1, singletons and short vowels are associated to one slot on the timing tier (Figure 3.1b). Contrastively, in the case of geminates, a single segment is associated to two slots on a timing tier, as in Figure 3.1a.

Figure 3.1: Timing slot representation of geminates and singletons



The timing tier is referred to as a CV-tier (cf. McCarthy 1981; Clements and Keyser 1983) or as a skeletal tier (cf. Levin 1985). Therefore, the difference between short and long segments (either vowels or consonants) is a difference in timing. The representation of a minimal pair of a word-medial singleton and a word-medial geminate (from Maltese) is shown in Figure 3.2.

Figure 3.2: CV-tier representation (examples from Maltese)



In some of the studies described in §§3.1-3.3[31], which looked at the phonetic implementation of a phonological contrast, authors advocated a representation which closely links phonological length to phonetic duration. Assuming that

[31] Note that some empirical studies make no direct claims about the representation of geminates.

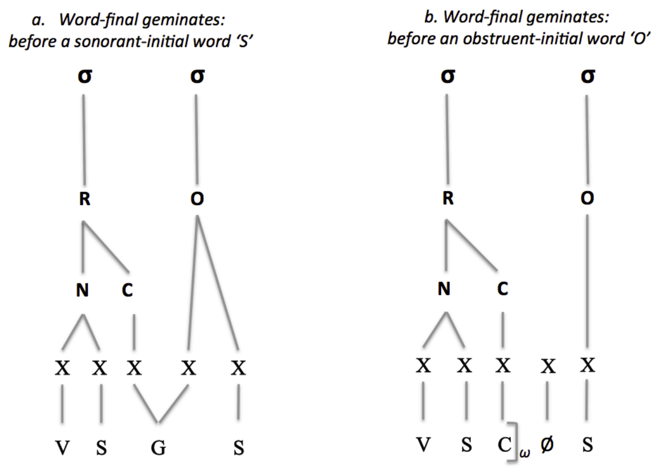
geminates are represented as two timing slots on a skeletal tier captures this link, so much so that geminate consonants have longer durations (regardless of their manner of articulation) when compared to their singleton counterparts, which are only linked to one timing slot (as in Figure 3.2 above).

For Tashlhiyt Berber, Ridouane (2007; 2010) claimed that geminates are best represented as two timing units associated with one melodic slot, where the timing measure relates to constriction duration. It is important to note that Ridouane (2007; 2010) does not specifically argue for a special representation of geminates in different positions of the word. However, his work suggests that the representation of geminates (at least for Tashlhiyt Berber) is valid for all positions and it should be applied regardless of where the geminate is.

Kraehenmann (2001) acknowledged that the phonological representation of word-initial geminates is debatable. However, Kraehenmann (2001) argued that a segmental approach is sufficient to capture the difference between singletons and geminates in different positions of the word. Kraehenmann (2001) suggested that the acoustic findings for word-initial geminates in Swiss German are in line with phonological theory. This is because, when initial geminates are within a phonological phrase, the contrast is neutralized and, therefore, geminates are produced very similarly to singletons. This neutralization can be explained through Stray Erasure (Itô 1986): one of the two geminate timing slots is deleted when the preceding context is an obstruent. Furthermore, when the contrast occurs at the edge of a phonological phrase, neutralization does not occur. Kraehenmann (2001) argued that neutralization does not occur since the two geminate timing slots are licensed at the level of the phonology. However, phonetically, in word-initial position the contrast is not realized. As a matter of fact, Swiss German stops do not seem to rely on other secondary correlates to enhance the contrast further. Therefore, at the edge of a phonological phrase in absolute word-initial position, geminates are phonologically licensed as two timing slots; however, phonetically voiceless geminates and singletons stops can become indistinguishable. This is supported by the fact that all 6 native Swiss German participants were not able to distinguish between absolute-initial singleton and geminates in a forced choice perception experiment. Kraehenmann (2001:141) concluded that for absolute word-initial geminate stops "the nature of the phonetic cue itself is at issue".

For word-final geminates in Swiss German, the phonological contrast in maintained in phrase-finally and phrase-medially. However, the contrast is neutralized phrase-medially when an obstruent follows the geminate. Kraehenmann (2001) argued that the second part of the geminate does not serve as an onset to the following syllable, since the onset already contains an obstruent. In this case, the unlinked timing slot for the geminate is deleted and this results in shorter geminate durations (as in Figure 3.3b).

Figure 3.3: Representation of word-final geminates in Swiss German (Kraehenmann 2001)

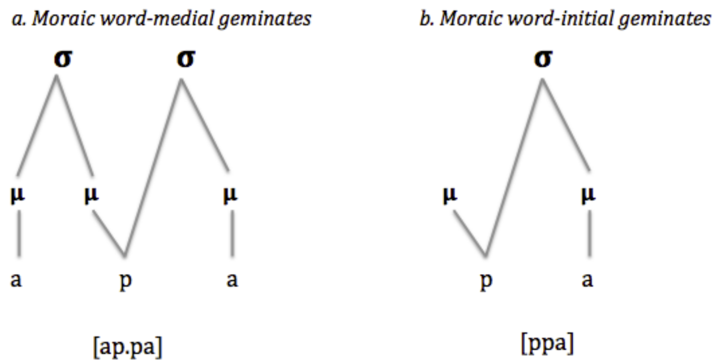


3.4.2 Moraic analysis

On the basis of moraic theory, following Hayes (1989), geminates are characterized in terms of their weight. By doing so, it is assumed that geminates participate in weight-related processes such as stress assignment and compensatory shortening (Curtis 2003).

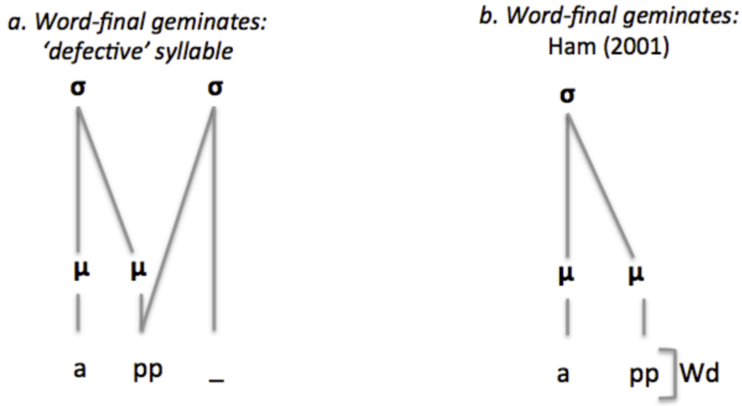
Under moraic theory, geminates bear a mora, where the first part of the geminate serves as a coda to the previous syllable and bears weight and the second part serves as an onset and does not bear weight (Figure 3.4)- this is referred to as a flopped structure (Hayes 1989). The syllabification of underlyingly moraic word-medial and word-initial geminates is given in Figure 3.4a and Figure 3.4b respectively.

Figure 3.4: Syllabification of moraic word-medial and word-initial geminates



In assuming a flopped structure for the representation of word-final geminates, Ham (2001:14) claimed that the following syllable would be a 'defective syllable' since the nucleus is empty (c.f. Figure 3.5a). Furthermore, according to Ham (2001), this representation is not needed in languages where codas do not bear weight, i.e. where Weight-by-Position does not apply. Therefore, word-final CVC structures are light and word-final CVG structures are heavy. The distinction between singletons and geminates is made through the bearing of a mora. However, in languages where codas bear a mora and word-final geminates also bear a mora, the distinction is less clear-cut. As a result, Ham (2001) proposes that in Bernese, Levantine Arabic and Hungarian, word-final singletons are extrametrical, therefore, weight-by-position does not apply in word-final CVC syllables (even though, it may apply in other positions in the word). Ham (2001: 15) proposes that word-final geminates are not represented as in Figure 3.5a, with a flopped structure and a defective following syllable, but rather as "word-final moraic consonants", as in Figure 3.5b.

Figure 3.5: Representation of word-final geminates (following Ham 2001)



3.4.3 Arguments for/against a segmental analysis and/or a syllable weight analysis

Three arguments are presented for and against a segmental analysis or a syllable weight analysis and these are stress bearing syllables in §3.4.3.1, weight bearing syllables in §3.4.3.2, and the patterning of consonant clusters and geminates in §3.4.3.3.

3.4.3.1 Stress bearing syllables

Ringen and Vago (2011) argue in favour of a segmental representation of geminates. One of the main counterarguments for a weight analysis is the possibility for weightless geminates in coda position. According to Ringen and Vago (2011:157), in Selkup, a west Siberian language, stress falls on the rightmost heavy syllable, or else on the initial syllable. CVC syllables in Selkup are considered to be light and they are not stressed. Therefore, if the first part of the geminate serves as the coda to a CVC, under a syllable weight analysis, this syllable is expected to be heavy, and thus attracts stress. However, in Selkup this is not the case, when a geminate closes a CVC, it is considered to be light and stress falls elsewhere.

Opposing arguments come from Latin, Italian and Japanese (among other languages, cf. Curtis 2003). In these languages, geminates pattern like all other consonants with respect to syllable weight. To exemplify through Latin, CVV, CVC, and CVG syllables are all heavy syllables, as in (6) (cf. Tranel 1991; Davis and Topintzi 2014 <h.o>). Stress falls on the penultimate syllable if it is heavy; otherwise it falls on the antepenultimate.

(6) Heavy syllables in Latin (c.f. Tranel 1991:293)[32]
/maˈ**riː**tus/ 'married' = CVV
/aˈ**ris**ta/ 'awn' = CVC
/aˈ**nel**lus/ 'little ring' = CVG

3.4.3.2 Weight bearing syllables

The moraic nature of word-initial geminates becomes clearer when looking at Trukese word-initial geminates (as discussed in Davis 1999). Word-initial geminates in Trukese are moraic. Trukese has a bimoraic minimal word requirement for lexical words. Nouns in Trukese are of CVV shape; e.g., [təə] 'iselt' and [maa] 'behaviour'. Moreover, nouns can also be made up of initial geminates and short vowels such as [tto] 'clam' and [ssɔ] 'thwart of a canoe'. The latter is taken as evidence for the mora in word-initial geminates in Trukese.

In contrast, word-initial geminates in Leti provide a case where word-initial geminates are not weight bearing. Leti is discussed in depth in Hume et al. (1997) and Muller (2001). The main argument against the moraicity of word-initial geminates in Leti arises from the fact that words containing such geminates pattern with light syllables, and therefore, are non-moraic. In addition, syllables with geminates do not attract stress. Moreover, Hume et al. (1997) argue that in Leti lexical words must be minimally bimoraic. If word-initial geminates in Leti were moriac, they argue that the language would have sequences of word-initial geminate and short vowel e.g. *[t.te]. However, they claim that these words are not present in the language. Thus, this is taken as evidence that word-initial geminates are in fact not moraic. As a result, word-initial geminates in Leti are represented as a single root node multiply linked to

[32] Translation from: http://latin-dictionary.net/

two timing positions (Hume et al. 1997; Muller 2001). Muller (2001) proposes that word-initial geminates in Leti (and Cypriot Greek, which is discussed in §3.4.3.3) are best accounted for through a *Composite Model*. The Composite Model is a hybrid model comprising elements of prosodic timing and prosodic weight models. According to Muller (2001), geminates (regardless of their position in the word) consist of a single segmental root node that is linked to two timing slots. Moreover, under the Composite Model, mora assignment is added in the prosodic representation only in language-specific cases. For instance, as described above, word-initial geminates in Trukese are moraic as there is a strict prosodic minimal requirement. On the other hand, Muller (2001) argues that languages such as Leti and Cypriot Greek are non-moraic and, therefore, moras are not included in their prosodic representation.

3.4.3.3 Patterning of consonant clusters and geminates

Moreover, Ringen and Vago (2011) also discuss the patterning of consonant clusters and geminates. In a segmental analysis, both consonant clusters and geminates are represented by two slots on the timing tier. Ringen and Vago (2011) show that Hungarian [+coronal] CC and geminates trigger epenthesis after verbal stems, as in (7).

(7) Hungarian epenthesis (c.f. Ringen and Vago 2011:165)

(7a) no epenthesis after C- or V-final stems:

[kɒ**p**-s] 'you receive'

(7b) epenthesis after CC-final stems:

[a:**ld**-**ɒ**s] 'you bless'

(7c) Epenthesis after G-final stems:

[hɒ**ll**-**ɒ**s] 'you hear'

They argue that epenthesis in (7b) and (7c) is triggered because consonant clusters and geminates are represented as two slots on the timing tier. Furthermore, they attribute this phenomenon to a segmental length representation and not a syllable weight analysis.

A similar comparison can be drawn between word-initial geminates and onset clusters in Cypriot Greek. Muller (2001) provides evidence from Cypriot Greek to strengthen her argument against a moraic universal representation of geminates. Firstly, Muller (2001) compares geminates to singletons, where geminates, like single segments undergo palatalization before the high vowel /i/ (e.g., (8) below). Muller (2001) argues that this process is only possible if geminates and singletons are similarly represented: as a single root node.

(8) Palatalization before the high vowel /i/ in Cypriot Greek

(8a) ka**k**os 'bad (masc. sg.)' ka**ʃ**i 'bad (fem. sg.)

(8b) sa**kk**os 'jacket (nom.sg.)' sa**ʃʃ**i 'jacket (nom. pl.)' *sa**kʃ**i

Moreover, Muller (2001) compares word-initial geminates to onset clusters in Cypriot Greek. Muller (2001) shows that word-initial geminates pattern with minimal distance sonority onset clusters (such as /ps/), in that they trigger final nasal deletion of the definite /tin/(fem.), /ton/(masc.): compare examples (9a) and (9b).

(9) Final nasal deletion in Cypriot Greek

(9a) to **pp**aran 'the money' *ton pparan

(9b) to **ps**aʃin 'the poison' *tin psaʃin

As a result, Muller (2001) argues that there is no supporting evidence for the presence of the mora in Cypriot Greek and thus, she assumes that word-initial geminates are non-moraic. Therefore, the above phonological phenomena show that word-initial geminates in Cypriot Greek pattern together with consonant clusters and singletons in different phonological processes. Thus, this patterning is better explained through explicit timing relationships than moraic constituents, as for instance, word-initial geminates and onset consonant clusters are represented differently under moraic theory.

Contrastively, in Arabic, unlike Hungarian and Cypriot Greek, consonant clusters and geminates do not pattern similarly. Davis (2011) and Davis and Ragheb (2014) illustrate that in Hadhrami Arabic word-final consonant clusters trigger epenthesis e.g. /bint/ → [binit] 'girl', but word-final geminates do not, e.g. [rabb] 'Lord'. Davis and Ragheb (2014) clearly state that in word-medial position, it is very difficult to distinguish the two representations apart. However, in word-final position, there are some asymmetries between consonant clusters and geminates. Due to these asymmetries, Davis and Ragheb (2014) argue that a syllable weight analysis does not advocate for a patterning of consonant clusters and geminates. Therefore, a syllable weight analysis captures this difference best.

3.4.3.4 Summary: The representation of geminates

The literature proposes numerous models for the representation of geminates. The representation of geminates is a controversial issue in phonology (cf. Davis 2011). In §3.4, I outlined the two main representations for geminates in the literature. First, I discussed a segmental length analysis for geminates, which states that geminates are two slots on a timing tier. Secondly, I presented a moraic analysis of geminates, which states that geminates are underlying moraic (unlike singleton that do not bear a mora). Even though, most of current research seems to favour a moraic analysis (cf. Davis 2011), Ringen and Vago (2011) present arguments for a segmental length analysis.

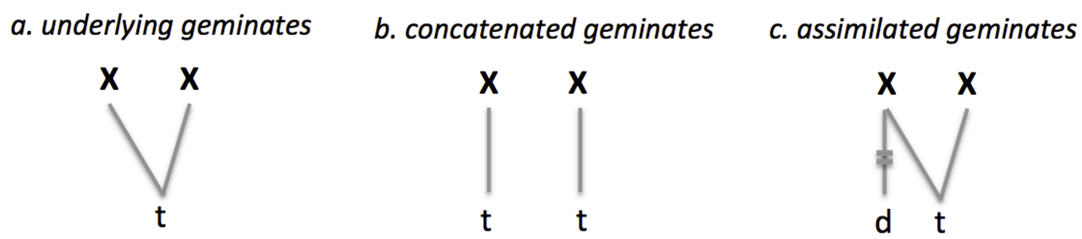
3.5 On Lexical and Surface Geminates

As described above, underlying geminates are considerably longer than their singleton counterparts. An issue that the literature has not fully addressed in detail is whether there are similarities or differences across different types of geminates. This is driven by the fact that lexical and surface geminates are assumed to have different phonological representations. Therefore, their phonetic realization can be expected to differ. Lexical geminates, or underlying geminates (Curtis 2003), are geminates that contrast with their short counterparts within the same morpheme; as in word-medial geminates in Italian in (10) and in a segmental approach are represented as in Figure 3.6a.

(10) *sete* 'thirst' vs. *sette* 'seven'

Geminates may also arise through a number of different morphological processes. Surface geminates are defined as "heteromorphemic geminates that may arise by concatenation of two identical consonants at a word boundary or by total assimilation" (Ridouane 2010: 77; Curtis 2003). Ridouane (2010) further distinguishes between concatenated geminates (i.e., two similar segments next to each other; cf. Figure 3.6b) and assimilated geminates (the assimilation of one segment into another; cf. Figure 3.6c below). It is argued that these different geminate types have different representations, as shown in Figure 3.6 (Hayes 1986; Curtis 2003; Ridouane 2010).

Figure 3.6: Representation of lexical and surface geminates (from Ridouane 2010)



Ridouane (2010) compares lexical geminates and surface geminates. Following Hayes (1986), assimilated geminates (for example, arising from external sandhi) are attributed to feature spreading and delinking (examples include Sardinan postlexical geminates; cf. Ladd and Scobbie 2003). However, surface geminates are represented very similarly to lexical geminates: as two timing slots associated with a single melodic unit. On the other hand, concatenated geminates are represented differently, as two timing slots each associated with a melodic unit. Particular focus is given here to the difference between lexical and assimilated geminates. Ridouane (2010) presents results from a production study on Tashlhiyt Berber, including voiced and voiceless dental stops and fricatives (/tt dd ss zz/) and voiced and voiceless velar stops (/kk gg/). Five native speakers were recorded, all target consonants were preceded by the vowel /a/. Also, the position of the geminate was constant. Both temporal measures: such as constriction duration (closure duration for stops and consonant duration for fricative) and VOT and non-temporal measures: such as burst amplitude were measured.

The results show that lexical geminates, assimilated geminates and concatenated geminates have similar constriction durations. In addition, all stops had similar VOT durations. However, two results were different among the geminate types: first, the duration of the vowel preceding lexical and assimilated geminates was significantly shorter than that before concatenated geminates. Second, lexical and assimilated geminates had higher release energy than concatenated geminates. Ridouane (2010) argued that phonologically derived geminates (i.e., assimilated geminates) have the same temporal values as lexical geminates, which in turn, favours the representation of such geminates having two timing slots. The major contribution of these results is that "assimilated geminates are acoustically identical to lexical geminates": they both involve the same primary and secondary correlates (Ridouane 2010: 80). On the other hand, concatenated geminates do not manifest the phonetic correlates of lexical and assimilated geminates. Ladd and Scobbie (2003) also show that the duration ratio of word-medial singletons to word-medial geminates was comparable to that of word-initial singletons and word-initial assimilated geminates in Sardinian. To conclude, Ridouane (2010) suggested that all geminate types are manifested with longer constriction durations when compared to singletons which favours the representation of geminates with two timing slots. Therefore, there might a similar phonological representation for different geminate types, but it seems that secondary correlates are only enhanced in lexical and assimilated geminates.

3.6 Gemination in Maltese

Having discussed gemination in a broad cross-linguistic perspective, I will now discuss gemination in Maltese against this background, bearing in mind both the phonetic correlates that have been established for geminates, and the issues arising from their phonological representation.

Geminates in Maltese can occur underlyingly in word-initial (e.g., /**<u>ss</u>**ɔlvɐ/ *ssolva* 'to be solved'), word-medial (e.g., /hɐ**<u>ff</u>**ɛr/ *ħaffer* 'to dig') and word-final (e.g., /ɔ**<u>mm</u>**/ *omm* 'mother') position. However, as shown in Chapter 2 §2.5, the phonetic realization of word-initial geminates involves the insertion of an epenthetic vowel before the word-initial geminate, i.e., /ssɔlvɐ/ → [ɪssɔlvɐ] *ssolva* 'to be solved'.

Surface geminates in Maltese occur through total assimilation and the concatenation of identical sounds. For example, the regressive assimilation of the definite article /l/ before coronal sounds results in assimilated geminates (discussed in this chapter §3.6.3.2), e.g., [**s-s**ʊːʔ] *s-suq* 'the market'. Moreover, the concatenation of two identical sounds across a word boundary can result in gemination e.g. [ʃtɹɐː**t t**iːnɐ] *xtrat tina* 'she bought a fig'.

Gemination in Maltese is at the core of this dissertation. This chapter gives an overview of how gemination arises in Maltese. First, in §3.6.1, I present which phonemes can be geminated in Maltese. After that, I illustrate word-medial (§3.6.2), word-initial (§3.6.3) and word-final gemination (§3.6.4) in Maltese by referring particularly to the root-and-pattern morphology but also to other lexical categories in the language.

3.6.1 Distribution of geminate consonants in Maltese

All consonants in the sound inventory of Maltese can be geminated. However, the distribution of geminate consonants is conditioned by their place in the word. Voiceless obstruents, namely, the stops /p t k/, the fricatives /f s ʃ/, the affricates

/tʃ ts/, as well as the sonorants /l m n r/ can be geminated in initial, medial and final positions in the word. Table 3.10 provides some examples.

Table 3.10: Gemination of voiceless obstruents and sonorants in Maltese

Segment	**Initial**	**Medial**	**Final**
/p/	/**pp**ɐɹkjɐ/ *pparkja* 'to park'	/mɐ**pp**ɐ/ *mappa* 'map'	/tɐ**pp**/ *tapp* 'plug'
/t/	/**tt**ɐllɐb/ *ttallab* 'to beg'	/fɐ**tt**ɐɹ/ *fattar* 'to crush'	/ʃɐ**tt**/ *xatt* 'shore'
/f/	/**ff**ɪɹmɐ/ *ffirma* 'to sign'	/sɐ**ff**ɐɹ/ *saffar* 'to whistle'	/gɔ**ff**/ *goff* 'bulky'
/ʃ/	/**ʃʃ**ɐhhɐm/ *xxaħħam* 'to be fattened'	/kɐ**ʃʃ**ɐ/ *kaxxa* 'box'	/bɛ**ʃʃ**/ *bexx* 'to spray'
/tʃ/	/**tʃtʃ**ɐɾɾɐt/ *ċċarrat* 'to be torn'	/bo**tʃtʃ**ɐ/ *boċċa* 'a marble'	/pɐpɔ**tʃtʃ**/ *papoċċ* 'bed slippers'
/m/	/**mm**ɐɹkɐ/ 'to mark'	/sɐ**mm**ɐɹ/ *sammar* 'to nail'	/(ʔ)ɛ**mm**/ *hemm* 'there'
/r/	/**rr**ɐːbjɐ/ 'to be angry'	/fɛ**rr**ɐʔ/ *ferraq* 'to separate'	/dʒɐ**rr**/ *ġarr* 'to carry'

Note that there is a change in quality in the case of /r/, at least for speakers of Standard Maltese: in singleton cases it is produced as an alveolar approximant [ɹ], whereas in geminate forms it is realized as the alveolar tap [ɾ]. However, some speakers produce an alveolar tap [ɾ] instead of an alveolar approximant [ɹ] in singletons, and when it occurs in geminates it is produced as two-tap trill (Azzopardi-Alexander p.c. 2015).

Voiced obstruents (/b d g v z dʒ/) and glides (/j w/) can be geminated in word-initial and word-medial position. Table 3.11 lists some examples. The fact that there are no geminate voiced obstruents in word-final position is due to the fact that voiced obstruents are devoiced word-finally (as discussed in Chapter 2 §2.3.7).

Table 3.11: Gemination of voiced obstruents and glides in Maltese

Segment	Initial	Medial
/b/	/**bb**ɐːza/ *bbaza* 'to bases'	/kɐ**bb**ɐɹ/ *kabbar* 'to make s.t grow'
/dʒ/	/**dʒdʒ**ɐɾɾɐp/ *ġġarrab* 'to be experienced'	/vlɛ**dʒdʒ**ɐ/ *vleġġa* 'arrow'
/v/	/**vv**ɔːtɐ/ *vvota* 'to vote'	/(ʔ)ɐ**vv**ɪːs/ *avviż* 'ad'
/w/	/**ww**ɛldjɐ/ *wweldja* 'to weld'	/dɐ**ww**ɐl/ *dawwal* 'to illuminate'

Furthermore, the glottal stop /ʔ/ and the glottal fricative /h/ are geminated only word-medially and finally, see Table 3.12.

Table 3.12: Gemination of /ʔ/ and /h/ in Maltese

Segments	Medially	Finally
/ʔ/	/fɐ**ʔʔ**ɐs/ *faqqas* 'to hatch'	/dɐ**ʔʔ**/ *daqq* 'to play'
/h/	/ʃɐ**hh**ɐm] *xaħħam* 'to fatten'	/sɛ**hh**/ *seħħ* 'to occur'

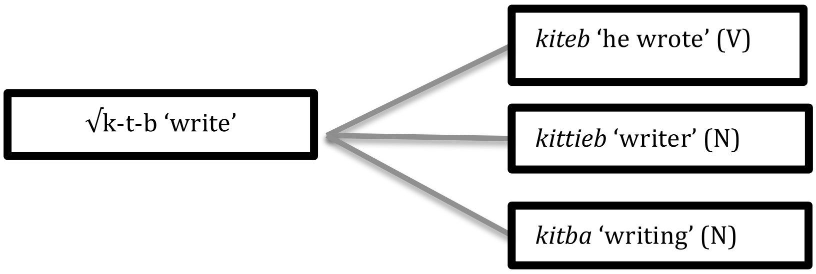
3.6.2 Word-medial geminates in Maltese

Maltese Semitic verbs[33] follow root-and-pattern morphology similar to other varieties of Arabic. Word-medial gemination in Maltese is a morphophonological process arising from its root-and-pattern morphology, which applies across the board to verbs of Semitic origin. This morphophonological process, which is similar in numerous Arabic dialects, operates on verbal forms. The morphological structure of a root in root-and-pattern morphology is non-linear (also referred to as discontinuous or non-concatenative). The root (√), which can be seen as the most salient meaningful element in a Semitic word, is made up of

[33] The difference between Maltese Semitic and non-Semitic verbs is addressed in §3.6.3.1 and §3.6.3.3 of this chapter respectively.

2 to 4 consonants. These consonants occur in a fixed sequence. The root establishes the basic semantic area and words derived from such a root are semantically related; consider the root ‘k-t-b’ in Figure 3.7 below.

Figure 3.7: √Root and pattern derivations in Maltese



The root is mapped onto a pattern (also referred to as a theme) to derive both nominal and verbal forms. The pattern includes both the vocalic sequence for that root and also the CV-skeleton; i.e., the placeholder for the consonants in the root. Table 3.13 shows the distribution of the root *k-s-r* into verbal patterns. The different verbal patterns keep (to some extent) the same semantic meaning of the root but have a different aspectual meaning; e.g., reflexive, passive, intensive. In Maltese root-and-pattern morphology there are 10 verbal patterns in which roots can be realized. However, in Maltese root-and-pattern morphology, not all roots are realized in all the patterns. Mifsud (1995) proposes that on average each root is realized in 3 or 4 of the patterns in the system. On the other hand, Spagnol (2011) shows that on average each root is realized in two verbal patterns.

Table 3.13: Root and verbal patterns: k-s-r[34]

Root	**Verbal Pattern**	**Number**	**Example**	**Aspect**
√k-s-r	$C_1iC_2eC_3$	I	*kiser* ‘he broke’	
	$C_1iC_2C_2eC_3$	II	*kisser* ‘he smashed’	intensive
	t-$C_1iC_2C_2eC_3$	V	*tkisser* ‘it was smashed’	passive
	n-$C_1iC_2eC_3$	VII	*nkiser* ‘it was broken’	passive

[34] Root k-s-r does not derive any patterns from Pattern III or VI for instance.

The base form for verbal forms is verbal pattern I, which is of a CVCVC shape, the shape of strong verbal forms. Other verbal forms in the pattern are derived from pattern I (as can be seen in Table 3.4 above). Pattern II, which is built on Pattern I, doubles the second radical consonant (in (11) below).

(11) Doubling of the second radical

Pattern I → $C_1vC_2vC_3$

Pattern II → $C_1vC_2C_2vC_3$

In Table 3.13, pattern II of the base form *kiser* is *kisser* - resulting in a geminated medial consonant. The gemination of the medial consonant in Pattern II applies to all phonemes in Maltese.

Furthermore, Maltese has word-medial geminates which do not arise through this morphophonological process. However, unlike the word forms created via pattern II, which create minimal pairs[35], there are only few minimal pairs in non-morphological forms. Some examples are listed in (12).

(12) Word-medial geminates

[pɐː**p**ɐ] *papa* 'pope'; [pɐ**p.p**ɐ] *pappa* 'food'

[sɐ.**p**ʊn] *sapun* 'soap'; [dʒɐ**p.p**ʊn] *Ġappun* 'Japan'

3.6.3 Word-initial Geminates in Maltese

The aim of this section is twofold. First, I give an overview of the literature on word-initial geminates in Maltese and second, I discuss relevant phenomena related to word-initial gemination. Word-initial gemination in Maltese is present in Semitic verbs (§3.6.3.1), in lexemes with the definite article (§3.6.3.2) and non-Semitic verbs (§3.6.3.3).

[35] Minimal pairs are created between Patterns I and II. It is worth noting that this is only the case where roots have both patterns (as there are some roots which do not have both patterns).

3.6.3.1 Semitic Verbs

In the introduction above, I listed some examples of word-initial gemination, in the following sections I present more detail on word-initial gemination in Semitic verbs, the definite article and non-Semitic verbs. First, in this sub-section, I address word-initial gemination in Semitic verbs.

First, word-initial geminates in Semitic verbs only arise when the first consonant of the root is [+coronal –sonorant]. Second, word-initial geminates only arise through [+coronal –sonorant] word-initial consonants in Pattern V. To illustrate, in Table 3.14, Pattern II of the root √lbs is *libbes* 'to be worn', which has a word-medial geminate. This is imposed by root-and-pattern morphology, where Pattern II verbs are derived from Pattern I by geminating the medial consonant. Pattern V is built on the CV-structure of Pattern II but in Pattern V, the prefix *t-* is added to the verbal pattern II, as is shown by *tlibbes* 'to be dressed' in Table 3.14. However, if the first radical consonant in the root is [+coronal –sonorant], this consonant regressively assimilates. In terms of its aspectual meaning, Pattern V has a passive/reflexive meaning. Table 3.14 shows examples of roots (and their derivations) beginning with /l/ and /r/ which are [+coronal +sonorant] and /d͡ʒ/ and /ʃ/ which are [+coronal -sonorant].

Table 3.14: Root and pattern derivations

Root[36]	Pattern I	Pattern II	Pattern V	Feature
√lbs	[lɪbɛs] *libes* 'to wear'	[lɪbbɛs] *libbes* 'to dress'	[**tl**ɪbbɛs] *tlibbes* 'to be dressed'	[+coronal +sonorant]
√rsʔ	[rɛsɐʔ] *resaq* 'to approach'	[rɛssɐʔ] *ressaq* 'to bring s.th closer'	[**tr**ɛrrɐʔ] *tressaq* 'to be brought forward'	[+coronal +sonorant]
√d͡ʒbd[37]	[dʒɪ.bɛt] *ġibed* 'to pull'	[dʒɛb.bɛt] *ġebbed* 'to pull'	/**dʒ.dʒ**ɛb.bɛd/ *ġġebbed* 'to be stretched'	[+coronal -sonorant]
√ʃrb[38]	[ʃɔ.rɔp] *xorob* 'to drink'	[ʃɐr.rɐp] *xarrab* 'to make s.th wet'	/**ʃ.ʃ**ɐr.rɐb/ *xxarrab* 'to get wet'	[+coronal -sonorant]

The [+coronal -sonorant] pattern V verbal forms have geminates in word-initial position. This is the only case where a word-initial lexical geminate originates in Maltese Semitic verbal morphology. Table 3.15 lists the [+coronal –sonorant] sounds in Maltese which undergo word-initial gemination in Pattern V verbal forms.

Table 3.15: [+coronals –sonorant] sounds in Maltese

Alveolar	Postalveolar
t d	
s z	ʃ
ts tʃ	dʒ

The coronal sounds in Maltese, also known as *the sun letters* in Maltese and other varieties of Arabic, regressively assimilate in the case of the definite article (this is discussed below in §3.6.3.2). However, there is a difference in which sounds can be assimilated before the definite article and in Pattern V verbal forms. /n r

[36] The root consonants in the column root are given in phonemic transcription and not in standard orthography.
[37] Readers are reminded that voiced obstruents are finally devoiced in Maltese.
[38] Same as above.

l/ which are [+coronal +sonorant] do not assimilate the first root consonant in Pattern V[39]. Compare (13) and (14) below.

(13) *[+coronal +sonorant]: no assimilation*

[**tl**ɪbbɛs] *tlibbes* 'to be worn'

[**tr**ɛssɐʔ] *tressaq* 'to be approached'

(14) *[+coronal -sonorant]: assimilation*

[**ʃʃ**ɐrrɐp] *xxarrab* 'to get wet'

[**zz**ɛwwɛtʃ] *żżewweġ* 'to get married'

Roots can also be made up of four radicals, which are called quadriliterals (cf. Ellul 2010 for a current analysis of quadriliteral verbs in Maltese). There are two types of quadriliterals: simple, which have four distinct radical consonants: $C_1VC_2C_3VC_4$ and reduplicative, where the first syllable is repeated: $C_1VC_2C_1VC_2$. These are exemplified in (15).

(15) Quadriliterals

Simple: √ħrbt [hɐr.bɐt] *ħarbat* 'to mix up'

Reduplicative: √frfr [fɐr.fɐr] *farfar* 'to dust'

Quadriliteral forms, unlike triliteral forms, undergo only one derivational process, which is the addition of the prefix [t] to create passive forms. Word-initial geminates also arise, when the prefix [t] is added before roots whose first consonant is [+coronal –sonorant], as in (16).

[39] However, they regressively assimilate in the definite article (see §3.6.3.2).

(16) Quadriliteral

√ħrbt *[+coronal +sonorant]: no assimilation*

[**h**ɐr.bɐt] *ħarbat* ‘to mix up’,

[**th**ɐr.bɐt] *tħarbat* ‘to be mixed up’

√xqlb *[+coronal -sonorant]: assimilation*

[**ʃ**ɐʔ.lɛp] *xaqleb* ‘to move s.th in a direction’,

[**ʃʃ**ɐp.lɛp] *xxaqleb* ‘to be moved in a direction’

In addition, I would like to point out that any inflected forms that arise from the Pattern II and Pattern V retain the gemination, whether it is in initial or medial position. Table 3.16 shows 3 examples of derived and inflected forms from Pattern I, II and V. In Pattern I, there is no gemination in the derived form and by consequence inflected forms do not have it. On the other hand, in Patterns II and V, there is gemination in the derived forms and they surface also in the inflected forms.

Table 3.16: Gemination across derived and inflected forms

Root	Pattern	Derived Example	Inflected Example	Gemination
√d h l	Pattern I	[dɐhɐl] *daħal* ‘to enter’	[dhɐlt] *dħalt* ‘I entered’	NO
	Pattern II	[dɐ**hh**ɐl] *daħħal* ‘to insert’	[dɐ**hh**ɐlt] *daħħalt* ‘I inserted’	YES: medial
	Pattern V	[**dd**ɐ**hh**ɐl] *ddaħħal* ‘to be instered’	[**dd**ɐ**hh**ɐlt] *ddaħħalt* ‘I was entered’	YES: initial and medial

Furthermore, non-Semitic stems maintain their word-initial geminate also in morphologically related words (17).

(17) non-Semitic morphologically related words

Verbal form: /**m.m**ɐr.kɐ/ ‘to mark’

Derived passive particle: /**m.m**ɐr.kɐt/ ‘it was marked’

To sum up, word-initial geminates arise before Semitic roots, where the first consonant in the root is [+coronal –sonorant]. Gemination arises in Pattern V of the root-and-pattern verbal morphology. Typically, verbal forms derived from tri-consonantal roots, have word-initial geminates tend to have word-medial geminates too. In the following section, I describe how word-initial geminates arise in nouns, in particular nouns with an initial [+coronal] sound.

3.6.3.2 The Definite Article

Word-initial geminates can also surface from the assimilation of the definite article. The definite article in Maltese, which originates from Arabic, is *(i)l-.* Before vowels, the article is realized as [l-], e.g., [l-ɐtt] 'the act'. Before consonants, the article can take the prothetic vowel /ɪ/, thus realized as [ɪl] (e.g., [il-kelb] 'the dog'), after a word ending in a consonant or at the beginning of the phonological phrase (Comrie 1980). Just like Arabic (Watson 2007), the [l] of the definite article in Maltese regressively assimilates in terms of place of articulation to following [+coronal] sounds.

In the previous section, the assimilation caused by the feature [+coronal] was discussed in light of the morphology of Pattern V (c.f. Table 3.6). Sounds which are [+coronal +sonorant] do not assimilate before the verbal prefix /t/, as in for example (13) above. However, in the case of the definite article, [+coronal +sonorant] sounds assimilate the definite article; as in /r/ in *ras* 'head' and /n/ in *nar* 'fire' and *nokkli* 'curls' in Table 3.17. On the other hand, in verbal forms /n r l/ do not assimilate. Therefore, the assimilation of the definite article occurs before [+coronal] Semitic and non-Semitic sounds.

Table 3.17: The definite article in Maltese

	Semitic nouns	**non-Semitic nouns**
ARTICLE DOES NOT ASSIMILATE	[ɪ**l.k**ɛlp] *il-kelb* 'the dog'	[ɪ**l.m**ɐk] *il-mug* 'the mug'
	[ɪ**l.ʔ**ɐlp] *il-qalb* 'the heart'	[ɪ**l.k**un.tʃɛrt] *il-kunċert* 'the concert'
ARTICLE ASSIMILATES	[ɪ**s.s**ɐjf] *is-sajf* 'the summer'	[ɪ**ts.ts**ɪ.jɐ] *iz-zija* 'the aunt'
	[ɪ**r.r**ɐːs] *ir-ras* 'the head'	[ɪ**t.t**ɐts.tsɐ] *it-tazza* 'the cup'
	[ɪ**n.n**ɐːr] *in-nar* 'the fire'	[ɪ**n.n**ɔk.klɪ] *in-nokkli* 'the curls'

A second observation is that the affricate /dʒ/ does not assimilate in the case of the definite article e.g., *ġelat* /dʒɛː.lɐt/ 'ice-cream', *il-ġelat* [ɪ**l.dʒ**ɛː.lɐt] 'the ice-cream' but it does in the case of the derived verbal forms. Borg (1997) claims that the non-assimilation of the definite article before /dʒ/ is present in Classical Arabic and other varieties of Arabic. One possible explanation of this is the fact that /dʒ/ historically derives from the velar /g/, which does not assimilate (cf. Kambuziya 2007 for a description of this change). Comrie (1980) argues that the non-assimilation of /dʒ/ in Maltese is an exception in the phonological rule for /l/-assimilation.

The assimilation processes for Semitic verbs in §3.6.3.1 and the definite article in §3.6.3.2 are very similar, however, a distinction in the assimilation of [+coronal – sonorant] initial sounds for word-initial geminate and the assimilation of [+coronal] initial sounds for the definite article is made respectively. This phonological restriction on word-initial gemination is not present in non-Semitic verbs.

3.6.3.3 Non-Semitic Verbs: Romance and English Verbs

Verbs have been integrated into Maltese from Italian and English. The syllabic structure of such verbs varies widely, ranging from two to five syllables, and deviates from the rigid prosodic structure of Semitic verbs.

Mifsud (1995) claims that initial gemination is a distinctive feature of non-Semitic verbs. He also adds that even though non-Semitic stems undergo gemination, their phonetic surface realization requires a prothetic vowel. However, this prothetic vowel is dropped when the preceding words ends in a vowel.

For verbs originating in both Italian and English, Mifsud (1995) describes in detail the phonological conditions in which initial gemination is and is not carried out. In his description, Mifsud (1995) separates verbs of Italian and English origin and classifies them as 'Type C' and 'Type D' verbs, respectively. However, for the present purposes, it will suffice to treat both as non-Semitic verbs. Mifsud (1995) sets the scene by identifying the different syllable structures in the stem verb, mainly focusing on the vocalic and consonantal sequences of the leftmost edge. By doing so, three stems are identified in both Italian and English verbs:

1) V-stems
2) CV-stems
3) CC-stems

Vowel initial stems, *v-stems*, do not undergo word-initial gemination, see (18) for examples.

(18) V-stems

Italian [ɛspɛrimɛntarɛ] → Maltese [ɛspɛrɪmɛntɐ] 'to experiment'

English [əfɔ:d] → Maltese [ɐffɔrdjɐ] 'to afford'

Maltese has integrated a number of non-Semitic verbs that are vowel-initial in their language origin, but the initial vowel has been deleted in their integration. This mainly affected verbs coming from Italian such as *abbastare*, which was integrated as *bbasta* 'to suffice'. It is possible that the stem in Romance underwent a process of apheresis.[40] If this is the case, the initial gemination is not a result of the same morphological process underlying word-initial gemination for non-Semitic verbs, but it might be word-initial because of the process of apheresis (cf. Mifsud 1995).

Furthermore, both Italian and English stems with a vowel-nasal-consonant sequence, as in (19), do not undergo gemination.

(19) Vowel-nasal-consonant sequences

Italian [**ɪn**teressa] → Maltese [**ɪn**tɛrɛssɐ] 'to interest'

Mifsud (1995) argued that some Italian stems of a vowel + nasal went through a process of regressive assimilation instead of a process of initial gemination, as in (20).

(20) Vowel +nasal consonant

Italian [**in**tende] → Maltese [**tt**ɛndɐ] 'to intend'

Italian stems beginning with a vowel-sibilant-consonant sequence go through a process of apheresis in their integration. Therefore, in its integration into Maltese, the initial vowel is deleted and the sibilant does not undergo gemination. This process is limited to Italian stems as English does not have such structures. Mifsud (1995) attributed this process to an analogy to similar (Semitic) Maltese forms: e.g. *staħba* 'to hide oneself'. Thus vowel sibilant consonant stems result in a sibilant-cluster onset in Maltese: *sklama* 'to exclaim'.[41]

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[40] Apheresis can be defined as the process of deleting or losing one or more sounds at the beginning of the word in an unstressed syllable..

[41] Note that in some varieties of Maltese, some speakers might have an alternation of the verb beginning with a vowel e.g. *sklama* ~ *e/isklama* 'to exclaim'.

Mifsud (1995) claimed that in cases such as *abbasta* → *bbasta* it is very difficult to say whether such forms underwent a process of apheresis or a process of initial gemination (especially as there is also the verb *bastare*). Mifsud (1995) claimed that initial gemination is a morphological process that integrated borrowed verbs from Italian and English into Maltese. Diachronically, it is possible that certain verbs went through a phonological process. However, synchronically, these verbs have an initial geminate and they should be treated just as any other initial geminated verb.

In CV-stems, any word-initial consonant can be geminated. Table 3.18 lists some examples from Italian and English.

Table 3.18: Non-Semitic verbs: CV-stems

Language of origin			**Example**	**Translation**
Italian	'firmare'	**Maltese**	*ffirma*	'to sign'
Italian	'solidificare'		*ssoda*	'to solidify'
English	'book'		*bbukkja*	'to book'
English	'chance'		*ċċansja*	'to change'

Italian stems with a sonorant as a first consonant lost the pretonic vowel in Maltese and resulted in a CC-onset. As a result, initial gemination is blocked in such cases, where the first consonant is a resonant, and this results in a sonorant-initial cluster (e.g., /lm/): Italian ***la**menta* → Maltese ***lm**enta* 'to complain'. Mifsud (1995:150) reminded his readers that 'a euphonic vowel is required in surface realisations'. However, this is not the case for English stems. On the other hand, CV.C-sequences, which do not begin with a resonant, delete the pretonic vowel and undergo gemination: Italian ***co**manda* → Maltese ***kk**manda* 'to order'. This results in a geminate + consonant sequence.

The first consonant of a CC-onset in both Italian and English stems can be geminates as shown in Table 3.19.

Table 3.19: Non-Semitic verbs: CC-stems

Language of origin	Example		Example	Meaning
Italian	'brilla'	**Maltese**	*bbrilla*	'to excel'
Italian	'tratta'		*ttratta*	'to treat'
English	'print'		*pprintja*	'to print'
English	'freak'		*ffreakja*	'to freak'

In the case of sibilant initial clusters, initial gemination is blocked. Also, sibilant initial clusters are not preceded by a prothetic vowel. However, there are some exceptions for sibilant cluster coming from English stems. According to Mifsud (1995), sibilant-sonorant clusters (including the glide /w/) can undergo gemination in Maltese. For instance: *slide* → /**ssl**ɐjdjɐ/; *shred* → /**ʃʃr**ɛdjɐ/; *swerve* → /**ssw**ɛrvjɐ/. However, Mifsud (1995) lists *snob* and *switch* as exceptions, since they are not geminated in the perfective form (e.g. *snobbja* 'to snob') but are geminated in the imperfective forms (e.g. *jissnobbja* 'he snobbed').

This subsection has shown that word-initial gemination in non-Semitic verbs is widespread and most borrowed verbs have a word-initial status.

3.6.3.4 The status of word-initial geminates

In Chapter 2 §2.4 and §2.5, I argued that word-initial geminates are disallowed in the phonology of Maltese and tend to require a vocalic insertion. This insertion was triggered by the need to syllabify all segments in a phonology string. Therefore, it goes without saying that the status of word-initial geminates in Maltese is very controversial.

Azzopardi (1981: 50, **emphasis added**) states:

> "No geminate consonant can occur word initially or syllable initially because in Maltese, the geminated consonant in this position is always pronounced with a **very short vowel** /ɪ/ the epenthetic vowel… But geminated consonants **never** occur word-initially."

Mifsud (1995:143) claimed "the phonetic surface realization of such verbs requires a prothetic vowel unless the preceding word ends in a vowel". Hoberman and Aronoff (2003:73) stated that "In Maltese there is always a prothetic vowel before initial geminates unless the preceding word in the same phonological phrase ends in a vowel." With reference to the definite article, Comrie (1980:25) commented that 'before consonants, the article takes prothetic 'i', to give il-, at the beginning of a phonological phrase or after a consonant'.

Maltese does not seem to be the only language, in which word-initial geminates are preceded by a vocalic insertion. Marshallese, a language spoken by 58,000 speakers in the Republic of the Marshall Islands, also has a similar process (Harrison 1995, Wilson 2003). Harrison (1995) argues that the difference between Ralik and Ratak dialects of Marshallese are mainly lexical. However, she adds that the non-lexical difference is the placement of an inserted vowel with respect to word-initial geminates. In Ralik, the Marshallese dialect spoken on the western islands, word-initial geminates are preceded by an epenthetic vowel (which are shown in **bold**) in (21) below.

(21) Ralik word-initial geminates (from Harrison 1995)
/ppiŋ/ → [**i**p̠p̠iŋ] 'skilled in jumping'
/llor/ → [**e**l̠l̠or] 'shade, shadow'

On the other hand, in Ratak, the Marshallese dialect spoken on the eastern islands, an epenthetic vowel is inserted between the geminates as in (22) below.

(22) Ratak word-initial geminates (from Harrison 1995)
/ppiŋ/ → [p̠**i**p̠iŋ] 'skilled in jumping'
/llor/ → [l̠**e**l̠or] 'shade, shadow'

Furthermore, Bolognesi (1998:153) reports that some speakers may insert a vocalic insertion before word-initial geminates (and also sC clusters) in Campidanian Sardinian[42] (in 23).

(23) Campidanian Sardinian (from Bolognesi 1998)

[**i**]tstsuɣu *neck*

[**i**]ʃʃimpru *fool*

3.6.3.5 Geminate Integrity in Maltese

Geminate integrity refers to the fact that geminates cannot be split by vocalic insertions (Hayes 1986; Kenstowicz 1994; Curtis 2003). Therefore, vocalic insertions cannot be inserted between the halves of geminates. The word-initial geminates in Ratak in (8) do not show geminate integrity as an epenthetic vowel is inserted between the geminates. In contrast, Hayes (1986) provided evidence from Palestine Arabic, where word-final geminates obey geminate integrity (and are not split by epenthesis), but word final consonant clusters are split by epenthesis, as in (24).

(24) Palestine Arabic (Hayes 1986)

/ʔa**mm**/ → [ʔa**mm**] 'mother'

/ʔa**kl**/ → [ʔa**k**i̲**l**] 'food'

Moreover, Hayes (1986) proposed that heteromorphemic geminates, unlike concatenated geminates, also resist epenthesis. Therefore, in the case of Palestine Arabic, heteromorphemic geminates arise through total assimilation; geminates are not split up by epenthesis (as in 25).

(25) Palestine Arabic (Hayes 1986)

Concatenated geminates: /fu**t** + **t**/ → [fu**t**i̲**t**] 'I entered'

Heteromorphemic geminates: /**l**+ **z**yir/ → [**zz**yir] 'the small'

[42] See Lai (2015) for a discussion of word-initial geminates in Sardinian.

In Maltese, geminates in word-medial and word-final position show geminate integrity and are never split up by epenthesis (as in 26).[43]

(26) Word-medial and word-final geminates

[fɐ**hh**ɐɹ] ‘to compliment’

[(ʔ)ɔ**mm**] ‘mother’

As their medial and final counterparts, word-initial geminates in Maltese also show geminate integrity, following Hayes’s (1986) definition, that the vocalic insertion is right before the geminate and not in between. Therefore, the geminate is not split, as in (27). As shown in Chapter 2 §2.2.3, obstruent-initial onsets in Maltese are never split up epenthesis.

(27) Maltese word-initial geminates

[ɪ̠**dd**ɐhhɐl] *iddaħħal* ‘to be entered’

[ɪ̠**ss**ɐrrɐf] *issarraf* ‘to be exchanged’

This supports the argument that word-initial geminates in Maltese are genuine geminates. However, word-initial geminates are not really word-initial, but pattern similarly to word-medial geminates. This is because word-initial geminates in Maltese are assumed to be ambisyllabic, like word-medial geminates, and require a vowel before the first part of the geminate.

3.6.3.6 Interim summary: word-initial geminates in Maltese

The aim of the above subsection was to show that word-initial geminates in Maltese are conditioned by a number of morphological and morphophonological restrictions. Furthermore, word-initial geminates tend to be preceded by an epenthetic vowel, which in turn, makes them more similar, structurally, to word-medial geminates. This is investigated further in Chapter 5 and Chapter 6.

[43] It is interesting to compare Maltese to other dialects of Arabic with respect to the realization of word-final consonant clusters. This is because, in Maltese, such clusters are never split but by epenthesis, but can be split up in other dialects as in Levantine Arabic.

3.6.4 Word-final geminates in Maltese

In this final section, I discuss word-final gemination in Maltese. Root-and-pattern morphology also plays an important part in word-final gemination. In §3.6.2, I showed how roots are typically made up of 2 to 4 consonants and different verbal and nominal patterns can be derived. Of particular interest for word-final gemination in Maltese (and other Arabic dialects) are "biconsonantal roots" (McCarthy 1981:396). Biconsonantal roots, also known as doubled or geminate roots in the literature, are realized with the gemination of the second consonant in the root (i.e. C_2). Table 3.20 shows examples of triconsonantal roots and biconsonantal roots and their respective first pattern.

Table 3.20: Root types: strong and biconsonantal[44]

(Strong) Triconsonantal Roots: $C_1C_2C_3$		**Biconsonantal Roots: C_1G**	
Root	**Example**	**Root**	**Example**
/f-t-h/	/fɛtɐh/ *fetaħ* 'to open'	/d-ʔ-ʔ/	/dɐ**ʔʔ**/ *daqq* 'to play'
/t-l-f/	/tɪlɛf/ *tilef* 'to lose'	/b-ʃ-ʃ/	/bɛ**ʃʃ**/ *bexx* 'to spray'
/m-r-d/	/mɐrɐt/ *marad* 'to become sick'	/ʃ-m-m/	/ʃɐ**mm**/ *xamm* 'to smell'

The final geminate of these verbs is an integral part of the inflected and derived forms of the verbs. Therefore, when morphological prefixes and suffixed are added- the geminate is part of the surface form and is not deleted or reduced. However, it might shift to medial position as in the examples in (28).

(28) Inflection verbal forms

/dɐ**ʔʔ**ɛjt/ *daqqejt* 'I played' (compared to /dɐ**ʔʔ**/ *daqq* 'he played')

/ɪndɔ**ʔʔ**u/ *indoqqu* 'we play' (compared to /dɐ**ʔʔ**/ *daqq* 'he played')

[44] Examples of roots taken from *ġabra* (Camilleri 2013).

Word-final gemination is not limited to verbal patterns and to words of Semitic origin, but it is also found in other lexical categories, such as nouns and adjectives, and in words of non-Semitic origin in the Maltese lexicon as shown in (29).

(29) Examples of word-final geminates
Semitic: /(ʔ)ɔ**mm**/ *omm* ‘mother’ (Noun)
Non-Semitic (Italian): /zɪ**pp**/ *żipp* ‘zipper’ (Noun)
Non-Semitic (Italian): /lɪ**ʃʃ**/ *lixx* ‘smooth’ (Adjective)

3.6.5 Geminates in Maltese and syllable types

Geminates are assumed to be ambisyllabic, “typically span the syllable break” (Kenstowicz 1994:45), where the first half of the geminate is syllabified as a coda to the previous syllable and the second half of the geminate is syllabified as an onset to the following syllable. At least, this is true for word-medial geminates cross-linguistically. Yet, this is not the case for word-initial and word-final geminates.

In Maltese, word-medial and word-initial geminates have a similar structure, in that the geminate is preceded by a vowel. In the case of word-initial geminates, this is considered to be an epenthetic vowel, whereas, in the case of word-medial geminates it is a lexical vowel. Nevertheless, I also assume that word-initial and word-medial geminates in Maltese span the syllable boundary and are ambisyllabic. It is also important to mention that word-initial and word-medial geminates can be also followed by other consonants as in (30).

(30a) Word-initial: /**ppr**ɔgrɐmmɐ/ *pprogramma* ‘to programme’
(30b) Word-medial: /ɐ**ppr**ɛtstsɐ/ *apprezza* ‘to appreciate’

Word-finally geminates are not considered to be ambisyllabic and are restricted to one syllable. Other consonants do not seem to precede word-final geminates.

However, verbs containing word-final geminates can have the negative suffix -ʃ following, as in (31).

(31a) /hɐ**bb**/ *ħabb* 'to love'
(31b) /mɐ hɐ**bb**ʃ/ *ma ħabbx* 'he didn't love'

3.7 Summary

The main objective of this chapter was to present a cross-linguistic perspective on gemination. In §3.1-3.3, I outlined the acoustic correlates, which can be manifested in word-medial, word-initial and word-final positions. The discussion illustrated that there is a primary correlate for gemination, i.e. constriction duration, which is present in all languages that have geminates regardless of their position in the word. In contrast, secondary correlates (such as VOT, the duration of the vowel before geminates) can serve as correlates in some languages but not in others. The primary and secondary cues of geminates in Maltese will be investigated in production studies 1-3 in Chapters 5, 6, 7 respectively.

In §3.4, I discussed the two representations of gemination that dominate the literature; namely a segmental approach and a moraic analysis. Moreover, I presented arguments in favour and against these representations. In addition, a hybrid representation, which links the role of acoustic timing into a phonological model (Hume et al. 1997; Muller 2001), was also discussed. In Chapter 9, I discuss the representation of geminates in Maltese by adopting a moraic analysis. In §3.5, the difference between lexical and surface geminates was presented and their representation was outlined. The acoustic correlates of lexical and surface geminates in Maltese are studied in Production Study 1 in Chapter 5.

Having discussed the phonetics and phonology of geminates in a cross-linguistic perspective, I home in on gemination in Maltese in §3.6. Primarily, gemination in Maltese arises through a morphological process in the root-and-pattern system, which seems to be a special phenomenon for Semitic languages (cf. Curtis 2003). Gemination is also used as a morphophonological element to incorporate loan verbs in Maltese. In root-and-pattern morphology, word-medial gemination in Maltese arises through the gemination of the medial consonant (e.g. [rɛsɐʔ] *resaq* 'to approach' and [rɛ**ss**ɐʔ] *ressaq* 'to bring s.th closer'). In addition, word-medial gemination is also found in words of non-Semitic origin (such as [mɐppɐ] *ma**pp**a* 'map', [tɐ**tsts**ɐ] *tazza* 'cup'). However, unlike the Semitic verbal forms, minimal pairs for the non-Semitic words do not always exist. Word-initial gemination in Maltese is limited to Semitic and non-Semitic verbs and the definite article. There is a distinction to which sounds can be geminated depending on these three categories. For instance, for Semitic verbs only [+coronal –sonorant] segments can be geminated word-initially. The definite article before both Semitic and non-Semitic sounds regressively assimilated to [+coronal] sounds. On the other hand, there are not such phonological restrictions[45] on non-Semitic verbs, particularly verbs from English, which are continuously entering the language. Finally, the status of word-initial geminates is controversial as it has been argued that they are preceded by an epenthetic vowel (cf. Azzopardi 1981, Mifsud 1995, Hoberman and Aronoff 2003). In addition, Maltese is not the only language that inserts a vowel before word-initial geminates. This is also found in dialects of Marshallese and Campidanian Sicilian. Maltese also has word-final geminates: some of which arise because of the nature of the root in the root-and-pattern morphology, and in other words that happen to have word-final geminates.

In the subsequent chapter, I outline the general methodology with respect to the the segmentation process employed in the production studies in this dissertation.

[45] §3.6.3.3 described how and when gemination occurs in Italian originating verbs. However, nowadays, almost all loan verbs are from English.

Chapter 4: Methodology

In this chapter I describe the methodology used for the collection of data in production studies 1, 2 and 3. In §4.1, I give a general description of the method used (more specific information on the method is provided in the respective chapters). This leads to information on the language requirements to recruit participants for the studies in §4.2. In §4.3, I list the measurements used in each production study. In §4.4, I outline the general procedures of how the data was annotated. In §4.5, I summarize this chapter.

4.1 Method

The target words were presented to the participants in a carrier phrase. The speech material used in the different production studies is described in the relevant chapters of this thesis (i.e., Chapter 6 for Production Study 1: *Comparing lexical and surface word-initial geminates*, Chapter 8 for Production Study 2: *Comparing word-initial and word-medial geminates* and Chapter 9 for Production Study 3: *Comparing word-final and word-medial geminates*).

The target words were chosen from *ġabra*[46], an open lexicon for Maltese (Camilleri 2013), the *MLRS* corpus[47] (Gatt and Ceplo 2013) and Aquilina's (2001) *Maltese English Dictionary.*

A number of fillers were added to each list to serve as distractor items for the participants. For Production Study 1, filler items consisted of minimal pairs such as *rima* /rɪmɐ/ 'rhyme' and *prima* /prɪmɐ/ 'first'. For Production Study 2 (comparing word-initial to word-medial geminates) and Production Study 3 (comparing word-final to word-medial geminates), a number of filler items had words with segments which were not under investigation in the production study, such as /b, d/ (e.g. /ˈbɪdɛl/ *bidel* 'to change' vs /ˈbɪddɛl/ *biddel* 'to be changed'). Another set of filler items consisted of pairs of words, which either

[46] Ġabra website: http://mlrs.research.um.edu.mt/resources/gabra/
[47] MLRS website: http://mlrs.research.um.edu.mt/

have a glottal stop or a vowel in word-initial position such as (e.g. /ɐtt/ *att* 'act' and /ʔɐtt/ q*att* 'never').

All recordings for the production studies were carried out in a sound-attenuated room. A Rode NT1-A microphone was used for recordings. Recordings were carried out at a sample rate of 44.1 kHz at 16 bits per sample.

4.2 The language of participants

Due to the linguistic variety that dominates the Maltese islands (see Vella 2012 for a review), dominant speakers of Maltese were only considered for the production studies. Malta, despite being geographically small, presents itself with an interesting linguistic landscape. This is because Maltese and English are the two official languages in Malta, and besides those languages, there are numerous dialects. It is argued (e.g., Borg 1988, Vella 2012 and references therein) that Maltese speakers vary along a continuum with respect to their language dominance. Selecting dominant speakers of Standard Maltese was crucial in order to capture how geminates are produced in that variety of Maltese. Dominance in dialectal varieties and in English has shown to influence a speaker's choice of segmental material (e.g. comparisons of vowel quality in Standard Maltese and dialects of Maltese: Aquilina and Isserlin 1981; Chetcuti 2005; Said 2007; and Grech 2015 for Maltese English). Therefore, the main idea was to collect data from speakers with similar linguistic backgrounds: i.e., where Standard Maltese was used much more than any of their other languages, if they had any other languages.

The participants' dominance in Maltese was determined in the first instance by the experimenter who is a native speaker of Maltese. Furthermore, before doing the recordings all participants filled in a linguistic background questionnaire (based on Twist 2006[48]). The questionnaire data included information on the participants' choice of language to use at home and with their friends, a choice for Maltese in these domains being more likely to indicate dominance in Maltese.

[48] The linguistic background questionnaire can be found in Appendix 1.

4.3 Measurements

In Production Study 1 (lexical and surface word-initial geminates), the following acoustic parameters were measured:

- Closure duration for stops
- Constriction duration for fricatives
- Inserted vowel duration
- Glottal stop insertion
- Interconsonantal interval
- VOT for stops
- Tonic vowel

In Production Study 2 (comparing word-initial and word-medial geminates), the following acoustic parameters were measured:

- Closure duration for stops
- Constriction duration for fricatives and sonorants
- Closure duration for the stop portion and constriction duration for the frication portion for affricates
- Inserted vowel duration (only for word-initial geminates)
- Glottal stop insertion (only for word-initial geminates)
- VOT for stops

In Production Study 3 (comparing word-final and word-medial geminates), the following acoustic parameters were measured:

- Full consonant duration for stops
- Constriction duration for fricatives, affricates and sonorants
- Tonic vowel
- Rhyme duration (i.e., duration of tonic vowel + duration of following consonant)
- The duration of the vowel after word-medial singletons/geminates.

4.4 Annotation

Acoustic segmentation was carried out manually using Praat (Boersma & Weenik 2015). The criteria for the annotation carried out in the three production studies are divided into three parts. In subsections §§4.4.1-4.4.7, I provide the criteria employed for the annotation of closure duration in oral and nasal stops, frication duration in the fricatives /s ʃ f/, the duration of the affricate /tʃ/, the duration of the liquid /l/ and the duration of /r/. Since geminates are defined by longer durations, it was important to identify how the different segments were annotated.

In §4.4.8 and §4.4.9, I provide the criteria for the annotation of the vowel before and the vowel after geminates and singletons respectively. In §4.4.10 and §4.4.11, I provide the criteria for the annotation of the vocalic insertion and glottal stop insertion before word-initial geminates respectively. Furthermore, in §4.4.12, I provide the criteria for the annotation of an acoustic portion measuring these two insertions. The latter will be discussed in more detail in Chapter 5 §5.5.2.

4.4.1 Stops in word-initial and word-medial position

In the case of the voiced (/d/) and voiceless (/p t k/) stops, the constriction duration and voice onset time (VOT) were measured in word-initial and word-medial position. The constriction duration for the stops, singletons as well as geminates, was measured from the start of the closure to the release. VOT in both voiceless and voiced segments was measured as the interval between the release of the stop and the onset of the following vowel. Figure 4.1a shows the segmentation of closure duration and VOT for the singleton consonant /t/ and Figure 4.1b shows the segmentation closure duration and VOT for the geminate consonant /tt/.

Figure 4.1a: Segmentation of closure duration and VOT in the singleton /t/ in *tallab* 'hyp.'[49]

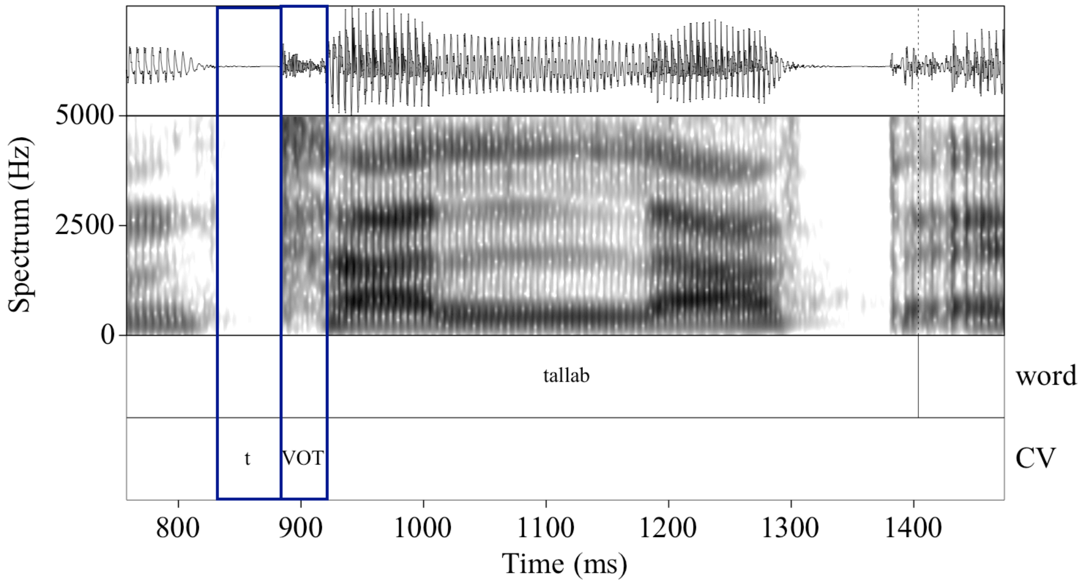
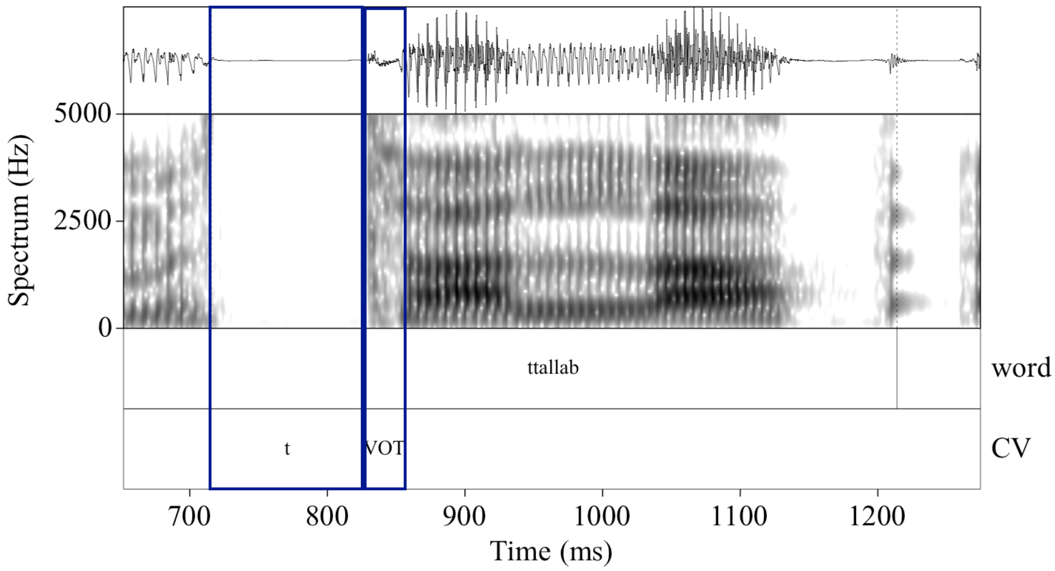


Figure 4.1b: Segmentation of closure duration and VOT in the geminate /tt/ in *ttallab* 'to beg'



In the case of the voiced stop /d/, the voice bar is usually present for most (as in the singleton in Figure 4.2a) or part (as in the geminate in Figure 4.2b) of the duration of the constriction. Nonetheless, the presence of a voice bar was not

[49] A faint dashed line in the 'word' tier in the following figures indicates a word boundary marker, this might precede or follow the target measurements.

taken to be a reliable indicator of the exact end of the stop. Figure 4.2a shows the segmentation of closure duration and VOT for the voiced singleton stop /d/ and Figure 4.2b shows the segmentation of closure duration and VOT for the voiced geminate stop /dd/.

Figure 4.2a: Segmentation of closure duration and VOT in the singleton /d/ in *daħħal* 'to insert'

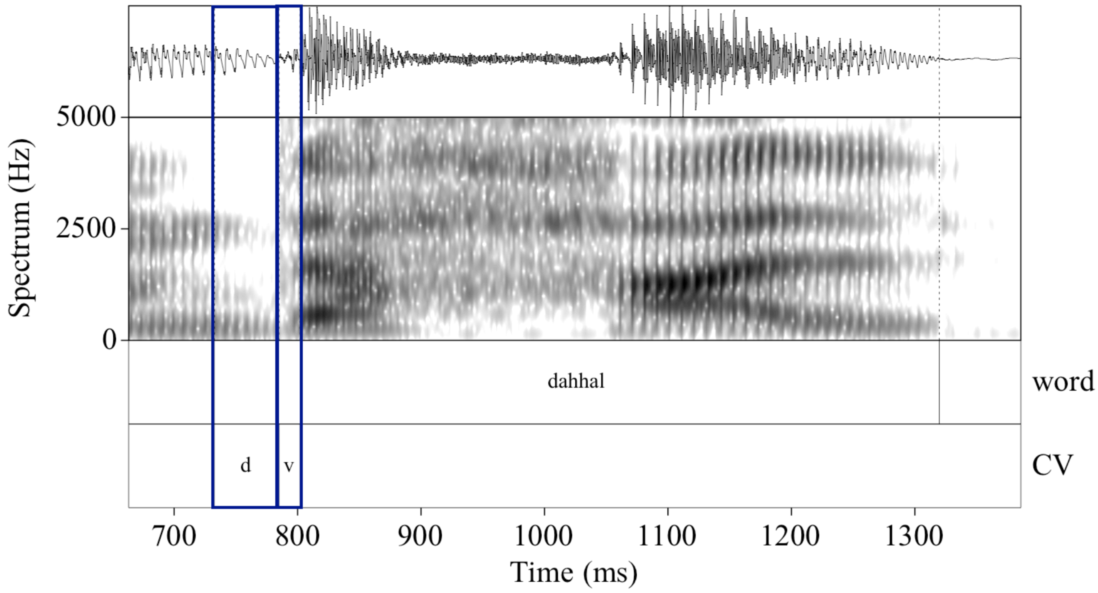
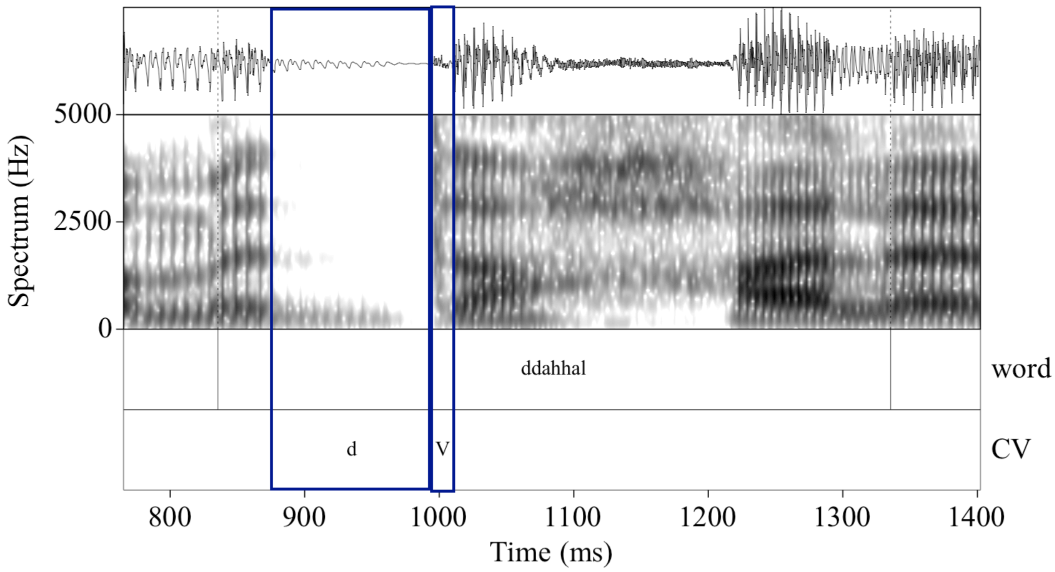


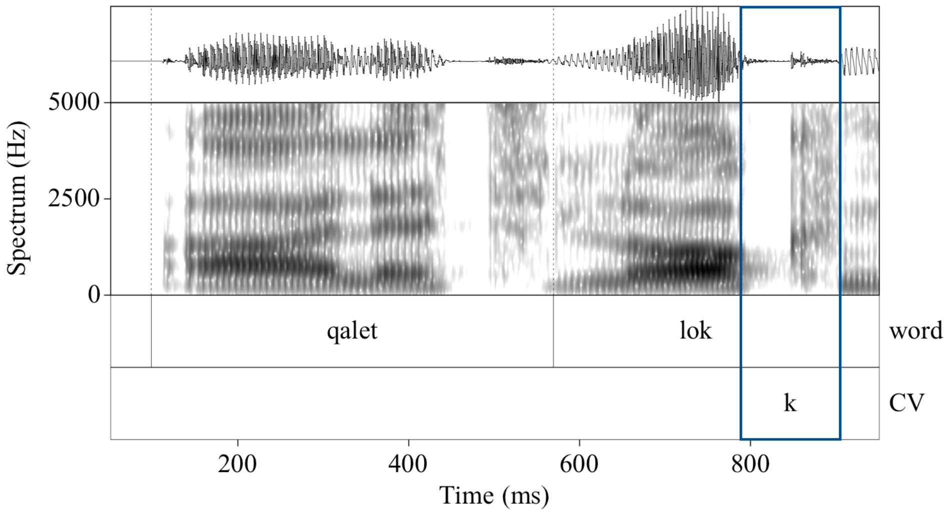
Figure 4.2b: Segmentation of closure duration and VOT in the geminate /dd/ in *ddaħħal* 'to be entered'



4.4.2 Stops in word-final position

In word-final position, there was a lot of across- and within-speaker variation. This is because speakers sometimes released the stops in word-final position fully, whereas they did not do this at other times. For instance, Figure 4.3 below shows a fully released word-final singleton /k/. Due to this high variability, for word-final stops, I report the full consonant duration including the VOT when present.

Figure 4.3: Word-final singleton /k/: fully released in *lok* ‘place’



4.4.3 Fricatives

The fricatives (/f, s, ʃ, z/) were measured from the start of the aperiodic noise to the start of the following vowel (as in Figure 4.4a for singleton /s/ and Figure 4.4b for geminate /ss/).

Figure 4.4a: Segmentation for singleton /s/ in *sabbar* ‘to comfort’

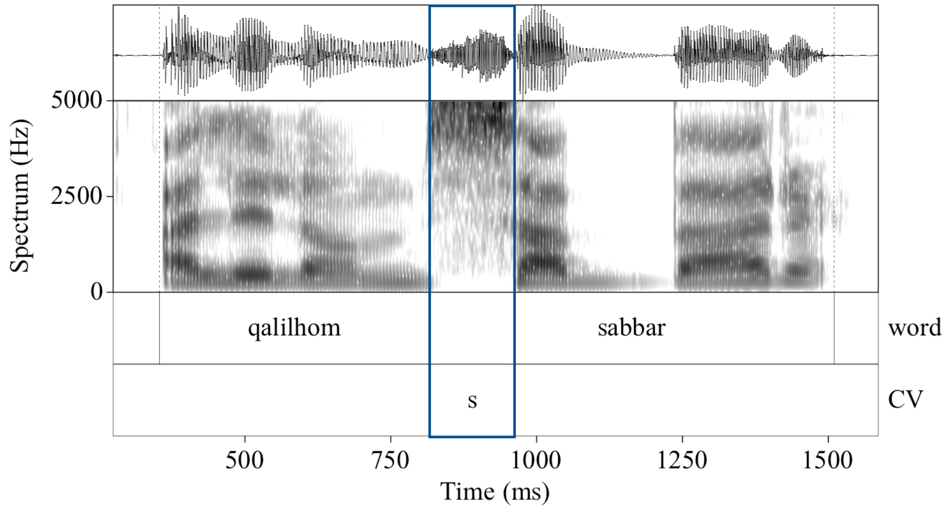
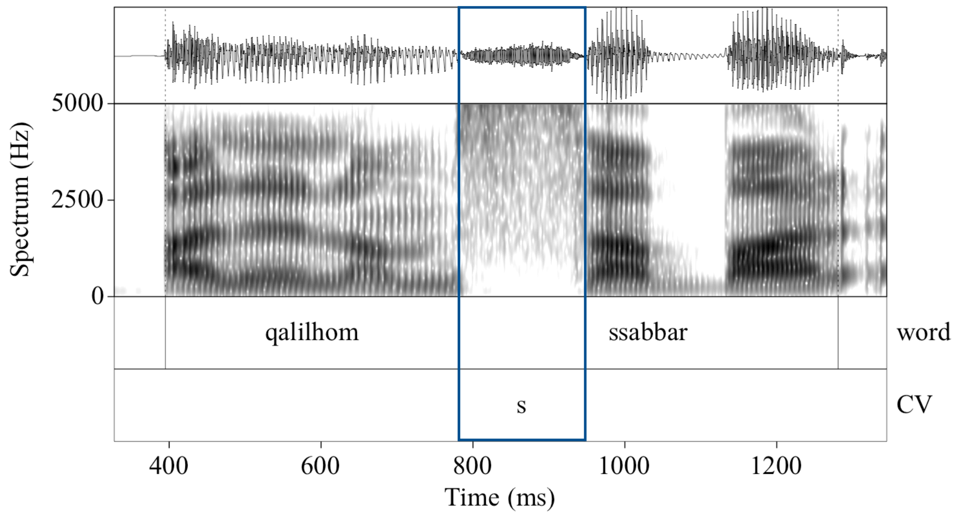


Figure 4.4b: Segmentation for geminate /ss/ in *ssabbar* ‘to be consoled’



4.4.4 Affricates

The consonant duration of the affricate /tʃ/ was measured from the start of the closure of the stop element in the affricate to the start of the following vowel as shown in Figure 4.5a for singletons and Figure 4.5b for geminates. The consonant duration of the affricate included the closure duration for the stop element as well as the aperiodic noise for the fricative element.

Figure 4.5a: Segmentation for singleton /tʃ/ in *ċuċata* ‘a stupidity’

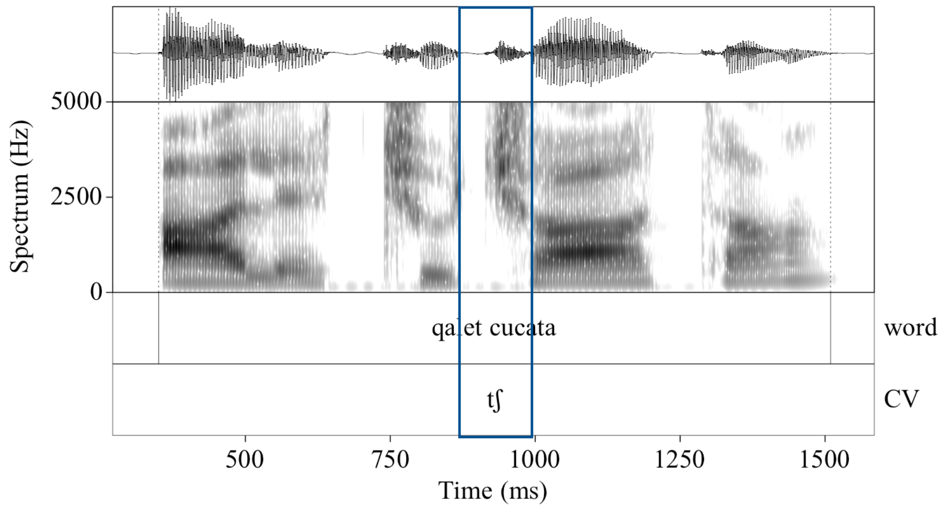
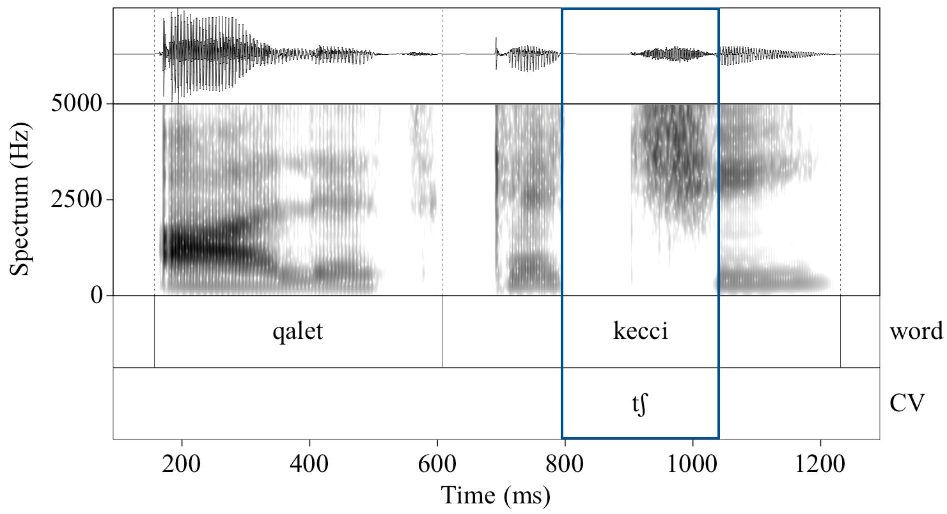
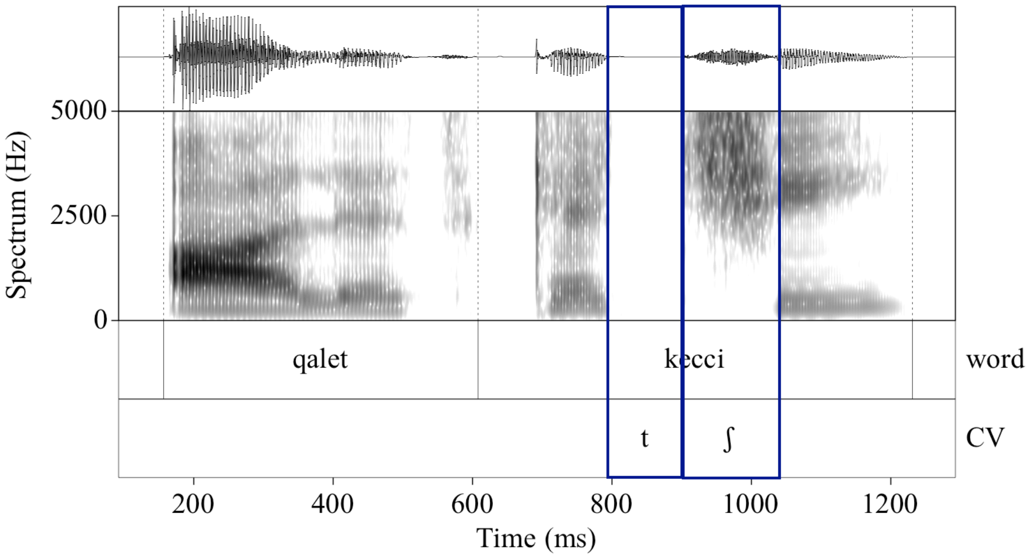


Figure 4.5b: Segmentation of geminate /tʃtʃ/ in *keċċi* ‘you (sing.) send someone away (imp.)’



In Production Study 2, the stop portion and the fricative portion of the affricate were investigated separately. These were segmented as shown in Figure 4.5c. The stop portion consisted of the closure duration and the frication portion consisted of the aperiodic noise for fricatives.

Figure 4.5c: Segmentation of the stop and fricative portions in the geminate affricate /tʃ/



4.4.5 Liquid /l/

Left boundaries for the liquid /l/ were placed when a drop in intensity in the waveform, as well as in formant frequency in the spectrogram, was visible following the preceding vowel, as in Figure 4.6. Right boundaries were placed when intensity and formant frequency increased again to signal the following vowel.

Figure 4.6a: Segmentation of singleton /l/ in *ħaleb* 'he milked'

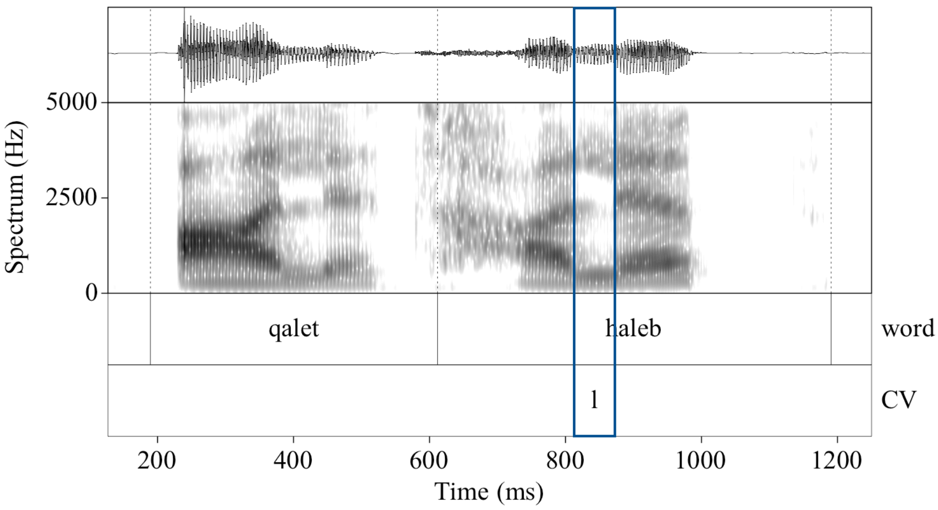
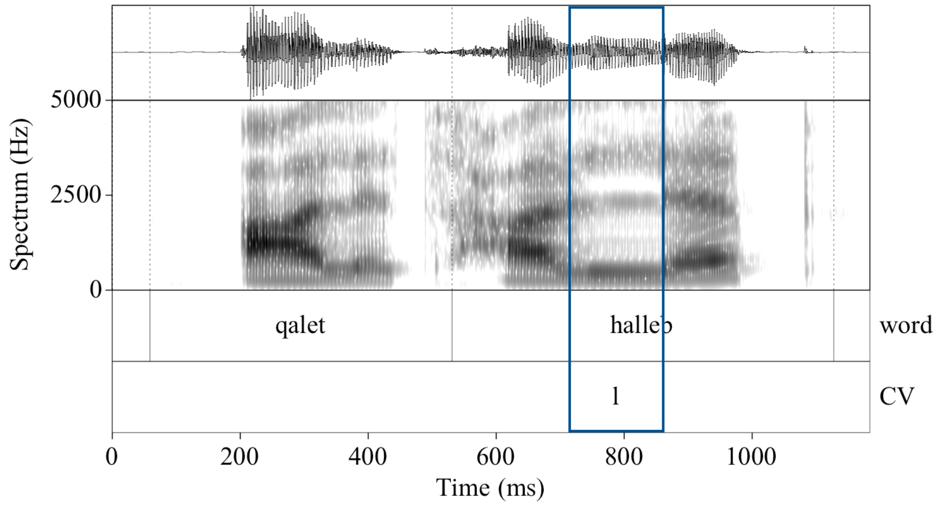


Figure 4.6b: Segmentation of geminate /ll/ in *ħalleb* ‘he milked the cow’



4.4.6 /r/

It is important to point out that the realization of /r/ in Maltese is variable. Borg and Azzopardi-Alexander (1997:302) argue that /r/ can be realized as either an approximant [ɹ] or as a tap [ɾ]. However, what determines this choice is unclear. For this reason, I transcribed all tokens including the segment /r/ as /r/. The segment /r/ was identified by a lowering of the first formant and a ‘gap’ between the first and second formants, as in Figure 4.7.

Figure 4.7a: Segmentation of singleton /r/ in *ħarab* ‘to run away’

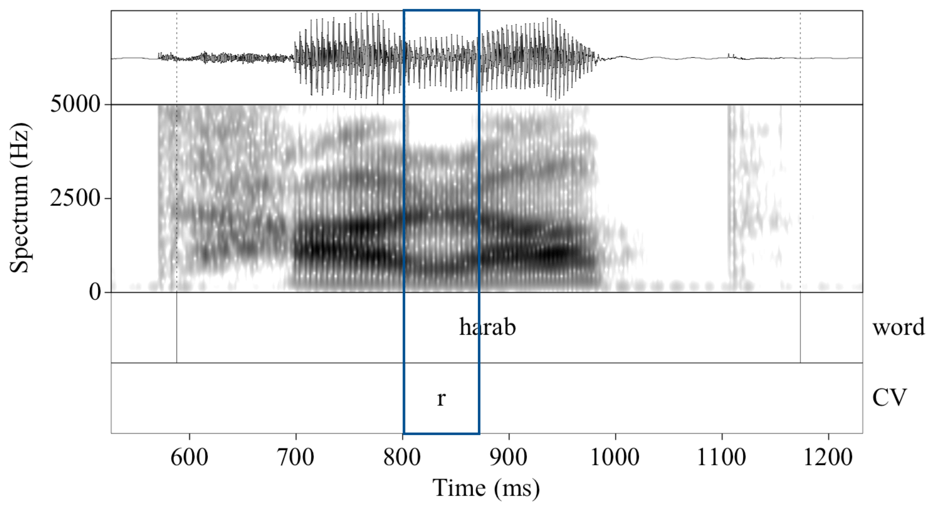
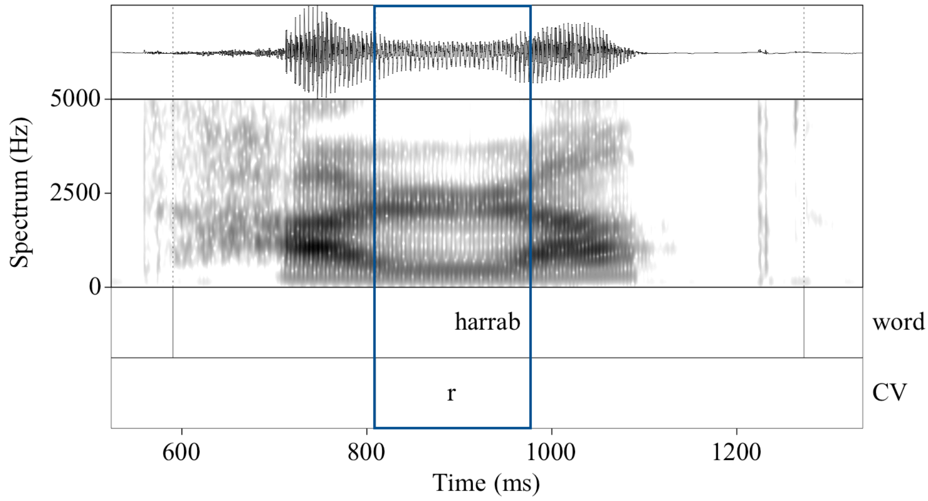


Figure 4.7b: Segmentation of geminate /rr/ in *ħarrab* 'to make s.o. run away'



4.4.7 Nasals

Left boundaries for nasals were placed where there was a marked drop in intensity relative to adjacent segments, with right boundaries being placed at the point where of a renewed increase in formant intensity (as in Figure 4.8).

Figure 4.8a: Segmentation for singleton /m/ in *lemaħ* 'to perceive'

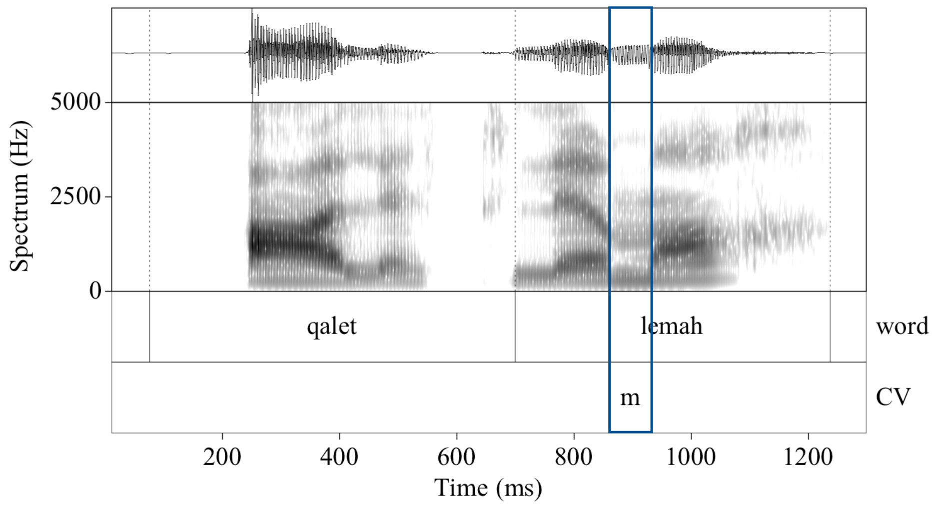
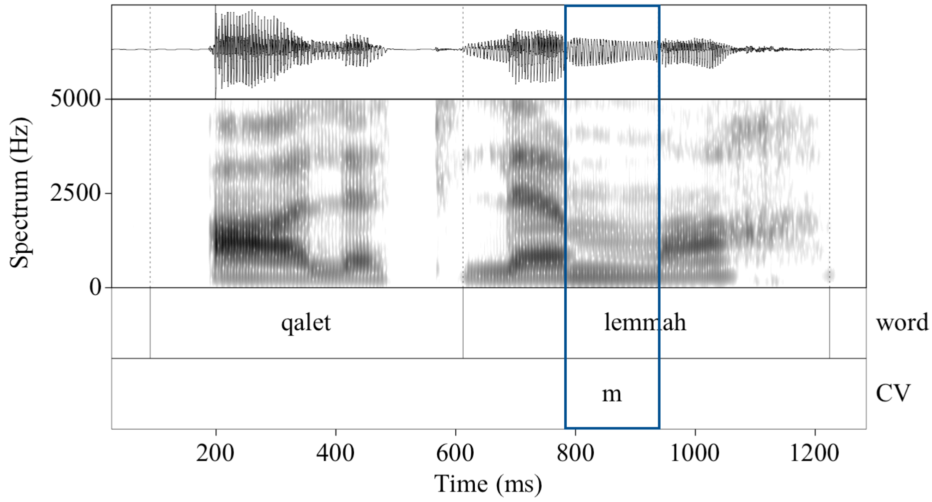


Figure 4.8b: Segmentation for geminate /mm/ in *lemmaħ* ‘to make s.o. aware of s.th’



One shortcoming in the design of Production Study 3 was that target words ending in word-final /m, n/ were followed by an initial /m/ in the word ‘mitt’, as in (5). In such cases, it was impossible to identify the end of the final /m, n/ and the start of the following /m/. As a result, these tokens were discarded.

(1) Qallek	o**mm**	**m**itt darba
He told you	mother	a hundred times

4.4.8 The tonic vowel

The tonic vowel is defined as the vowel in the stressed syllable after the target consonant in word-initial position or the vowel in the stressed syllable before the target consonant in word-medial position (c.f. Zimmerman & Sapan 1958). Figure 4.9a shows the tonic vowel, /ɐ/, after a word-initial geminate and Figure 4.9b shows the tonic vowel, /ɐ/, before a word-medial geminate.

Figure 4.9a: Segmentation of the tonic vowel /ɐ/ after the word-initial geminate /ss/ in *ssabbar* 'to be consoled'

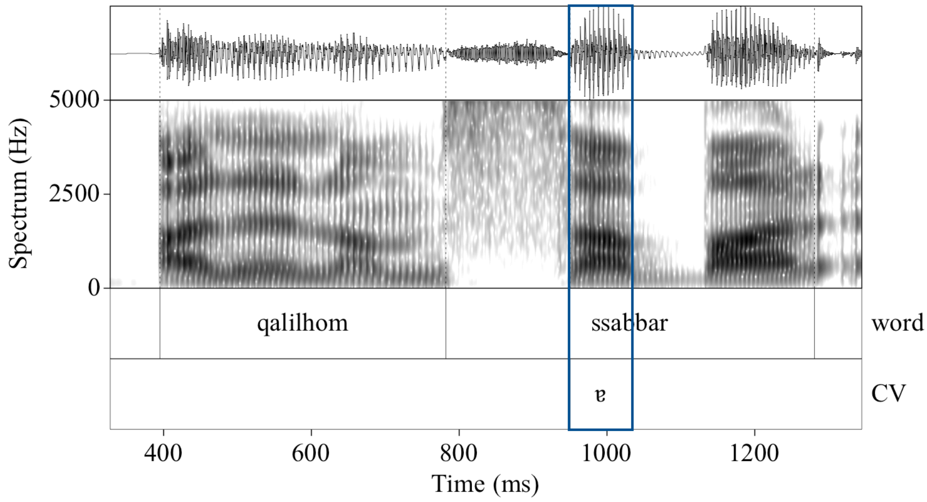
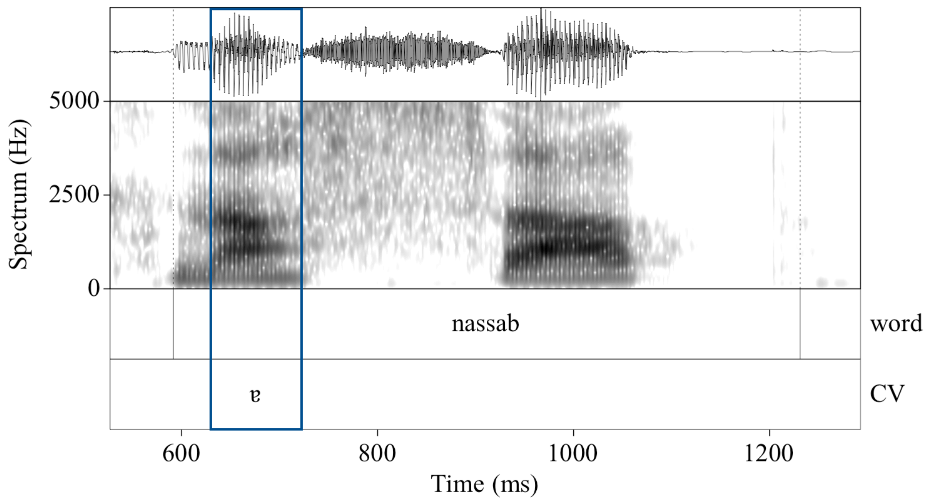


Figure 4.9b: Segmentation of the tonic vowel /ɐ/ before the word-medial geminate /ss/ in *nassab* 'to trap'



4.4.9 The vowel after word-medial geminates/singletons

The (unstressed) vowel after word-medial geminates was measured after the constriction duration of the target consonant until the start of the following consonant as in Figure 4.10a after singletons and Figure 4.10b after geminates.

Figure 4.10a: Segmentation of the vowel /ɐ/ after the word-medial singleton /t/ in *batan* 'to conceive an idea'

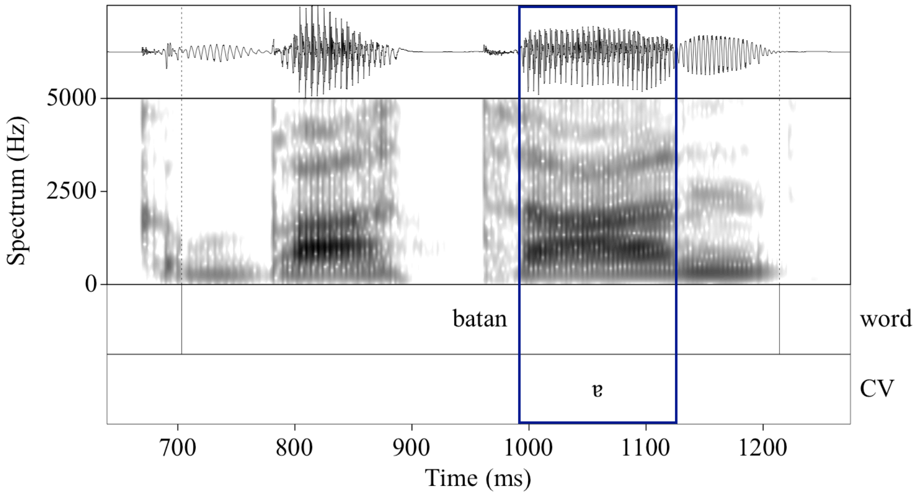
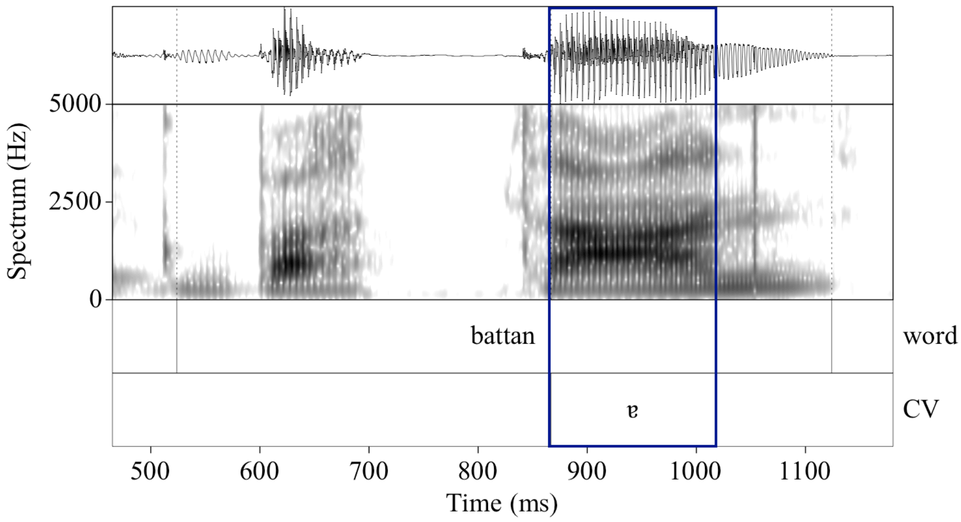


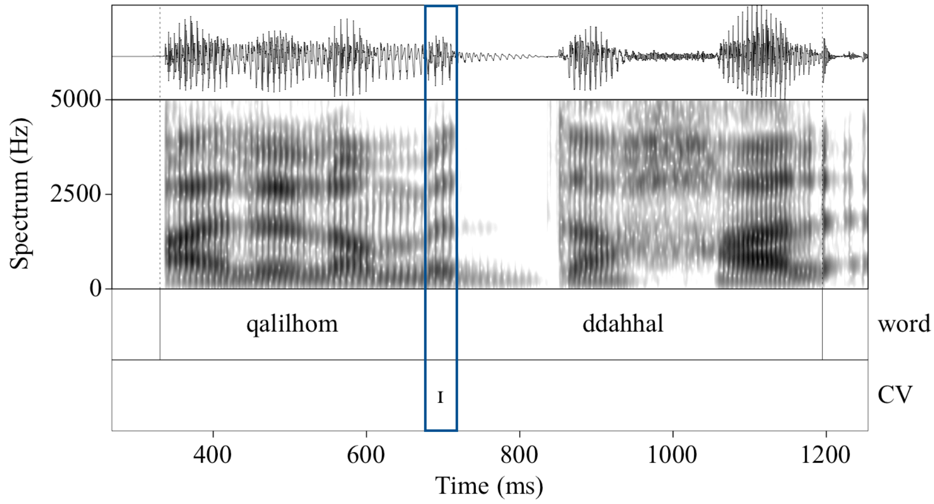
Figure 4.10b: Segmentation of the vowel /ɐ/ after the word-medial geminate /tt/ in *battan* 'to be conceived'



4.4.10 Vocalic insertion

The vocalic insertion, [ɪ], which was expected to occur before word-initial geminates (cf. Chapter 3 §3.6.3.4), was measured between the onset and offset of vowel related formants (Figure 4.11).

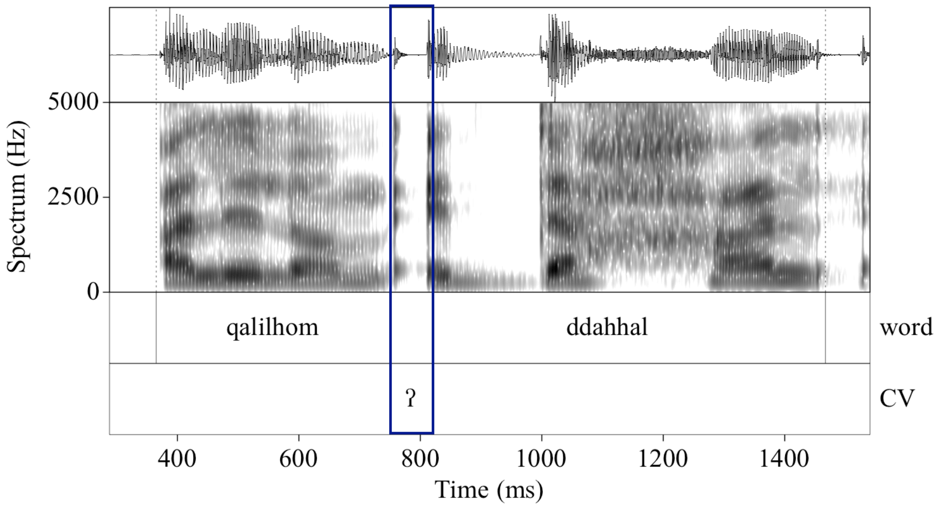
Figure 4.11: Segmentation of the vocalic insertion [ɪ] before word-initial geminate /dd/



4.4.11 Glottal stop insertion

When glottal stop insertions, i.e. [ʔ], were present, it was measured from the start of the glottal pulse, which was followed by a closure phase and another glottal pulse until the start of inserted vowel as in Figure 4.12. Note that a glottal stop insertion was always followed by the vocalic insertion [ɪ] and happened only before word-initial geminates (c.f. Chapter 5 and 6 for these results). The segment preceding the glottal stop insertion can either be: the nasal /m/ in the preceding word 'Qalilhom'; the vowel /ɐ/ in the preceding word 'Qalilha'; the voiceless velar stop /k/ in the preceding word 'Qallek'; or the latter's substitute, the voiceless alveolar stop /t/ in the preceding word 'Qalet'.

Figure 4.12: Glottal stop insertion [ʔ] before the vowel [ɪ] before the word-initial geminate /dd/



4.4.12 Inter-consonantal interval

The inter-consonantal interval captures any adjustments between the final vowel [ɐ] in ‘Qalilha’ and the start of the word-initial geminates. These adjustments span across a word-boundary. The discussion related to the inter-consonantal interval is in §5.5.2. In terms of annotation, the inter-consonantal interval was measured from the offset of the liquid /l/ in ‘Qalilha’ until the start of the geminate consonant in the target word. The segments, which made up the inter-consonantal interval varied among speakers. For some speakers, the inter-consonantal interval was made up of vowel material, i.e. the final vowel [ɐ] of ‘Qalilha’ (c.f. Figure 4.13a); or else a sequence of two vowel segments, i.e. the final vowel [ɐ] of ‘Qalilha’ and the vocalic insertion ([ɪ]) before word-initial geminates (c.f. Figure 4.13b)

Figure 4.13a: Segmentation of the inter-consonantal interval (1): the final vowel [ɐ] of 'Qalilha'

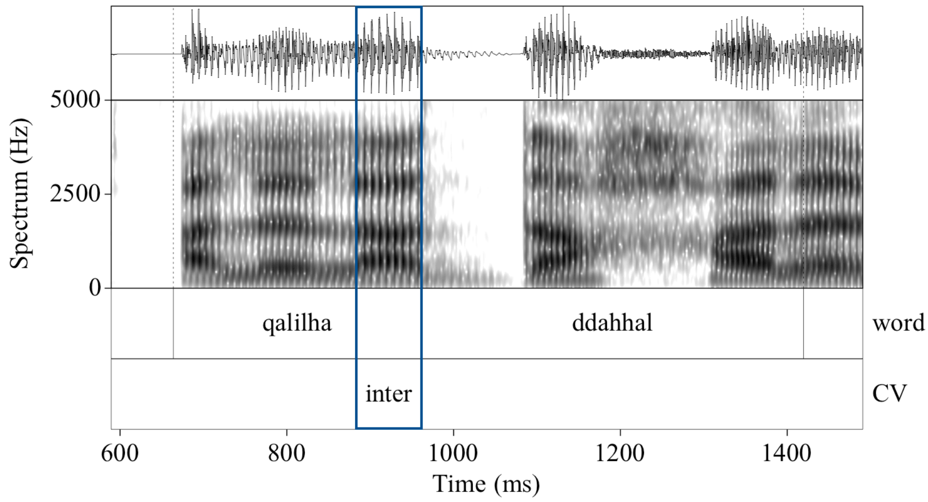
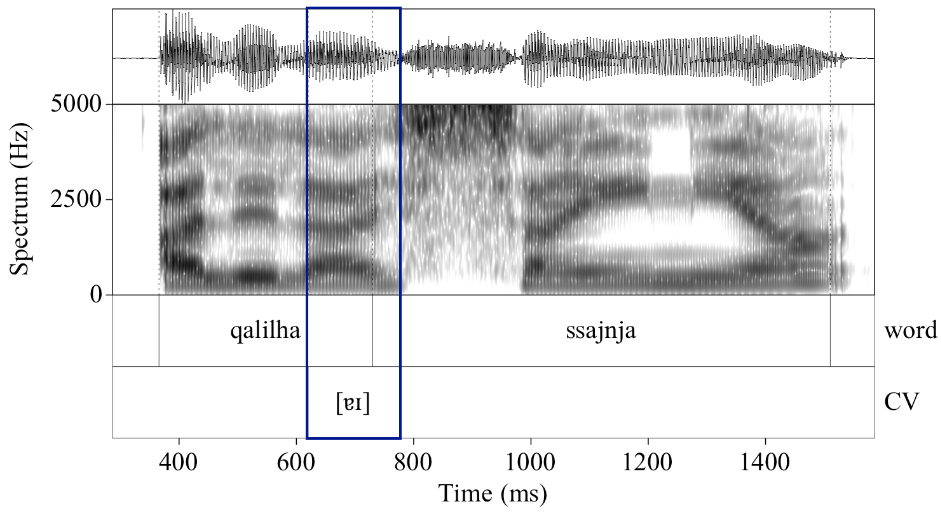
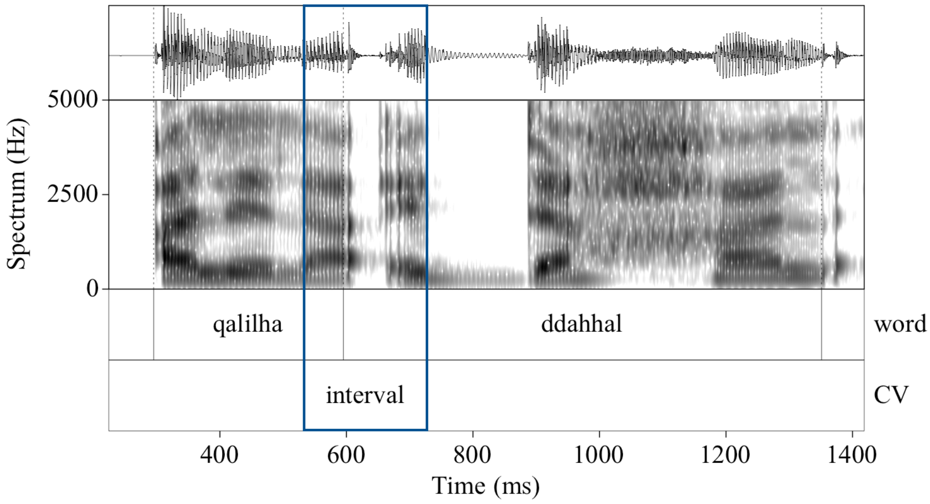


Figure 4.13b: Segmentation of the inter-consonantal interval (2): the final vowel [ɐ] of 'Qalilha' and the vocalic insertion ([ɪ]) before word-initial geminates



For some other speakers, the inter-consonantal interval was made up of the final vowel [ɐ] of 'Qalilha', a glottal stop insertion [ʔ] and the vocalic insertion before word-initial geminates. In Figure 4.13c, the inter-consonantal interval includes the glottal stop insertion and the vocalic insertion, which occur between the /l/ of 'qalilha' and before the start of the geminate consonant (in this case /dd/).

Figure 4.13c: Segmentation of the inter-consonantal interval (3): the final vowel [ɐ] of 'Qalilha', a glottal stop insertion [ʔ] and the vocalic insertion before word-initial geminates



4.5 Summary

In this chapter, I highlighted the measurements carried out in the following production studies in Chapter 5, 6, and 7. In the following chapter, lexical and surface word-initial geminates are compared. As a result of their comparison, the primary and secondary correlates of word-initial gemination in Maltese will be identified.

Chapter 5: Production Study 1- Lexical and surface word-initial geminates in Maltese

5.1 Introduction

In Chapter 3 §3.1, empirical studies on word-initial geminates in Kelantan Malay, Pattani Malay, Tashlhiyt Berber, Swiss German and Cypriot Greek were described. This overview has shed light on the fact that the primary correlate of word-initial geminates is constriction duration. However, in word-initial position, this correlate might not be available on the acoustic surface in the case of voiceless stops. In such a case, as Muller (2001) clearly illustrated, secondary cues are used in order to maintain the quantity contrast. Specifically, in Cypriot Greek, there were significant differences in voice onset time (VOT) between geminates and singletons. On the other hand, Swiss German, which like Cypriot Greek has geminate voiceless stops, does not use the secondary correlate of VOT to distinguish geminates from singletons. This suggests that across languages secondary correlates are less homogenous and are specific to the language under investigation.

The aim of Production Study 1 is to investigate the production of lexical and surface word-initial geminates in Maltese in morphological different contexts. As shown in Table 5.1 below, three geminate types were considered (all of which were discussed in Chapter 3 §3.6.3). Three morphological geminates types arise in Maltese which are described as follows: *lexical geminates of Semitic origin* ***(LGS)***, *lexical geminates of non-Semitic origin* ***(LGnS)***, and *assimilated geminates* ***(AG)***. These three geminate types were compared to a singleton counterpart. In this production study, durational correlates of gemination were considered. Based on the literature, presented in Chapter 3, constriction duration (for fricatives and closure duration for stops) was taken as the primary correlate and it was measured for both geminates and singletons. As secondary correlates, the duration of the tonic vowel was measured and, for stops, voice onset time (VOT) was also measured.

Table 5.1: Consonant Types for Production Study 1

	Type	**Example**
GEMINATES	Lexical geminate of Semitic origin (LGS)	/**dd**ɐhhɐl/ *ddaħħal* ‘to be entered’
	Lexical geminate of non-Semitic origin (LGnS)	/**dd**ɐjljɐ/ *ddajlja* ‘to dial’
	Assimilated geminate (AG)	/**d-d**ɐhlɐ/ *id-daħla* ‘the entrance’
SINGLETON	Singleton (S)	/**d**ɐhhɐl/ *daħħal* ‘to insert’

This chapter is structured as follows. In §5.2 I address specific issues of the methodology related to Production Study 1. In §5.3 I give the results for constriction duration from the production study, where I discuss constriction duration for stops and closure duration for fricatives separately. In this section I also compare lexical geminates to assimilated geminates (in §5.3.5). In §5.4 I present count data and durational data for the vocalic insertion before word-initial geminates. In §5.5 I outline what happens after the final vowel /ɐ/ in the preceding word ‘qalilha’. In §5.6 I discuss the two secondary correlates under investigation, namely, VOT and the duration of the tonic vowel. The results are discussed and summarized in §5.7 and the chapter concludes in §5.8.

5.2 Methodology

In this section, I describe the methodology related this production study, comparing lexical and surface word-initial geminates. In particular, I present the speech material (§5.2.1), information about the participants (§5.2.2) and the hypotheses in (§5.2.3).

5.2.1 Speech material

The speech material analysed in Production Study 1 is listed in Table 5.2. Target words were selected to allow for comparisons between word-initial singletons and geminates. Singletons were selected using items with **C**VGVC structure. The same root consonant sequence was used for singletons (S), lexical geminates of Semitic origin (LGS) and surface geminates (AG). To give one example, for the target segment /d/, the root √dħl[50] was used to create target words for singletons (e.g. /**d**ɐhhɐl/ *daħħal* 'to insert'), LGS (e.g., /**dd**ɐhhɐl/ *ddaħħal* 'to be entered') and AG (e.g., /ɪ**d-d**ɐhlɐ/ *id-daħla* 'the entrance').

All target words contained a coronal obstruent (/t, d, s, ʃ, z/) in word-initial position. Coronal obstruents were chosen as lexical geminates of Semitic origin (LGS) and assimilated geminates (AG) only allow for word-initial gemination in this manner of articulation (cf. Chapter 3 §3.6.3). Furthermore, all target words were controlled for stress, such that the penultimate syllable was stressed.

Two carrier phrases were used, where the word preceding the target differed with regards to its last segment. The frame of the carrier consisted of the preceding word, followed by the target word and the rest of the phrase, as in (1) and (2).

(1) **Qalilhom**	___________	erba' darbiet.
PRECEDING WORD	**TARGET WORD**	**REST OF THE PHRASE**
'he told them	_____________	four times'

(2) **Qalilha**	___________	erba' darbiet.
PRECEDING WORD	**TARGET WORD**	**REST OF THE PHRASE**
'he told her	_____________	four times'

The carrier phrase either consisted of a consonant-final (e.g. [ʔɐlɪlɔ**m**] *qalilhom* 'he told them') preceding word, where the consonant-final segment in the

[50] The root √dħl is realised as [dhl].

preceding word is /m/; or a vowel-final (e.g. [ʔɐlɪl**ɐ̲**] *qalilha*[51] 'he told her') preceding word, where the vowel-final segment in the preceding word is /ɐ/. Two carrier phrases with differing final segments were chosen was to investigate the presence or absence of a vocalic insertion before word-initial geminates as cited in the literature (cf. Chapter 3 §3.6.3.4; and more on this in Chapter 5 §5.4).

Table 5.2: Production Study 1: Speech Material

Target Segment	**Singleton**	**Geminates**		
		Lexical Non-Semitic	***Lexical Semitic***	***Assimilated***
/d/	/ˈ**d̲**ɐħħɐl/ *d̲aħħal* 'to insert'	/**d̲ˈd̲**ɐjljɐ/ *d̲d̲ajlja* 'to dial'	/**d̲ˈd̲**ɐħħɐl/ *d̲d̲aħħal* 'to be entered'	/ɪ**d̲ˈd̲**ɐħlɐ/ *id̲-d̲aħla* 'the entrance'
/t/	/ˈ**t̲**ɐllɐb/ *t̲allab* hyp.	/**t̲ˈt̲**ɐjpjɐ/ *t̲t̲ajpja* 'to type'	/**t̲ˈt̲**ɐllɐb/ *t̲t̲allab* 'to be begged'	/ɪ**t̲ˈt̲**ɐlbɐ/ *it̲-t̲alba* 'the prayer'
/s/	/ˈ**s̲**ɐbbɐr/ *s̲abbar* 'to comfort'	/**s̲ˈs̲**ɐjn.jɐ/ *s̲s̲ajnja* 'to sign'	/**s̲ˈs̲**ɐbbɐr/ *s̲s̲abbar* 'to be consoled'	/ɪ**s̲ˈs̲**ɐbɐr/ *is̲-s̲abar* 'the patience'
/ʃ/	/ˈ**ʃ̲**ɐħħɐm/ *x̲aħħam* 'to fatten'	/**ʃ̲ʃ̲**ɐmplɐ/ *x̲x̲ampla* 'to relax'	/**ʃ̲ʃ̲**ɐħħɐm/ *x̲x̲aħħam* 'to be fattened'	/ɪ**ʃ̲ʃ̲**ɐħɐm/ *ix̲-x̲aħam* 'the fat'
/z/	/ˈ**z̲**ɐrrɐt/ *ż̲arrat* 'to fray'	/**z̲ˈz̲**ʊmja/ *ż̲ż̲umja* 'to zoom'	/**z̲ˈz̲**ɐrrɐt/ *ż̲ż̲arrat* 'to be frayed'	/ɪ**z̲ˈz̲**ɐrdɐ/ *iż̲-ż̲arda* 'the loose threads'

In the study 20 target words were used (cf. Table 5.2), which were repeated 7 times in each of the 2 preceding contexts (i.e., 'qalilhom' or 'qalilha') (n = 280 per

[51] Note that the orthographic 'h' in *qalil<u>h</u>a* 'he told her' is a silent letter.

speaker). Fillers, which were unrelated to the target words, were placed in the same carrier phrases as the target words. The order of carrier phrases was pseudo-randomized once and this order was presented to all participants. The number of tokens per environmental condition (either following /m/ in 'qalilhom' or /ɐ/ in 'qalilha') was 1400; therefore, the overall total number of tokens was 2800. In the analysis of the results three fixed effects were considered: Consonant Type (i.e. singleton, lexical geminates of Semitic origin, lexical geminates of non-Semitic and assimilated geminates), Segment (i.e., /t d s ʃ z/) and Environment (i.e., the nasal /m/ in 'qalilhom' and the vowel /ɐ/ in 'qalilha').

5.2.2 Participants

Ten native speakers of Maltese (6 males, 4 females) took part in this study. The participants were between 18 and 29 years old (mean age = 23, median = 24). Most participants were following a post-graduate course at the University of Malta at the time of recording (except for the 18-year old participant, who was following a post-secondary course at another college). All participants took part voluntarily and were recruited via social media platforms. Dominant speakers of Standard Maltese speakers were recruited for the experiment.

5.2.3 Hypotheses

Geminates are expected to be longer than singletons and this is expected to be reflected in their consonant duration (closure duration for stops), which is considered as the primary correlate for gemination. Following the literature on the phonetic manifestation of lexical and surface geminates (i.e. Ridouane 2010 and Ladd and Scobbie 2003), no difference in consonant (or closure) duration is expected to be found between lexical and surface geminates in Maltese.

A vocalic insertion is expected to occur after the nasal consonant /m/ of the preceding word 'qalilhom' and before the word-initial geminate, following the claims of Azzopardi (1981), Mifsud (1995) Hoberman and Aronoff (2003). On the other hand, the literature does not predict a vocalic insertion between a preceding word ending in a vowel (such as the /ɐ/ in ‘qalilha’) and a target word with initial geminates. However, this is important for this study as it is investigated whether a vocalic insertion is also inserted when the preceding word ends in a vowel.

In terms of the secondary correlates to gemination, the literature has shown that these vary across languages. For instance, for word-initial geminates, VOT was considered as secondary correlate in Cypriot Greek (Muller 2001), Kelatan Malay (Hamzah et al. 2011), but not in Swiss German (Kraehenmann 2001). Furthermore, the results for VOT in medial geminates from Italian and (Lebanese) Arabic show that VOT does not serve as a correlate to gemination in either language (cf. Esposito and Di Benedetto 1999; Ham 2001, respectively). The duration of the tonic vowel was also measured as a secondary correlate.

5.3 Results: Constriction Duration

The constriction duration for fricatives and closure duration for stops are presented here. The results for constriction duration after ‘qalilhom’ and ‘qalilha’ are discussed separately. In §5.3.1, I present the constriction duration after the preceding word ‘qalilhom’ and in §5.3.2, I present the constriction duration after the preceding word ‘qalilha’. A summary of these results is given in §5.3.3. In §5.3.4, a statistical analysis in order to identify which fixed effects affect constriction duration is provided. This is followed by an examination of the constriction duration of lexical and surface geminates in §5.3.5. In §§5.3.6-5.3.8, I explore the singleton-to-geminate duration ratios in the two different conditions and then I look at the pooled results.

5.3.1 Constriction duration after the preceding word 'qalilhom'

In this section, I present the constriction duration[52] for the target segments after the preceding word *qalilhom* 'he told them'. As expected, all geminate types are longer than their singleton counterpart (cf. Table 5.3). In the case of geminate voiceless and voiced stops, lexical geminates of Semitic origin (LGS) have the longest closure duration out of the three geminate types. For fricatives, lexical geminates of non-Semitic origin (LGnS) had the longest constriction durations out of the three geminate types.

Table 5.3: Mean constriction duration and standard deviation of singletons and geminates (after the preceding word 'qalilhom')

Segment	**S**	**LGS**	**LGnS**	**AG**
/t/	57 (25)	128 (24)	114 (21)	115 (21)
/d/	40 (16)	125 (21)	111 (14)	116 (16)
/s/	121 (20)	171 (22)	172 (20)	161 (18)
/ʃ/	121 (22)	163 (18)	166 (22)	151 (21)
/z/	100 (22)	149 (18)	155 (20)	147 (23)
Pooled	88 (39)	147 (28)	143 (32)	138 (27)

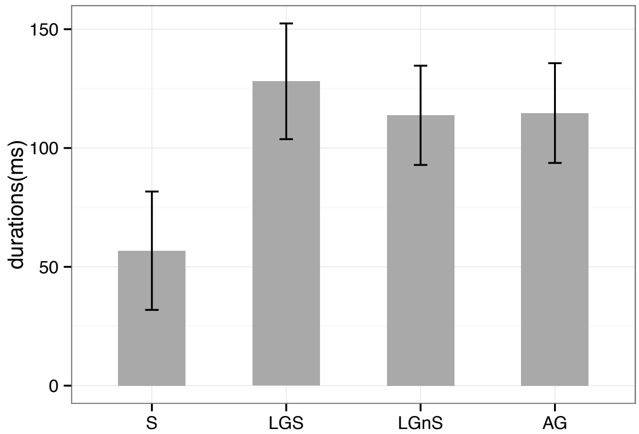
5.3.1.1 Stops

For the voiceless stop /t/ (cf. Figure 5.1), lexical geminates of Semitic origin (LGS) are 71ms longer than singletons (LGS: $\bar{x}$=128, sd=24; S: $\bar{x}$=57, sd=25), lexical geminates of non-Semitic origin (LGnS) are 57ms longer than singletons (LGnS: $\bar{x}$=114, sd=21; S: $\bar{x}$=57, sd=25) and assimilated geminates (AG) are 58ms longer than singletons (AG: $\bar{x}$=115, sd=21; S: $\bar{x}$=57, sd=25). The durational difference among the three geminate types was noticeably smaller than that between singletons and geminates. LGS were 14ms longer than LGnS (LGS: $\bar{x}$=128, sd=24; LGnS: $\bar{x}$=114, sd=21) and 13ms longer than AG (LGS: $\bar{x}$=128,

[52] Throughout all the four studies constriction duration was always measured in milliseconds.

sd=24; AG: x̄=115, sd=21), whereas AG were 1ms longer than LGnS (AG: x̄=115, sd=21; LGnS: x̄=114, sd=21).

Figure 5.1: Mean closure duration and error bars represent mean +/- 1 standard deviation for /t/ (after 'qalilhom')

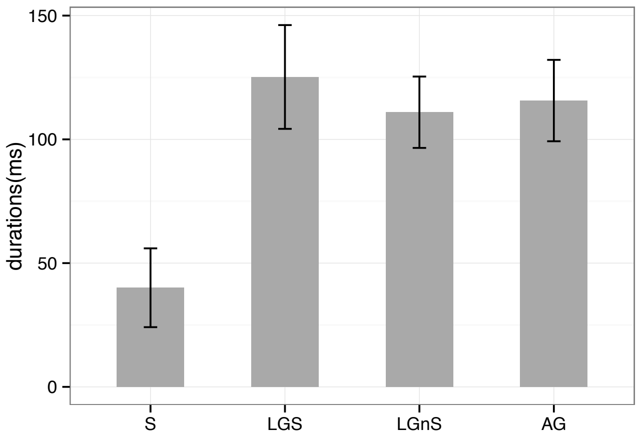


Legend
S – Singletons
LGS- Lexical Geminates Semitic
LGnS- Lexical Geminates non-Semitic
AG- Assimilated Geminates

For the voiced stop /d/ (cf. Figure 5.2), lexical Semitic geminates (LGS) were 85ms longer than singletons (LGS: x̄=125, sd=21; S: x̄=40, sd=16); lexical non-Semitic geminates (LGnS) were 71ms longer than singletons (LGnS: x̄=111, sd=14; S: x̄=40, sd=16) and assimilated geminates (AG) were 76ms longer than singletons (AG: x̄=116, sd=16; S: x̄=40, sd=16). The duration difference between the geminate types was noticeably smaller than that between singletons and geminates: lexical Semitic geminates (LGS) were 14ms longer than lexical non-Semitic geminates (LGnS) (LGS: x̄=125, sd=21; LGnS: x̄=111, sd=14) and 9ms longer than assimilated geminates (AG) (LGS: x̄=125, sd=21; AG: x̄=116, sd=16); assimilated geminates (AG) were 5ms longer than lexical non-Semitic geminates (LGnS) (AG: x̄=116, sd=16; LGnS: x̄=111, sd=14).

There was a discernable difference between voiceless and voiced singleton stops. The duration of the voiceless stop in singletons was 17ms longer than the duration of the voiced stops in singletons (Singleton /t/: S: x̄=57, sd=25; Singleton /d/: x̄=40, sd=16).

Figure 5.2: Mean closure duration and error bars represent mean +/- 1 standard deviation for /d/ (after 'qalilhom')



5.3.1.2 Fricatives

In the voiceless fricatives /s, ʃ/ and the voiced fricative /z/ (cf. Table 5.3), lexical geminates of non-Semitic origin (LGnS) had the longest duration, compared to the lexical geminates of Semitic origin (LGS) and assimilated geminates (AG).

For the voiceless fricative /s/ (cf. Figure 5.3), lexical geminates of Semitic origin (LGS) were 50ms longer than singletons (LGS: x̄=171, sd=22; S: x̄=121, sd=20), lexical geminates of non-Semitic origin (LGnS) were 51ms longer than singletons (LGnS: x̄=172, sd=20; S: x̄=121, sd=20) and assimilated geminates (AG) were 40ms longer than singletons (AG: x̄=161, sd=18; S: x̄=121, sd=20). The difference among the three geminate types was much smaller than that between singletons and geminates (as just reported for voiceless and voiced stops): lexical geminates of non-Semitic origin (LGnS) were 1ms longer than lexical geminates of Semitic origin (LGS) (LGnS: x̄=172, sd=20; LGS: x̄=171, sd=22), and 11ms longer than assimilated geminates (AG) (LGnS: x̄=172, sd=20; AG: x̄=161, sd=18). Lexical geminates of Semitic origin (LGS) were 10ms longer than assimilated geminates (AG) (LGS: x̄=171, sd=22; AG: x̄=161, sd=18).

Figure 5.3: Mean constriction duration and error bars represent mean +/- 1 standard deviation for /s/ (after 'qalilhom')

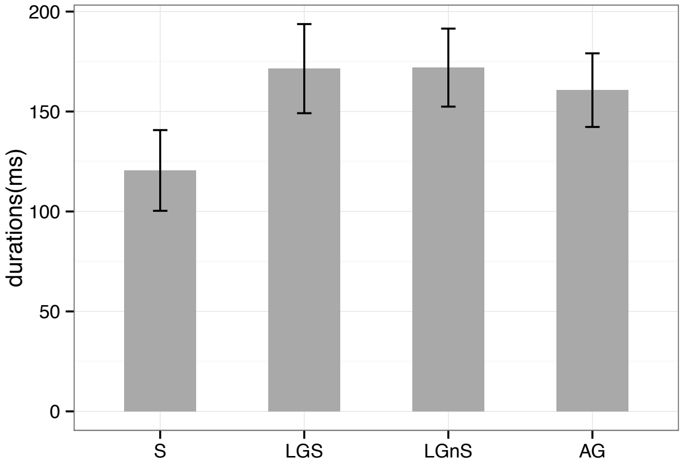


Figure 5.4 below shows the mean durations and standard deviations for singletons and the three geminate types for the voiceless fricative /ʃ/. Lexical geminates of non-Semitic origin (LGnS) had the longest mean duration (LGnS: $\bar{x}$=166, sd=22). LGnS were 45ms longer than singletons (LGnS: $\bar{x}$=166, sd=22; S: $\bar{x}$=121, sd=22). Lexical geminates of Semitic origin (LGS) were 42ms longer than singletons (LGS: $\bar{x}$=163, sd=18; S: $\bar{x}$=121, sd=22). Assimilated geminates were 30ms longer than singletons (AG: $\bar{x}$=151, sd=21; S: $\bar{x}$=121, sd=22). The difference among the different geminate types was noticeably smaller than that between singleton and geminates. Lexical geminates of non-Semitic origin (LGnS) were 3ms longer than lexical geminates of Semitic origin (LGnS: $\bar{x}$=166, sd=22; LGS: $\bar{x}$=163, sd=18) and 15ms longer than assimilated geminates (LGnS: $\bar{x}$=166, sd=22; AG: $\bar{x}$=151, sd=21). Lexical geminates of Semitic origin were 12ms longer than assimilated geminates (LGS: $\bar{x}$=163, sd=18; AG: $\bar{x}$=151, sd=21).

Figure 5.4: Mean constriction duration and error bars represent mean +/- 1 standard deviation for /ʃ/ (after 'qalilhom')

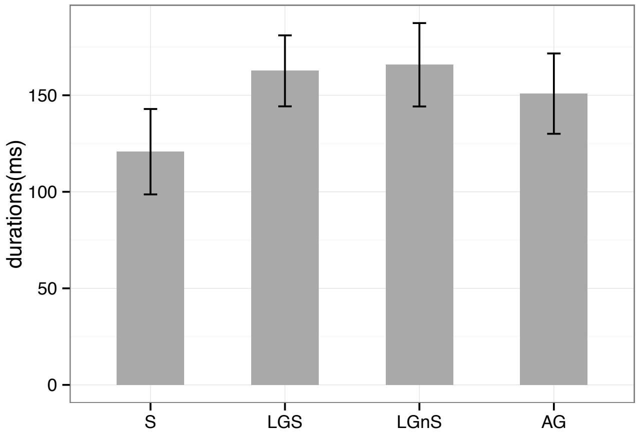
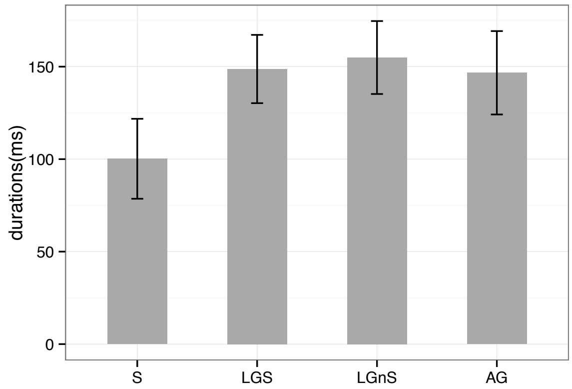


Figure 5.5 below shows the mean durations and standard deviations for singletons and the three geminate types for the voiceless fricative /z/. Lexical geminates of non-Semitic origin (LGnS) had the longest mean duration (LGnS: x̄=155, sd=20). LGnS were 55ms longer than singletons (LGnS: x̄=155, sd=20; S: x̄=100, sd=22). Lexical geminates of Semitic origin (LGS) were 49ms longer than singletons (LGS: x̄=149, sd=18; S: x̄=100, sd=22). Assimilated geminates were 47ms longer than singletons (AG: x̄=147, sd=23; S: x̄=100, sd=22). The difference among the different geminate types was noticeably smaller than that between singleton and geminates. Lexical geminates of non-Semitic origin (LGnS) were 6ms longer than lexical geminates of Semitic origin (LGnS: x̄=155, sd=20; LGS: x̄=149, sd=18) and 8ms longer than assimilated geminates (LGnS: x̄=155, sd=20; AG: x̄=147, sd=23). Lexical geminates of Semitic origin were 2ms longer than assimilated geminates (LGS: x̄=149, sd=18; AG: x̄=147, sd=23).

Figure 5.5: Mean constriction duration and error bars represent mean +/- 1 standard deviation for /z/ (after 'qalilhom')



Furthermore, just as in the stops, voiceless fricative singletons were longer than voiced fricative singletons: voiceless fricative singletons were 21ms longer than voiced fricatives (/s/: $\bar{x}$=121, sd=20; /ʃ/: $\bar{x}$=121, sd=22; /z/: $\bar{x}$=100, sd=22).

5.3.1.3 Interim summary: constriction duration after the preceding word 'qalilhom'

The descriptive analysis of the results shows that, unsurprisingly, geminates are longer than singletons. There is also a slight tendency for assimilated geminates to be shorter than lexical geminates of Semitic origin and lexical geminates of non-Semitic origin.

5.3.2 Constriction duration after the preceding word 'qalilha'

In the previous section, I reported the results of the duration of the target consonants when the preceding word ended in a consonant (i.e. the nasal /m/ in 'qalilhom'). In this section, I report the results for the duration of the target consonants in the context of when the preceding word ended in a vowel (i.e. the vowel /ɐ/ in 'qalilha' 'he told her').

Similarly to the previous results, all geminate types had longer durations than their singleton counterparts (cf. Table 5.4). Therefore, this shows the phonological contrast was maintained in different contexts.

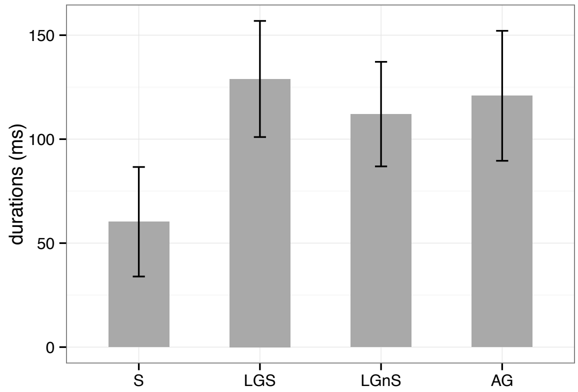
Table 5.4: Mean constriction duration and standard deviation of singletons and geminates (after the preceding ‘qalilha’)

Segment	S	LGS	LGnS	AG
/t/	60 (26)	129 (28)	112 (25)	121 (31)
/d/	59 (14)	119 (25)	115 (16)	115 (32)
/s/	107 (20)	180 (27)	175 (25)	171 (29)
/ʃ/	114 (22)	166 (24)	166 (24)	159 (21)
/z/	88 (16)	146 (25)	148 (27)	145 (27)
Pooled	85 (30)	148 (33)	143 (34)	142 (34)

5.3.2.1 Stops

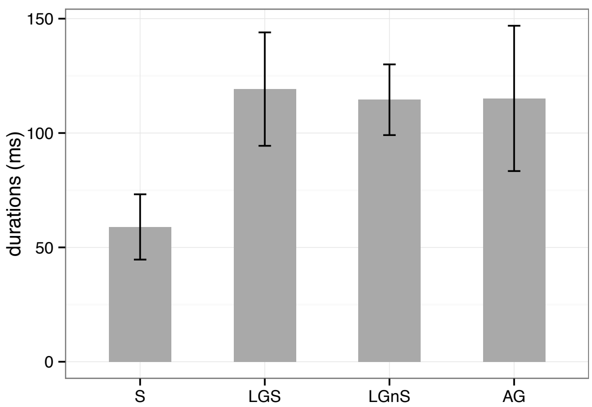
For voiced and voiceless stops, lexical geminates of Semitic origin (LGS) had the longest durations. Figure 5.6 shows the mean durations and standard deviations of the segment /t/ in all four consonant conditions. In the case of the voiceless stop /t/, lexical geminates of Semitic origin (LGS) were 69ms longer than their singleton counterpart (LGS: $\bar{x}$=129, sd=28; S: $\bar{x}$=60, sd=26). Lexical geminates of non-Semitic origin (LGnS) were 52ms longer than their singleton counterpart (LGnS: $\bar{x}$=112, sd=25; S: $\bar{x}$=60, sd=26); and assimilated geminates (AG) were 61ms longer (AG: $\bar{x}$=121, sd=31; S: $\bar{x}$=60, sd=26). As reported previously, the durational difference among the different geminate types was smaller than that between singleton and geminates. Lexical geminates of Semitic origin (LGS) were 17ms longer than lexical geminates of non-Semitic origin (LGnS) (LGS: $\bar{x}$=129, sd=28; LGnS: $\bar{x}$=112, sd=25) and 8ms longer than assimilated geminates (AG) (LGS: $\bar{x}$=129, sd=28; AG: $\bar{x}$=121, sd=31). Assimilated geminates (AG) were 9ms longer than lexical geminates of non-Semitic origin (LGnS) (AG: $\bar{x}$=121, sd=31; LGnS: $\bar{x}$=112, sd=25).

Figure 5.6: Mean closure duration and error bars representing mean +/- 1 standard deviation for /t/ (after 'qalilha')



For the voiced stop /d/, similar differences to the voiceless stop /t/ were found (cf. Figure 5.7). Lexical geminates of Semitic origin (LGS) are 60ms longer than singletons (LGS: x̄=119, sd=25; S: x̄=59, sd=14); lexical geminates of non-Semitic origin (LGnS) and assimilated geminated (AG) are 56ms longer than their singleton counterparts (LGnS: x̄=115, sd=16; S: x̄=59, sd=14; AG: x̄=115, sd=32). In terms of the durational differences among the geminate types: lexical geminates of Semitic origin (LGS) are 4ms longer than both lexical geminates of non-Semitic origin (LGnS) and assimilated geminates (AG): (LGS: x̄=119, sd=25; LGnS: x̄=115, sd=16; AG: x̄=115, sd=32). The duration of lexical geminates of non-Semitic origin (LGnS) and assimilated geminates (AG) are comparable (LGnS: x̄=115, sd=16; AG: x̄=115, sd=32).

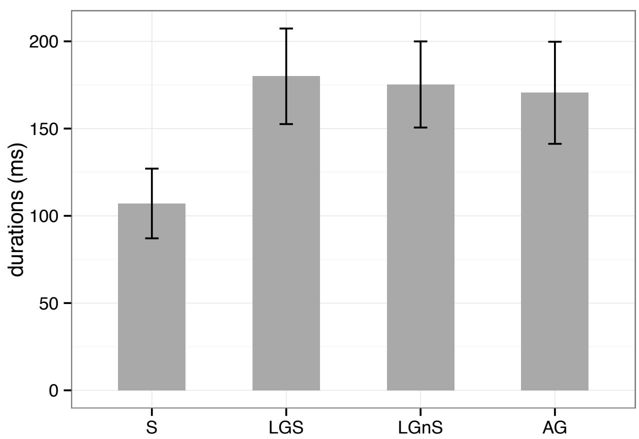
Figure 5.7: Mean closure duration and error bars representing mean +/- 1 standard deviation for /d/ (after 'qalilha')



5.3.2.2 Fricatives

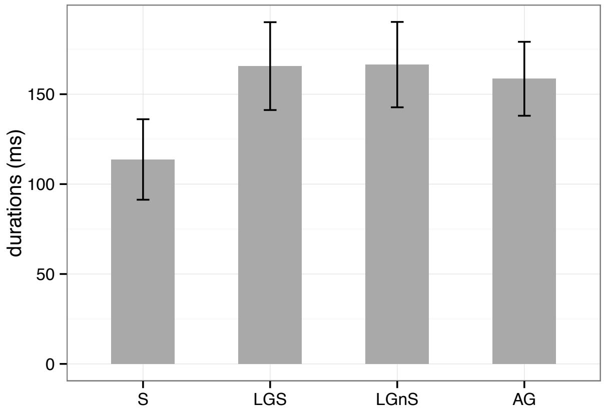
For the voiceless fricative /s, ʃ/, lexical geminates of Semitic origin (LGS) had the longest durations out of all the three geminate types. Figure 5.8 shows the mean durations and standard deviations for the voiceless fricative /s/. Lexical geminates of Semitic origin (LGS) were 73ms longer than their singleton counterparts (LGS: $\bar{x}$=180, sd=27; S: $\bar{x}$=107, sd=20); lexical geminates of non-Semitic origin were 68ms longer than singletons (LGnS: $\bar{x}$=175, sd=25; S: $\bar{x}$=107, sd=20); assimilated geminates were 64ms longer than singletons (AG: $\bar{x}$=171, sd=29; S: $\bar{x}$=107, sd=20) The difference among the different geminate types was small: lexical geminates of Semitic origin (LGS) were 5ms longer than lexical geminates of non-Semitic origin (LGnS) (LGS: $\bar{x}$=180, sd=27; LGnS: $\bar{x}$=175, sd=25) and 9ms longer than assimilated geminates (AG) (LGS: $\bar{x}$=180, sd=27; AG: $\bar{x}$=171, sd=29). Lexical geminates of non-Semitic origin (LGnS) were 4ms longer than assimilated geminates (LGnS: $\bar{x}$=175, sd=25; AG: $\bar{x}$=171, sd=29).

Figure 5.8: Mean constriction duration and error bars represent mean +/- 1 standard deviation for /s/ (after 'qalilha')



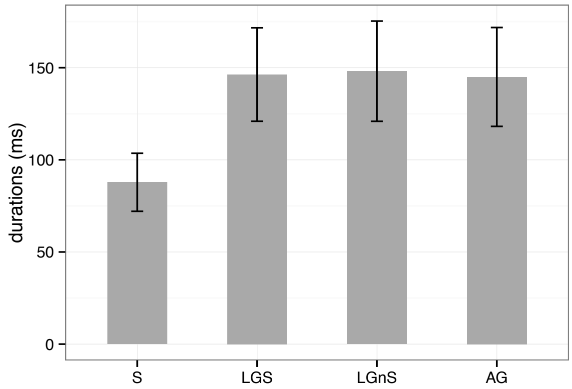
The differences in duration for /ʃ/ (cf. Figure 5.9) were smaller than that of /s/: lexical geminates of Semitic origin (LGS) and lexical geminates of non-Semitic origin were 52ms longer than singletons (LGS: $\bar{x}$=166, sd=24; LGnS: $\bar{x}$=166, sd=24; S: $\bar{x}$=114, sd=22); and assimilated geminates (AG) were 45ms longer than singletons (AG: $\bar{x}$=159, sd=21; S: $\bar{x}$=114, sd=22). The difference among the different geminate types was much smaller than that between singletons and geminates. Furthermore, the duration of lexical geminates of Semitic origin (LGS) and lexical geminates of non-Semitic origin (LGnS) are comparable (LGS: x̄=166, sd=24; LGnS: x̄=166, sd=24). However, both lexical geminate types were 7ms longer than assimilated geminates LGS: x̄=166, sd=24; LGnS: x̄=166, sd=24; AG: x̄=159, sd=21).

Figure 5.9: Mean constriction duration and error bars represent mean +/- 1 standard deviation for /ʃ/ (after 'qalilha')



For the voiced fricative /z/, lexical geminates of non-Semitic origin (LGnS) had the longest constriction duration compared to the other geminate types (cf. Figure 5.10). Lexical geminates of non-Semitic origin (LGnS) were 60ms longer than singletons (LGnS: x̄=148, sd=27; S: x̄=88, sd=16), lexical geminates of Semitic origin were 58ms longer than singletons (LGS: x̄=146, sd=27; S: x̄=88, sd=16) and assimilated geminates (AG) were 57ms longer than singletons (AG: x̄=145, sd=27; S: x̄=88, sd=16). The difference among the different geminate types was small: lexical geminates of non-Semitic origin (LGS) were 2ms longer than lexical geminates of Semitic origin (LGnS) (LGnS: x̄=148, sd=27; LGS: x̄=146, sd=27), lexical geminates of non-Semitic origin were 3ms longer than assimilated geminates (AG) (LGnS: x̄=148, sd=27; AG: x̄=145, sd=27) and assimilated geminates were 1ms longer than lexical geminates of Semitic origin (LGS) (LGS: x̄=146, sd=27; AG: x̄=145, sd=27).

Figure 5.10: Mean constriction duration and error bars represent mean +/- 1 standard deviation for /z/ (after 'qalilha')



5.3.3 Overall summary: Constriction duration

So far, I have shown that all three word-initial geminate types are longer than their singleton counterpart. This contrast was present when the preceding word ended in a consonant (i.e. 'qalilho**m**') and also when the preceding word ended in a vowel (i.e. 'qalilh**a**').

Overall, the difference among the three geminate types is discernably smaller than that between the geminates and the singletons. Also, as expected, there is a difference in the duration between voiceless and voiced segments. Voiceless stops and fricatives seem to have a longer duration than voiced stops and fricatives.

Therefore, the next step is to statistically infer whether and to what extent Consonant Type (S, LGS, LGnS and AG), Manner (stops or fricatives) and Environment (whether the preceding word ended in a consonant or a vowel) affect constriction duration.

5.3.4 What really effects constriction duration: Consonant Type, Manner or Environment?

This section seeks to determine the role of Consonant Type (i.e., singleton (S), lexical geminates of Semitic origin (LGS), lexical geminates of non-Semitic origin (LGnS), assimilated geminates (AG)), Manner (i.e., stops or fricatives) and/or Environment (i.e. the preceding context: consonantal 'qalilho**m**'; vocalic 'qalilh**a**') in determining constriction duration, by submitting the results discussed above to statistical modeling.

All data were analysed in R (R Core Team 2015) using linear mixed-effect models, using the package *lme4* (Bates et al. 2015), and were evaluated using *lmerTest* (Kuznetsova et al. 2015).[53] Following Barr et al. (2013), models were built with a maximal random effects structure, this included random intercepts and random slopes for the three fixed effects and their interaction. However, this led to problems of convergence. As a result, the models were built by omitting covariances from the variance-covariance. The fixed effects of Consonant Type (S, LGS, LGnS, AG), Manner (i.e. stops /t, d/; fricatives /s, ʃ, z/) and Environment (consonantal: 'qalilhom' or vocalic: 'qalilha') were centered to reduce collinearity. I adopted a model-comparison approach, testing the goodness-of-fit of different models to determine the impact of the two independent variables; for this purpose, I report each model's Bayesian Information Criterion (BIC) together with the model chi-square (χ^2) obtained on the basis of its log-likelihood estimate.

In order to investigate whether all three fixed effects contribute to explain the difference between singletons and geminates, a model comparison was carried out (cf. Table 5.7). A baseline (model 1) which was made up of only the intercept and the random effects was built. The fixed effects- Consonant Type, Manner and Environment were investigated separately (i.e. model 2, model 3 and model 4). These models were compared to the baseline. A model including Consonant Type

[53] The same statistical analysis is carried out in this dissertation (unless stated otherwise). A model comparison approach is adopted throughout.

and Manner as fixed effects terms (model 5) was built. Model 5 was compared to model 2 and model 3 (cf. Table 5.5). Model 6 included the interaction of Consonant Type and Manner, which was compared to Model 5. Model 5 was compared to model 7, which included the three fixed effect terms: Consonant Type, Manner and Environment. Model 8 included the fixed effect terms of Consonant Type and Manner and the interaction of Environment and was compared to model 7. Finally, model 9 included the interaction of the three fixed effect terms. This was compared to model 8.

Table 5.5: Model goodness of fit: Constriction Duration- pooled data (*** = p < 0; * = p < 0.01, *n.s.* = not significant)

Model	**Fixed Effects**	**BIC**	χ^2
1	Intercept	23702	-
2	Consonant Type	23706	4.124 * (relative to model 1)
3	Manner	23694	16.411 *** (relative to model 1)
4	Environment	23710	0.0331 *n.s.* (relative to model 1)
5	Consonant Type + Manner	23700	18.045 *** (relative to model 1)
6	Consonant Type * Manner	23708	0.1706 *n.s.* (relative to model 5)
7	Consonant Type + Manner +Environment	23708	0.01 *n.s.* (relative to model 5)
8	Consonant Type + Manner * Environment	23716	0.1086 *n.s.* (relative to model 7)
9	Consonant Type * Manner * Environment	23737	2.2869 *n.s.* (relative to model 8)

The models including Consonant Type (model 2) and Manner (model 3) as fixed effects had a better fit to the data than the baseline, suggesting that duration of constriction depends on both whether the consonant was a singleton or a geminate and manner. However, the model including Environment (model 4) did not explain the data any better than a model consisting only of the intercept. Model 5, which includes Consonant Type and Manner, has a better fit to the data than model 1. This suggests that the constriction duration is affected by both fixed effect terms. Therefore, model 2 and model 3, which include the fixed effects Consonant Type and Manner separately, were compared to model 5, which includes both fixed effects. The comparison in Table 5.6 shows that the comparison of model including manner (model 3) is not statistically better than the model including Consonant Type and Manner (model 5) as fixed effects.

Table 5.6: Model Comparison: Consonant Type, Manner (*** = p < 0; *n.s.* = not significant)

Comparison	χ^2
Model 2, Model 5	13.921 ***
Model 3, Model 5	1.6337 *n.s.*

The same procedure was carried out with Model 7. Model 2, model 3 and model 4, which include the fixed effects Consonant Type, Manner and Environment separately, where each compared to Model 7. The model comparison is presented in Table 5.7 (below). Including Manner as a fixed effect does not lead to a better goodness of fit.

Table 5.7: Model Comparison: Consonant Type, Manner, Environment (*** = p < 0; *n.s.* = not significant)

Comparison	χ^2
Model 2, Model 7	13.931 ***
Model 3, Model 7	1.6347 *ns*
Model 4, Model 7	18.022 ***

Only Consonant Type and Manner contribute in explaining the data better. Furthermore, comparing model 5 to model 7 suggests that the latter does not explain the data any better. However, model 8 and model 9 did not explain the data better than model 6, which suggests there is no role for Environment on constriction duration. This suggests that constriction duration is affected by Consonant Type and Manner, but the presence of a final consonant or a vowel in the preceding word might not affect the duration of the target consonant. The model that explains the data best is model 5.

Table 5.8: Summary of Model 5: Consonant Type + Manner

Fixed Effects	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	142.187	5.734	24.795	<2e-16 ****
Consonant Type	-7.594	5.770	-1.316	0.202 *n.s.*
Manner	-21.459	3.727	-5.759	1.06e-05 ***

Model 5 includes both Consonant Type and Manner, which were separately found (Model 2 and 3) to provide better goodness of fit than the baseline. On the other hand, the combined Model 5, while better than Model 2 with only Consonant Type, is not better than Model 3, which only has Manner. It is excluded that this is due to an interaction, since the results show that an interaction term does not improve fit over just main effects. At the same time, the results for Model 5 also show that consonant fails to reach significance. Therefore, some caution is required in interpreting the results where the role of Consonant Type is concerned: As the comparison of Model 2 versus baseline makes clear, the difference between consonant types does play a role, with different constriction durations for each type, but ultimately it is Manner that is the most important factor.

5.3.5 Lexical vs. surface geminates

The overall means indicate that the different geminate types did not differ from each other in terms of their duration (cf. §5.3). In order to investigate whether the three geminate types (i.e. LGS, LGnS and AG) are significantly different from each other, each geminate type was compared to every other. In order to achieve this, a linear mixed effects model was constructed with Consonant type as fixed effect. The Consonant Type fixed effect was dummy-coded, so that each level was compared to a fixed reference level. Assimilated geminates (AG) was chosen as the reference level since there was a tendency for assimilated geminates to have a shorter mean duration than the other geminate types. The mean duration of the lexical geminates of Semitic origin (LGS), lexical geminates of non-Semitic origin (LGnS) and singletons (S) were compared to the reference level (i.e. assimilated geminates (AG)).

As expected, the means of assimilated geminates (AG) are statistically significantly different from the means of singletons (AG: $\bar{x}$=138, sd=27; S: $\bar{x}$=88, sd=39; $p < 0.001$). However, the means of assimilated geminates (AG) and lexical geminates of non-Semitic origin (LGS) were not significantly different (AG: $\bar{x}$=138, sd=27; LGS: $\bar{x}$=137, sd=28; p=0.8). Furthermore, the means of assimilated geminates (AG) and lexical geminates of Semitic origin (LGS) were also not significantly different (AG: $\bar{x}$=138, sd=27; LGnS: $\bar{x}$=143, sd=32; p=0.6). Therefore, lexical geminates and assimilated geminates did not any exhibit differences in their phonetic durations.

5.3.6 Duration ratio after the preceding word 'qalilhom'

The literature suggests that different manners of articulation exhibit different singleton-to-geminate duration ratios. For instance, following Aoyama and Reid (2006) stops would be expected to have a longer singleton-to-gemination duration ratio than fricatives. As a matter of fact, the singleton-to-geminate duration ratio for stops was much larger than that of fricatives. The duration of geminated stops (pooled across the three geminate types) was more than double that of singleton stops (1:2.4). On the other hand, the fricative singleton-to-geminate duration ratio was 1:1.4 (pooled across the three geminate types). For a breakdown of the singleton-to-geminate duration ratio per geminate type refer to Table 5.9.

5.3.7 Duration ratio after the preceding word 'qalilha'

After the preceding word 'qalilha', the singleton-to-geminate duration for stops (pooled across all geminate types) was 1:2.1, which decreased from 1:2.4 from the consonantal preceding word context. However, in the case of the fricatives, the singleton-to-geminate duration ratio was 1:1.6 (pooled across all geminate types), which shows an increase from 1:1.4 in the consonantal preceding context. Note that despite these small differences, Environment was not found to have a statistically significant effect on constriction duration (cf. §5.3.4). Table 5.9 shows the singleton-to-geminate duration ratios for each geminate type and manner in both environment contexts.

Table 5.9: Singleton-to-geminate durations for singletons (S), lexical geminates of Semitic origin (LGS), lexical geminates of non-Semitic origin (LGnS) and assimilated geminates (AG) after 'qalilhom' and 'qalilha'

	Manner	**S : LGS**	**S : LGnS**	**S : AG**
'Qalilhom'	**Stops**	1:2.6	1:2.3	1:2.3
	Fricatives	1:1.4	1:1.4	1:1.3
'Qalilha'	**Stops**	1:2	1:1.9	1:2
	Fricatives	1:1.6	1:1.58	1:1.5

5.3.8 Pooled duration ratios

Below, I present the overall mean durations for the closure duration of stops and the constriction duration of fricatives. Table 5.10 shows the duration ratios pooled across all speakers and the two preceding word conditions (environment). Overall, the singleton-to-geminate duration ratio for stops is 1:2.3, which was comparable to the duration ratio of the consonantal condition (i.e. after the preceding word 'qalilhom': 1:2.4) and to the vowel condition (i.e. after the preceding word 'qalilha': 1:2.1). In addition, the singleton-to-geminate duration ratio for fricatives is 1:1.5, which is also comparable to the duration ratio found in consonantal condition (i.e. 1:1.4) and the vowel condition (i.e. 1:1.6).

Table 5.10: Singleton-to-geminate durations (pooled across environment conditions) for singletons (S), lexical geminates of Semitic origin (LGS), lexical geminates of non-Semitic origin (LGnS) and assimilated geminates (AG)

Manner	S : LGS	S : LGnS	S : AG
Stops	1:2.3	1:2	1:2.1
Fricatives	1:1.5	1:1.5	1:1.4

5.4 Insertions between the preceding word 'qalilhom' and word-initial geminates

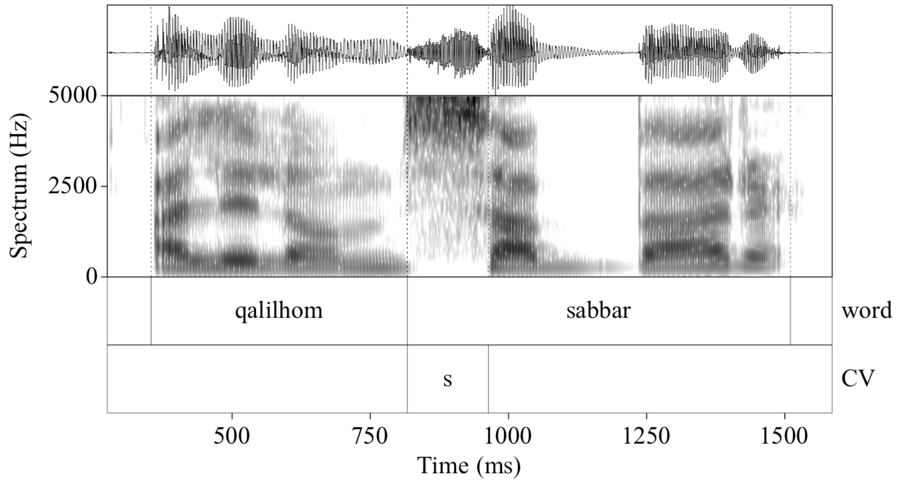
Descriptions of word-initial geminates in Maltese claim that word-initial geminates are preceded by an epenthetic vowel (Azzopardi 1981, Misfud 1995, as discussed in Chapter 2 §2.3 and Chapter 3 §3.6.3.4). In this section, I show the number of insertions across the ten speakers in §5.4.1. I investigate the duration of the vocalic insertion in §5.4.2. In §5.4.3 I report that the vocalic insertion was some times preceded by an epenthetic glottal stop.

5.4.1 Number of vocalic insertions[54] before word-initial geminates

A vocalic insertion is always expected to be inserted when word-initial geminates are preceded by a consonant (cf. Hoberman and Aronoff 2003). Therefore, in this production study, a vocalic element of [ɪ]-like quality was expected to be inserted between the final nasal of 'qalilhom' and the following word-initial geminate. However, vocalic insertions are not expected before singletons, as a matter of fact, there are no vocalic insertions before singletons in the data. Figure 5.11 is a typical case in point, showing that between the final nasal /m/ of the preceding word 'qalilhom' and the following word-initial singleton, /s/ of *sabbar* 'to comfort', there were no vocalic insertions.

[54] In Production Study 1 (this chapter) and Production Study 2 (Chapter 6), I use the term *vocalic insertion* (or vocalic element) to refer to the vowel before word-initial geminates in Maltese. By doing so, I adopt what I believe is a term which has no direct implications in terms of phonetic or phonological interpretations.

Figure 5.11: No vocalic insertions between the preceding word 'qalilhom' and the following singleton /s/ in *sabbar* 'to comfort'



On the other hand, in 96% of the geminate cases there were clear vowel formants between the nasal /m/ in the preceding word 'qalilhom' and the following geminate consonant, a typical case in point is shown in Figure 5.12. Table 5.11 shows a breakdown of the number of vocalic insertions before each geminate type across all tokens.

Figure 5.12: Vocalic insertion between the preceding word 'qalilhom' and the word-initial geminate /dd/ in *ddaħħal* 'to be inserted'

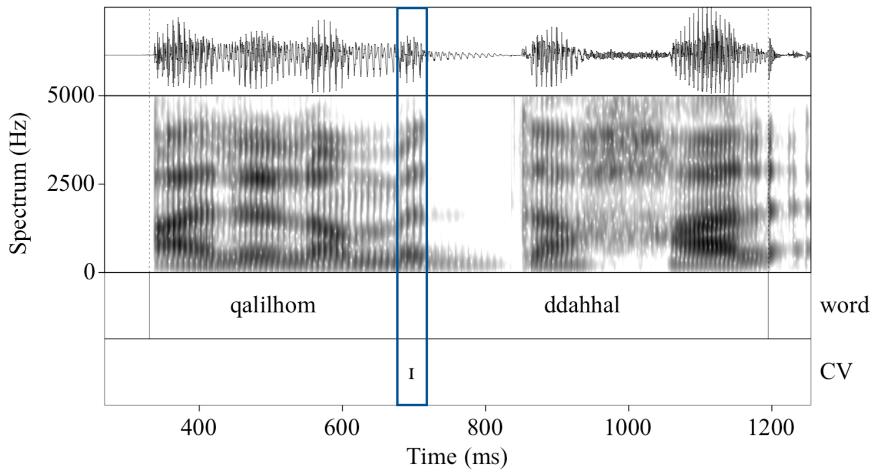


Table 5.11: Number of vocalic insertions after the preceding word 'qalilhom' per geminate type pooled across all speakers and manners of articulation

Geminate Type	**Frequency**	**Percentage**
Lexical Geminates non-Semitic (LGnS)	338/350	97%
Lexical Geminates Semitic (LGS)	325/350	93%
Assimilated Geminates (AG)	344/350	98%
TOTAL	1007 /1050	96%

In addition, the count data of the vocalic insertion was further investigated for each speaker. This was carried out in order to see if there is variation within- and across- speakers. It could be the case that some speakers have a high tendency to insert vocalic elements, while others might not. Across the board, most speakers behaved similarly (cf. Table 5.12), in such a way that they often have a vocalic insertion before both lexical and assimilated geminates. Note that, speaker 6 had the lowest number of vocalic insertions.

Table 5.12: Vocalic insertions per speaker (percentages shown in parentheses)

	Geminate Type			
Speaker	**Lexical Semitic (LGS)**	**Lexical non-Semitic (LGns)**	**Assimilated (AG)**	**TOTAL**
1	35 (100%)	35 (100%)	35 (100%)	105 (100%)
2	29 (83%)	31 (89%)	35 (100%)	95 (90%)
3	35 (100%)	35 (100%)	35 (100%)	105 (100%)
4	31 (89%)	34 (97%)	34 (97%)	99 (94%)
5	31 (89%)	32 (91%)	35 (100%)	98 (93%)
6	24 (69%)	31 (89%)	30 (86%)	88 (84%)
7	35 (100%)	35 (100%)	35 (100%)	105 (100%)
8	35 (100%)	35 (100%)	35 (100%)	105 (100%)
9	35 (100%)	35 (100%)	35 (100%)	105 (100%)
10	35 (100%)	35 (100%)	35 (100%)	105 (100%)

Therefore, corroborating the claims in the literature, I provide acoustic evidence for the vocalic insertion and conclude that it is a strategy that is used by all speakers, whereby; speakers have a tendency to insert a vowel of [ɪ]-like quality before both lexical and surface word-initial geminates.

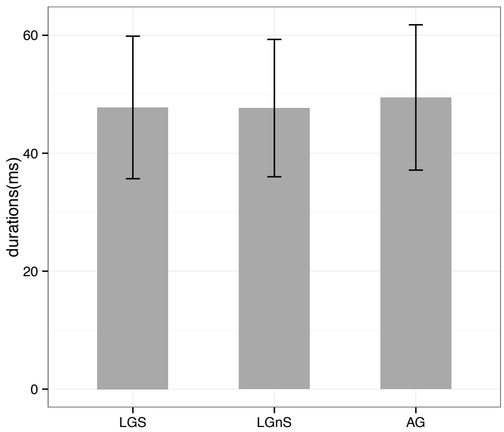
5.4.2 Duration of the vocalic insertion

The count data presented in the previous section corroborates the claims described earlier (in Chapter 3 §3.6.3.4) by Azzopardi (1981) and Hoberman and Aronoff (2003). In this production study there was a vocalic insertion after the nasal /m/ in the preceding word 'qalilhom' and before the start of the lexical or surface word-initial geminates. The literature (cf. Hall 2006, Hall 2013 and Ali et al. 2008) suggests that that the production of epenthetic vowels varies across speakers, words and position in words, unlike lexical vowels. At least for some dialects of Arabic, namely, Moroccan and Levantine, there are no durational differences between epenthetic and lexical vowels. Ali et al. (2008) investigated the insertion of epenthetic vowels between word-initial consonants in Moroccan Arabic. They argued that a vowel of schwa-like quality is inserted between C_1 and C_2 to break up a word-initial cluster. Their results suggested that there are no durational differences between epenthetic and lexical vowels. Even though they say that there's variation across words, they do not say whether there is variation across speakers. The insertion of an epenthetic vowel within clusters can depend on the clusters itself: for instance, Ali et al. (2008) show that in word-initial s-clusters, such as /sk/, there are no vocalic insertions. However, in clusters such as /fh/, /bk/ and /br/, a schwa was inserted.

Furthermore, in an acoustic study of epenthetic and lexical vowels in Lebanese Arabic, Hall (2013) reported that the phonetic realization of such vowels resulted in cross-speaker variation: some speakers significantly differentiated between the two vowels and other speakers did not. Hall (2013) investigated the insertion of an epenthetic vowel between consonant clusters in coda position. The duration of this vowel was compared to that of a lexical vowel and the durations of both vowels were comparable. Hall (2013) reported that the duration of the epenthetic vowel was 60ms, whereas the duration of the lexical vowel was about 61ms.[55] Moreover, Hall (2013) reported that epenthetic vowels had higher F1 and lower F2 values when compared to lexical vowels, albeit with a lot of variability. Statistical analyses showed that F2 values were significantly different between lexical and epenthetic vowels, where the latter were characterized with lower F2 values.

Given these results, the duration of the vocalic insertions were investigated in order to identify whether the duration of the vocalic insertion was comparable before the three geminate types. The mean durations in Figure 5.13, pooled across all 10 speakers and manners of articulation, show that the durations of the vocalic insertion before each geminate type is comparable. The acoustic duration of the vocalic insertion was longest before assimilated geminates (AG: $\bar{x}$=49ms, sd=12), whereas the mean duration of the vocalic insertion before lexical geminates of Semitic origin (LGS) and lexical geminates of non-Semitic origin (LGnS) was similar ($\bar{x}$=48ms, sd=12 for both LGS and LGnS). The overall average difference between the geminates types in production is of 1ms, which is taken to reflect that there is no difference between the three geminate types.

Figure 5.13: Mean acoustic duration and error bars represent mean +/- 1 standard deviation of the vocalic insertion after 'qalilhom' pooled across all speakers and manners of articulation



[55] This contradicts Gouskova and Hall's (2009) paper, which states that epenthetic vowels are shorter than lexical vowels in Lebanese Arabic. Hall (2013) explains that this difference could be due whether speakers are asked to read in a colloquial speaking style or a slower rate.

The duration of the vocalic insertion was also investigated separately for stops and fricatives (cf. Table 5.13). This was carried out to explore whether the durations of the vocalic insertion were similar or different before stops and fricatives. A descriptive analysis of the means confirms that the duration of the vocalic insertion was similar before stops and fricatives.

Table 5.13: Mean acoustic duration and standard deviation of vocalic insertion per manner pooled across all speakers

	LGS	**LGnS**	**AG**
Stops	47 (11)	47 (8)	49 (10)
Fricatives	49 (13)	48 (13)	50 (14)

In Table 5.14, I show a breakdown of the duration of the vocalic insertion before each geminate type per speaker. The range of durations is from 40-59ms for lexical geminates of Semitic origin (LGS), 38-59ms for lexical geminates of non-Semitic origin (LGnS) and 40-60ms for assimilated geminates (AG). All in all, this observation suggests that there might be a lower and an upper limit of how short or long this specific vocalic insertion can be, i.e. the inserted vowel cannot be shorter than 38ms and not longer than 60ms.

Table 5.14: Mean acoustic duration and standard deviations of vocalic insertion per speaker

Speaker	**LGS**	**LGnS**	**AG**
1	51 (9)	49 (10)	52 (13)
2	40 (7)	40 (7)	45 (10)
3	59 (10)	59 (9)	61 (11)
4	43 (8)	45 (9)	49 (9)
5	42 (7)	42 (5)	46 (11)
6	40 (9)	47 (10)	46 (11)
7	55 (12)	57 (11)	60 (11)
8	44 (9)	46 (9)	43 (8)
9	56 (12)	53 (14)	54 (9)
10	42 (14)	38 (10)	40 (10)

In order to investigate whether the three geminate types (i.e. LGS, LGnS and AG) had similar durations, a model comparison was carried out (i.e. Table 5.15). Following Barr et al. (2013), models were built with a maximal random effects structure, this included random intercepts and random slopes for the fixed effect. The fixed effect of Consonant Type (LGS, LGnS, AG) was centered to reduce collinearity. A baseline (model 1 in Table 5.15) that was made up of only the intercept and the random effects was built. The contribution of the fixed effect, Consonant Type, was investigated separately (i.e. model 2 in Table 5.15). Model 2 was compared to the baseline.

Table 5.15: Model comparison: duration of vocalic insertion

Model	**Fixed Effects**	**BIC**	χ^2
1	Intercept	7287.8	-
2	Consonant Type	7294.5	0.2737 *not significant*

The comparison of model 2 to model 1 shows that the addition of the fixed effect Consonant does not explain the data better than the baseline. Therefore, this confirms that duration of the vocalic insertion is not greatly affected by the three different geminate types that follow such vowel.

5.4.3 Glottal Stop Insertion

In Chapter 2, I reported that in Maltese vowel-initial syllables and/or words can be realized with a preceding epenthetic glottal stop. In the data from Production Study 1, there were cases were the vocalic insertion (i.e., [ɪ]) before lexical and assimilated word-initial geminates was preceded by a glottal stop insertion (i.e., [ʔ]). In this section, I present the number of glottal stop insertions following the two preceding words (i.e. ‘qalilhom’ and ‘qalilha’ respectively).

5.4.3.1 Number of glottal stop insertions after the preceding word 'qalilhom'

The insertion of a glottal stop was subject to within- and across- speaker variation. As a matter of fact, in this production study, the vocalic element, [ɪ], was preceded by a glottal stop insertion, [ʔ], by 4 out of the 10 speakers; this was also subject to within-speaker variation. Glottal stop insertions were present before the vocalic insertions in all three geminate types (i.e. lexical geminates of Semitic origin (LGS), lexical geminates of non-Semitic origin (LGnS) and assimilated geminates (AG)). 3 out of the 4 speakers were female speakers (i.e. Speaker 8, 9 and 10 in Table 5.16). Table 5.16 lists the 4 speakers (out of the 10 speakers recorded in Production Study 1) and the number of occurrence of glottal stop insertions before lexical and assimilated geminates.

Table 5.16: Number of glottal stop insertions for speakers 6, 8, 9, 10. Percentage (%) out of the total within a category (35) are shown in parenthesis

Speaker, Gender	**# before LGS**	**# before LGnS**	**# before AG**	**TOTAL**
6 (M)	6 (17%)	7 (20%)	15 (43%)	28 (27%)
8 (F)	16 (47%)	14 (40%)	12 (34%)	42 (40%)
9 (F)	3 (9%)	1 (3%)	1 (3%)	5 (14%)
10 (F)	31 (89%)	33 (94%)	34 (97%)	98 (93%)
TOTAL	56/140 (40%)	55/140 (39%)	62/140 (44%)	-

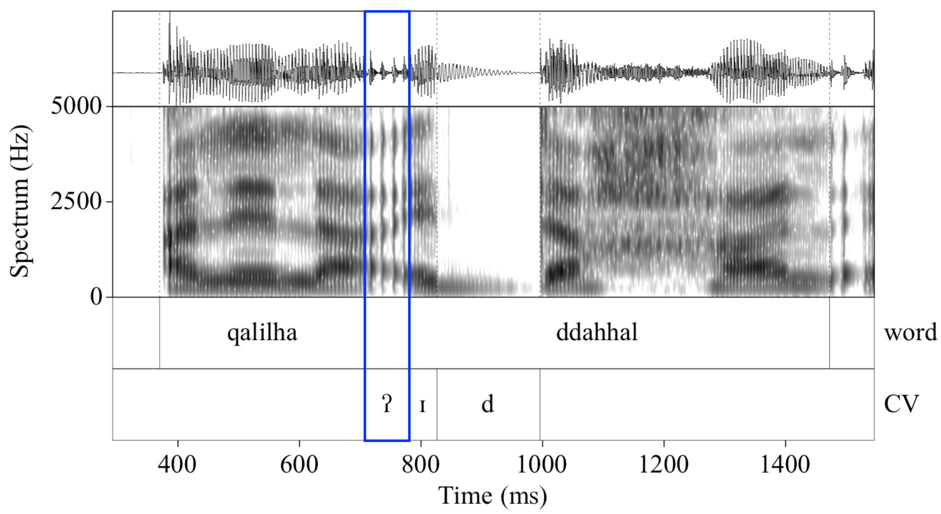
Speakers 6 and 10, had the highest glottal stop insertions before assimilated geminates (AG), while speakers 8 and 9 had the highest glottal stop insertions before lexical geminates of Semitic origin (LGS). Across the four speakers, speaker 10 had the most instances of glottal stops insertions, and, thus, the highest percentage rates. In addition, for speaker 10 glottalisation was comparable across the different geminate types. It is interesting to note that speaker 6 has six insertions before lexical geminates of Semitic origin (LGS) and seven insertions before lexical geminates of non-Semitic origin (LGnS), whereas the number of insertions before assimilated geminates is 15 (i.e., double than that before LGS and LGnS).

Overall, pooling over the four speakers, assimilated geminates (AG) had the highest percentage rate of glottal stops insertions (i.e. 44%; count=62/140). The number of glottal stop insertions before lexical geminates of Semitic origin (LGS) was 40% (count=56/140). Lexical geminates of non-Semitic origin (LGnS) had the least number of glottal stop insertions (i.e., 39%; count=55/140).

5.4.3.2 Number of glottal stop insertions after the preceding word 'qalilha'

Glottal stop insertions were also found between the final vowel /ɐ/ of the preceding word 'qalilha' and the inserted vowel before word-initial geminates. The glottal stop insertion after the preceding word 'qalilha', similar to the glottal stop insertion after the preceding word 'qalilhom', was subject to within- and across- speaker variation. 6 speakers out of the 10 speakers inserted a glottal stop between the final vowel /ɐ/ of the preceding word 'qalilha' and the inserted vowel before the word-initial geminate (cf. Figure 5.14).

Figure 5.14: Glottal stop insertion after the preceding word 'qalilha' and the vocalic insertion before word-initial geminate /dd/ in *ddaħħal* 'to be inserted'



In light of the data in Table 5.17, speaker 10 had the higher number of glottal stop insertions out of the six speakers. The other five speakers (i.e. 1, 6, 7, 8, and 9) had a fairly smaller number of glottal stop insertions, compared to Speaker 10. There is some overlap in the speakers that inserted a glottal stop after preceding word ‘qalilhom’ and ‘qalilha’: namely, Speakers 6, 8, 9, 10 had glottal stop insertions after both preceding words. On the other hand, Speakers 1 and 7 inserted a glottal stop after the preceding word ‘qalilha’ but not after the preceding word ‘qalilhom’.

Table 5.17: Frequency of glottal stop insertions per speaker and geminate type after the preceding word ‘qalilha’

Speaker	**LGS**	**LGnS**	**AG**
1	18/35 (51%)	2/35 (6%)	8/35 (23%)
6	3/35 (9%)	2/35 (6%)	1/35 (3%)
7	-	2/35 (6%)	-
8	2/35 (6%)	1/35 (3%)	8/35 (23%)
9	1/35 (3%)	7/35 (20%)	-
10	33/35 (94%)	26/35 (74%)	31/35 (86%)

As shown in Table 5.18, after the preceding word ‘qalilhom’ there were more glottal stop insertions (49.4%) than after the preceding word ‘qalilha’ (41.4%). The number of glottal stop insertions before assimilated geminates (AG) was highest for the preceding word ‘qalilhom’, whereas for the preceding word ‘qalilha’, there were the most glottal stop insertions before lexical geminates of Semitic origin (LGS). Nonetheless, the number of glottal stop insertions before lexical geminates of Semitic origin (LGS) were comparable across the two preceding word conditions.

Table 5.18: Glottal stop insertions after the preceding words ‘qalilhom’ and ‘qalilha’

Geminate type	**Counts after ‘qalilhom’**	**Counts after ‘qalilha’**
LGS	56 (16%)	57 (16.3%)
LGnS	55 (15.7%)	40 (11.4%)
AG	62 (17.7%)	48 (13.7%)
TOTAL	173 (49.4%)	145 (41.4%)

5.5 What happens after the /ɐ/ in ‘qalilha’?

The literature, in particular Hobermann and Aronoff (2003) and Mifsud (1995), did not predict a vocalic insertion before word-initial geminates when they are preceded by a word ending in a vowel. The data presented here indicates that for some speakers, there are some durational adjustments of the final vowel /ɐ/ in the preceding word ‘qalilha’. Note that these adjustments span across a word boundary. For other speakers, such adjustments are not present. In §5.5.1, I investigate the duration of the final vowel /ɐ/ and in §5.5.2, I define the inter-consonantal interval and show its adjustments before geminates and singletons.

5.5.1 Duration of the vowel /ɐ/

In a preliminary study, Galea et al. (2014) report vowel lengthening across a word boundary in some speakers. In order to see whether vowel lengthening occurred before geminates across all speakers, the duration of the final /ɐ/ in ‘qalilha’ was measured (cf. Table 5.19). 12% of the tokens (n=167) were removed as the vowel /ɐ/ was followed by a pause or a glottal stop, which does not enable a one-to-one comparison across all geminate types.

Table 5.19: Mean durations of /ɐ/ per speaker across all words

Speaker	S	LGS	LGnS	AG
1	79 (11)	87 (12)	85 (13)	83 (11)
2	76 (10)	74 (9)	73 (9)	77 (11)
3	93 (9)	98 (14)	106 (20)	101 (13)
4	86 (20)	93 (18)	93 (16)	99 (16)
5	86 (14)	92 (16)	87 (15)	92 (14)
6	100 (24)	90 (17)	88 (16)	94 (17)
7	110 (17)	131 (33)	132 (23)	149 (23)
8	94 (21)	100 (19)	101 (20)	103 (20)
9	105 (17)	132 (28)	129 (28)	134 (29)
10	109 (31)	156 (3)	141 (27)	155 (40)

Taking S (singletons) as the baseline, the mean durations of the final vowel /ɐ/ in ‘qalilha’ show that this vowel is susceptible to adjustments (either an increase or a decrease in duration). For almost all speakers, except for Speakers 2 and 6 in Table 5.19, there is an increase in the duration of the final vowel /ɐ/ in ‘qalilha’ before word-initial geminates. On the other hand, for Speakers 2 and 6, there is a decrease in the duration of the final vowel /ɐ/ in ‘qalilha’ before word-initial geminates. The degree of increase varies within and across speakers. For 5 out of the 10 speakers (i.e., Speakers 1, 3, 4, 5 and 8), there is an increase in the duration of the final vowel before word-initial geminates which ranges from 1ms to 13ms. For instance, for Speaker 1, there is an increase of 8ms before lexical geminates of Semitic origin (S: $\bar{x}$=79, sd=11; LGS: $\bar{x}$=87, sd=12); an increase of 6ms before lexical geminates of non-Semitic origin (S: $\bar{x}$=79, sd=11; LGnS: $\bar{x}$=85, sd=13) and an increase of 4ms before assimilated geminates (S: $\bar{x}$=79, sd=11; AG: $\bar{x}$=83, sd=11). For Speakers 7 and 9, there was a greater increase of the duration of the final vowel /ɐ/ in the preceding word ‘qalilha’ than that of the previous mentioned 5 speakers. This is because the range of increase was between 21-39ms. To illustrate, for speaker 7, the duration of the final vowel /ɐ/ before lexical geminates of Semitic origin was 21ms longer than that before singletons (S: $\bar{x}$=110, sd=17; LGS: $\bar{x}$=131, sd=33); the duration of the final vowel before lexical geminates of non-Semitic origin was 22ms longer than that before singletons (S: $\bar{x}$=110, sd=17; LGnS: $\bar{x}$=132, sd=33); and the duration of the final vowel before assimilated geminates was 39ms, i.e. the greatest adjustment for Speaker 7 was before assimilated geminates (S: $\bar{x}$=110, sd=17; AG: $\bar{x}$=149, sd=23). Furthermore, Speaker 10, had the greatest range of increase durations: there was an increase of 47ms of the duration of the final vowel /ɐ/ before lexical geminates of Semitic origin when compared to the duration of the final vowel /ɐ/ before singletons (S: $\bar{x}$=109, sd=31; LGS: $\bar{x}$=156, sd=3); there was an increase of 32ms before lexical geminates of non-Semitic origin when compared to singletons (S: $\bar{x}$=109, sd=31; LGS: $\bar{x}$=141, sd=27); and there was an increase of 46ms before assimilated geminates when compared to singletons (S: $\bar{x}$=109, sd=31; AG: $\bar{x}$=155, sd=40).

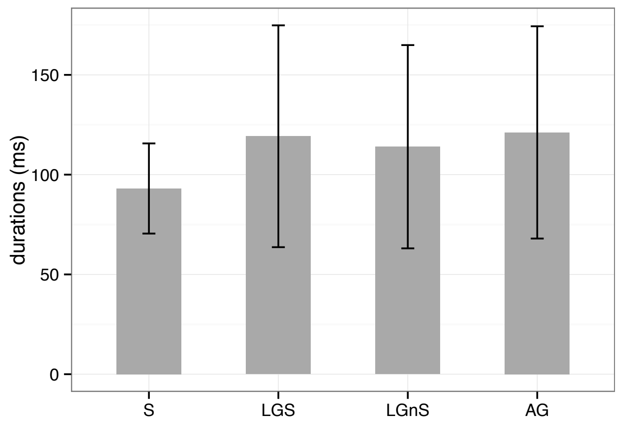
Eight of the ten speakers have to different degrees increased the duration of the final vowel /ɐ/ in the preceding word 'qalilha' before word-initial geminates. In contrast, two speakers (i.e. Speaker 2 and 6) had a decrease in duration of the final /ɐ/ before word-initial geminates. To take speaker 6 as an example, there was a decrease of 10ms before lexical geminates of Semitic origin, compared to their singleton counterpart (S: $\bar{x}$=100, sd=24; LGS: $\bar{x}$=90, sd=17); before lexical geminates of non-Semitic origin there was a decrease of 12ms (S: $\bar{x}$=100, sd=24; LGnS: $\bar{x}$=88, sd=16); and before assimilated geminates there was a decrease of 6ms (S: $\bar{x}$=100, sd=24; AG: $\bar{x}$=94, sd=17). This variability leads me to ask what role this vowel has in perception, and whether an increase or a decrease of its durations helps to perceive geminates better or faster, yet, this still needs to be empirically tested. Furthermore, whether these adjustments have any direct implications on the rhythmical structure of Maltese could also be empirically tested.

5.5.2 Inter-consonantal interval

The duration of final vowel /ɐ/ in the preceding word 'qalilha' was adjusted to various degrees before word-initial geminates. The inter-consonantal interval was measured from the offset of the liquid /l/ in the preceding word 'qalilha' until the start of the target consonant (i.e. either a singleton/geminate) in the target word (refer to Chapter 4 for details on segmentation). The interval spanned across a word boundary. The inter-consonantal interval was measured in order to investigate the adjustments which take place between the last consonant in the preceding word and the start of the following singleton/geminate.

It was expected for the inter-consonantal interval to be shortest before singletons and longest before geminates. The results confirm the prediction made (cf. Figure 5.15): the inter-consonantal interval was shortest before singletons and longest before geminates. Specifically, the inter-consonantal interval was longest before assimilated geminates (AG). The duration of the inter-consonantal interval before singletons was 93ms (sd=23). There was an increase of 26ms from singletons to lexical geminates of Semitic origin (LGS: $\bar{x}$=119, sd=56), an increase of 21ms from singletons to lexical geminates of non-Semitic origin (LGnS: $\bar{x}$=114, sd=51), and an increase of 28ms from singletons to assimilated geminates (AG: $\bar{x}$=121, sd=53). The increased durations of the inter-consonantal interval before geminates suggests that speakers seem to make adjustments before word-initial geminates.

Figure 5.15: Mean durations and error bars represent mean +/- 1 standard deviation of inter-consonantal interval



In order to investigate whether the duration of the inter-consonantal interval is discernably different before singletons and geminates, each Consonant Type was compared to each other. As previously outline in §5.3.4, a linear mixed effects model was constructed with Consonant Type (singleton, lexical geminates of Semitic origin, lexical geminates of non-Semitic origin and assimilated geminates) as fixed effect. The Consonant Type fixed effect was dummy-coded, so that each level was compared to a fixed reference level. In this case, since the duration of the inter-consonantal interval was shortest before singletons, Singletons (S) was chosen as the reference level. Therefore, the mean duration of the inter-consonantal interval before lexical geminates of Semitic origin (LGS), lexical geminates of non-Semitic origin (LGnS) and assimilates geminates (AG) was compared to the reference level (i.e. Singletons (S)). As expected, the mean duration of the inter-consonantal interval before all geminate types was statistically significantly longer than the duration of the interval before geminates (as in Table 5.20).

Table 5.20: Comparing the mean duration of the inter-consonantal interval before singletons (S) to the three geminate types (** = $p < 0.001$, * = $p < 0.01$)

Reference Level	**Compared Level**	***p***
S ($\bar{x}$=93, sd=23)	LGS ($\bar{x}$=119, sd=56)	< 0.01 **
S ($\bar{x}$=93, sd=23)	LGnS ($\bar{x}$=114, sd=51)	< 0.05 *
S ($\bar{x}$=93, sd=23)	AG ($\bar{x}$=121, sd=53)	< 0.01 **

The results for the inter-consonantal interval are discussed in §5.7 below.

5.6 Secondary Correlates

Two secondary correlates were investigated in this study, namely, voice onset time (VOT) and the duration of the tonic vowel. In §5.6.1, I investigate VOT in the voiceless stop /t/ and the voiced stop /d/ as correlates for gemination. In §5.6.2, I investigate the duration of the tonic vowel as a correlate to gemination.

5.6.1 VOT in stops

VOT was measured as the interval between the onset of the release and the onset of the following vowel for both the voiceless stop /t/ and the voiced stop /d/. The mean VOT durations (and standard deviations) of the voiceless and voiced stop, which were pooled across all speakers and preceding word conditions, are presented in Table 5.21.

Table 5.21: Mean VOT duration and standard deviations, pooled across speakers and preceding contexts

	S	**LGS**	**LGnS**	**AG**
Voiceless stop /t/	34 (8)	28 (8)	31 (8)	29 (8)
Voiced stop /d/	17 (4)	18 (5)	20 (5)	20 (16)

The mean duration of VOT is longer for the voiceless stop /t/ than for the voiced stop /d/. This can be compared to results found for Tashlhiyt Berber (Ridouane 2007), where a similar result was reported. For voiceless stops, there is a decrease in VOT from singletons to geminates. The VOT in lexical geminates of Semitic origin was 6ms shorter than singletons (S: $\bar{x}$=34, sd=8; LGS: $\bar{x}$=28, sd=8); the VOT in lexical geminates of non-Semitic origin was 3ms shorter than singletons (S: $\bar{x}$=34, sd=8; LGnS: $\bar{x}$=31, sd=8); and the VOT in assimilated geminates was 5ms shorter than singletons (S: $\bar{x}$=34, sd=8; AG: $\bar{x}$=29, sd=8). For the voiceless stop, singletons have the longest VOT.

On the other hand, singletons had the shortest VOT in the voiced stop /d/. VOT increases slightly in the three geminate types. The VOT in lexical geminates of Semitic origin (LGS) was 1ms longer than singletons (S: $\bar{x}$=17, sd=5; LGS: $\bar{x}$=18, sd=5); the VOT in lexical geminates of non-Semitic origin (LGnS) was 3ms longer than singletons (S: $\bar{x}$=17, sd=5; LGnS: $\bar{x}$=20, sd=5); and the VOT in assimilated geminates (AG) was 3ms shorter than singletons (S: $\bar{x}$=17, sd=5; AG: $\bar{x}$=20, sd=16).

In order to investigate whether the two fixed effects, i.e. Consonant Type and Voicing[56] (voiceless for /t/ and voiced for /d/), contribute to explain the difference in VOT, a model comparison was carried out (cf. Table 5.22). Following Barr et al. (2013), models were built with a maximal random effects structure, this included random intercepts and random slopes for the two fixed effects and their addition. The fixed effects of Consonant Type and Voicing were centered to reduce collinearity. A baseline (model 1) that was made up of only the intercept and the random effects was built. The contribution of the fixed effects: Consonant Type and Voicing were investigated separately (model 2, and model 3). These models were compared to the baseline. A model including Consonant Type and Voicing as fixed effects terms (model 4) was built. Model 4 was compared to model 2 and model 3. Finally, model 4 was compared to a model with the two fixed effects and their interaction (model 5).

Table 5.22: Model goodness of fit: VOT- pooled data (*** = p < 0, * p = 0.01, *n.s.* = not significant)

Model	**Fixed Effects**	**BIC**	χ^2
1	Intercept	7745.4	-
2	Consonant Type	7749.6	2.87 *n.s.* (relative to model 1)
3	Voicing	7739.9	12.563 *** (relative to model 1)
4	Consonant Type + Voicing	7746.7	12.756 *** (relative to model 1)
5	Consonant Type * Voicing	7748.3	5.4292 * (relative to model 4)

The model including Consonant Type (model 2) as a fixed effect does not have a better fit than the baseline. On the other hand, the model including Voicing as a fixed effect (model 3) had a better fit to the data than the baseline, suggesting that VOT depends on whether the stop is voiced or voiceless. The model

[56] Voicing was added as a fixed effect due to the discernable difference in the mean durations of VOT in voiceless and voiced stops.

including both fixed effects (model 4) explains the data better than the intercept, even though it has a higher BIC. Comparisons of model 2 to model 4, show that model 4 has a better goodness-of-fit than model 2, but model 4 does not explain the data any batter than model 3 (Table 5.23).

Table 5.23: Mean VOT duration: further model comparisons (** p = 0.001, *n.s.* = not significant)

Model	χ^2
Model 2, Model 4	9.886 **
Model 3, Model 4	0.1933 *n.s.*

The model that describes the data is model 5, even though it has minutely higher BIC. Therefore, the interaction term seems to work better. As it is shown in Table 5.24, Voicing seems to be the best predictor and it seems to interact with Consonant Type, but Consonant Type alone is not significant. I interpret this to mean that the duration of VOT is comparable in singletons and geminates, but there is an effect of whether the sound is voiced or voiceless.

Table 5.24: Summary of model 5: Consonant Type * Voicing (*** = p < 0, * p = 0.01, *n.s.* = not significant)

Fixed Effects	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	24.5271	1.29609	18.924	4.20e-10 ***
Consonant Type	-0.06386	0.53547	-0.119	0.9072 *n.s.*
Voicing	5.71481	0.86482	6.608	1.76e-05 ***
Consonant Type * Voicing	1.22957	0.42121	2.919	0.0249 *

5.6.2 Duration of the Tonic Vowel

The duration of the tonic vowel in singletons and geminates (e.g., [ˈsɐbbɐr] *sabbar* ‘to console’ and [ɪsˈsɐbbɐr] *ssabbar* ‘to be consoled’) was measured in order to investigate whether its duration serves as a correlate to gemination.

In this production study, the target words in singletons, lexical geminates of Semitic origin and assimilated geminates were controlled to have the vowel /ɐ/ as the tonic vowel. In the case of lexical geminates of non-Semitic origin, for most target words the tonic vowel was /ɐ/ but was followed by the glide /j/, which can potentially form the diphthong /ɐj/. Since singletons and lexical geminates of Semitic origin provided minimal pairs, such as *sabbar* 'to console' and *ssabbar* 'to be consoled', the duration of the tonic vowel in these two conditions were compared. Comparing the duration of the tonic vowel after singletons and lexical geminates (pooled across speakers and preceding word conditions), there was no discernible difference in its duration: (singleton: $\bar{x}$=91, sd=21, lexical geminates of Semitic origin: $\bar{x}$=90, sd=21), i.e. the durations were comparable. This was statistically tested, where a model including just the intercept was compared to a model including Consonant Type (singleton, geminate) as a fixed effect. The results, in Table 5.25, show that the model including Consonant Type as a fixed effect term does not explain the data any better than model 1, which includes just the intercept. Therefore, this confirms the descriptive analysis, that there is no difference in the duration of the tonic vowel after singletons and word-initial lexical geminates of Semitic origin.

Table 5.25: Model goodness of fit- Tonic vowel duration

Model	**Fixed Effects**	**BIC**	χ^2
1	Intercept	10660	-
2	Consonant	10668	0.0088 *not significant*

5.7 Discussion of Production Study 1 (Lexical vs. Surface geminates)

5.7.1 Duration of lexical and surface word-initial geminates

Lexical and surface word-initial geminates in Maltese are significantly longer than singletons. Furthermore, there was no difference in terms of constriction duration between Semitic and non-Semitic originating geminates. This result falls in line with previous research, albeit on other languages (e.g. Tashlhiyt Berber as shown by Ridouane 2010 and Sardinian Italian as shown by Ladd and

Scobbie 2003), which also show that there are no durational differences between lexical and surface geminates.

Overall, there was a difference in constriction duration between the two manners of articulation investigated in this production study: both in terms of actual constriction duration and singleton-to-geminate duration ratio. The duration ratio was longer in stops than in fricatives. This result is not surprising, especially when the results of this experiment are compared to that of other languages (cf. for word-medial geminates see Chapter 3 §3.1 and for word-initial geminates see Chapter 3 §3.2). It is possible that voiceless stops have longer closure durations than voiced stops as it is difficult to maintain voicing over time (Ohala 1983). Furthermore, with respect to voicing and fricatives, it is reported that in some languages voiceless fricatives are longer than voiced fricatives. For instance, Greek voiceless fricatives are longer than voiced fricatives (Nirgianaki et al. 2009).

In light of the results of Production Study 1, Maltese geminate stops were, on average, 2.2 times longer than singletons, whereas, Maltese geminate fricatives were 1.5 times longer than singletons. Voicing also played a role in the difference in duration ratios: voiced stops (/d/ = 1:2.46) and voiced fricatives (/z/ = 1:1.6) had a greater duration ratio than voiceless stops (/t/ = 1:2.18) and voiceless fricatives (/s/ = 1:1.5; /ʃ/ = 1:1.4) respectively.

5.7.2 Insertions before word-initial geminates

Word-initial geminates in Maltese were almost always preceded by a vocalic insertion, when the preceding word ended in a consonant, as in (3). This confirms the claims made in the literature (e.g., Mifsud 1995; Hobermann and Aronoff 2003).

(3) [ʔɐlɪlɔː**m ɪ**ddɐhhɐl]
Qalilhom iddaħħal
'he told them to be entered'

When word-initial geminates were preceded by a word ending in a vowel, as in (4), the inter-consonantal interval was measured. This is because durational adjustments were possible between the final /l/ in the preceding word 'qali**l**ha' and just before the start of the consonant (either singleton or geminate).

(4) [ʔɐlɪl**ɐ** ʃʃɐhhɐm]
Qalilha xxaħħam
'he told her to be fattened'

Furthermore, there were instances for some speakers (but not all) where the vocalic insertion was itself preceded by a glottal stop (cf. 5). Note that when the glottal stop insertion occurred, it was only present before the vocalic insertion which itself preceded the word-initial geminates.

(5) [ʔɐlɪlɔː**m ʔɪ**ddɐhhɐl]
Qalilhom iddaħħal
'he told them to be entered'

The glottal stop insertion before the vocalic insertion before word-initial geminates was not expected to occur. In addition, there is a difference in the number of the speakers that inserted a glottal stop before the vocalic insertion depending on the end of the preceding word. When the preceding word ended in a vowel, i.e. 'qalilha', the number of speakers that inserted a glottal stop before the vocalic insertion increased. This result shows that a vowel hiatus at a word-boundary is repaired by an epenthetic glottal stop (see Davidson and Erker (2014) for a similar result for American English). It is crucial to remember that the result from this production study was subject to within- and across- speaker variation. Other studies have shown that within words and across word-boundaries, vowel hiatus is resolved by the insertion of a glide, such as [j] or [w] (see McCarthy (1993) for English; Kawahara (2003) for Japanese). Furhtermore, glottal stop insertion (and glottalisation) before vowel-initial words is common in American English when such words are at the beginning of a new intonational phrase (cf. Pierrehumbert and Talkin 1992; Dilley et al. 1996). Given the carrier phrases used in this production study (i.e. *qalilhom* ‘he told them’ and *qalilha* ‘he told her’), which are reporting verbs, it is possible that target words were preceded by a glottal stop insertion to mark a new intonational phrase. However, a thorough analysis of this still needs to be carried out. The implications of these insertions before word-initial geminates on the phonological representation of geminates in Maltese are discussed in Chapter 6 §6.5.

5.7.3 Secondary correlates

Two secondary correlates for gemination were investigated for lexical word-initial geminates, namely, VOT and the duration of the tonic vowel. VOT does not serve as a correlate to gemination for lexical and surface word-initial geminates for either voiced or voiceless stops. This is because the duration of VOT for singletons was comparable to that of geminates. As expected, the duration of VOT for voiceless stops was significantly longer than that of voiced stops. I conclude that VOT in Maltese does not serve as a correlate for gemination, just as it does not in Swiss German for word-initial geminates (Kraehenmann 2001); and for word-medial geminates in Levantine Arabic (Ham 2001) or Italian (Esposito and DiBenedetto 1999).

The duration of the tonic vowel for singletons and geminates was also comparable and therefore, in this case, it does not serve as a cue to gemination. In this production study, pairs such as /'dɐhhɐl/ ‘to insert’ and /d'dɐhhɐl/ ‘to be entered’ were investigated. It is possible that the duration of the tonic vowel is comparable in such pairs, since there is a medial geminate and vowel shortening might be expected to occur in pairs such as /dɐ**h**ɐl/ ‘to enter’ and /dɐ**hh**ɐl/ ‘to insert’, where the former has a word-medial singleton and the latter has a word-medial geminate (this is investigated in Chapter 7 §7.4).

5.8 Conclusion

The most distinguishable feature of word-initial geminates in Maltese is the insertion of the epenthetic vowel, [ɪ]. Despite the fact that this feature was consistent when the preceding word ended in a consonant, and less so when the preceding word ended in a vowel, the inter-consonantal interval, in the case of a preceding word ending in a vowel, shows that there is an increase in duration of the segmental material before geminates and singletons. Therefore, phonetic adjustments are taking place before word-initial geminates, even when the previous word ends in a vowel.

In Chapter 6, I compare the production word-initial geminates/singletons to word-medial geminates/singletons across different manners of articulation.

Chapter 6: Production Study 2 - Comparing word-initial and word-medial geminates in Maltese

The results from Production Study 1, in Chapter 5, show that in Maltese, word-initial geminates have a similar syllable structure as word-medial geminates. In Production Study 2, this chapter, word-initial geminates were compared to word-medial geminates. In this production study, the corpus consisted of target consonants from different manners of articulation, unlike Production Study 1, where manner was restricted to stops and fricatives. This was done in order to make: 1) a cross manner of articulation comparison of the durations of gemination and 2) cross-linguistic comparisons with other languages that have geminates. The duration ratios for singleton-geminate pairs in word-initial and word-medial position were compared. Moreover, in the case of word-initial geminates the occurrence of insertions before geminates of different manners of articulation are reported.

The chapter is structured as follows: while the overall methodology is described in Chapter 4, in §6.1, aspects specific to the present study are described. In §6.2, the results for constriction duration are discussed. This is followed by an analysis of insertions before word-initial geminates in §6.3. Moreover, VOT in stops as a secondary correlate to gemination is presented in §6.4. Finally, the chapter concludes, in §6.5, with an overall discussion of the results.

6.1 Methodology

6.1.1 Goals of the experiment

In Production Study 2, word-initial geminates were compared to word-medial geminates. The results from Production Study 1 (Chapter 5) confirmed claims in the literature, in such a way that a vocalic insertion was almost always present before a word-initial geminate. Due to this, word-initial and word-medial geminates are considered to have similar representations. This is because word-medial geminates, by definition, are flanked between two vowels (as in 1a) and the results from Production Study 1 show that word-initial geminates also require a vowel before them and have a vowel following them (c.f. 1b).

(1) Geminates in Maltese
   (a) [fɛ**jj**ɐʔ] *fejjaq* ‘he cured’
   (b) [ɪ**ss**ɐbbɐr] *ssabbar* ‘he consoled’

Production Study 2 compares the duration ratios of geminates in the two different positions, in order to investigate whether the same phonological phenomenon leads to different phonetic realizations in different positions in a word.

6.1.2 Speech Material

In Production Study 1 target consonants were restricted to stops and fricatives. In this experiment, target consonants included stops and fricatives, but also other manners of articulation. The target consonants (singletons and geminates) in word-initial and word-medial position included voiceless stops, voiceless fricatives, voiceless affricates, liquids, and nasals, as shown in Table 6.1.

Table 6.1: Manners and segments for Production Study 2

Manner	**Segment**
Stops	/p t k/
Fricatives	/f s ʃ/
Affricate	/tʃ/
Liquid	/l/
-	/r/
Nasal	/m n/

Target words were presented in a carrier phrase. The word preceding the target words was either *qallek* ‘he told you’ or *qalet* ‘she said’, as in (2) and (3). The interchange of the preceding words occurred in order to avoid homorganic sequences beginning with the same segment.

(2) **Qallek**	____________	mitt darba
PRECEDING WORD	**TARGET WORD**	**REST OF THE PHRASE**
'he told you	____________	**a hundred times'**

(3) **Qalet**	____________	mitt darba
PRECEDING WORD	**TARGET WORD**	**REST OF THE PHRASE**
'she said	____________	**a hundred times'**

For all of the items in this production study, in the case of word-initial singletons: the target consonant was in both word-initial and syllable-initial position. However, in the case of word-medial singletons, the target consonant was in word-medial position but in syllable-iniital position.

For both the word-initial and word-medial condition and for each segment, 3 singleton and geminate pairs were chosen. Table 6.2 shows one target word example pair for all the manners of articulation investigated in this study in word-initial and word-medial position.[57] This yielded 33 word-initial singleton-geminate pairs and 33 word-medial singleton-geminate pairs. Therefore, a total of 132 target words per speaker. This led to 792 tokens for word-initial target words and 792 for word-medial target words, a total of 1584 tokens. Participants were presented with 132 target words and 132 filler items. 30% of the filler items were singleton and geminate pairs, while the other 70% were singleton and onset cluster pairs, vowel initial and glottal stop initial pairs.

[57] A full list of examples is shown in Appendix 2.

Table 6.2: Target items examples from one manner of articulation

		Word-initial		Word-medial	
Manner	**Segment**	**Singleton**	**Geminate**	**Singleton**	**Geminate**
Stop	**/p/**	/ˈ**p**ɐt.pɐt/ *patpat* 'to tap'	/**p.ˈp**ɐk.ja/ ppakja 'to pack'	/sɐ.ˈ**p**ʊn/ *sapun* 'soap'	/dʒɐ**p.ˈp**ʊn/ *Ġappun* 'Japan'
Fricative	**/f/**	/ˈ**f**ɪr.mɐ/ *firma* 'signature'	/**f.ˈf**ɪr.mɐ/ *ffirma* 'to sign'	/nɛ.ˈ**f**ɐʔ.lʊ/ *nefaqlu* 'he spent on him'	/nɛ**f.ˈf**ɐʔ.lʊ/ *neffaqlu* 'he made s.o. spend on him'
Affricate	**/tʃ/**	/ˈ**tʃ**ɐhhɐd/ *ċaħħad* 'to deprive s.o. of s.th'	/**tʃˈtʃ**ɐhhɐd/ *ċċaħħad* 'to deprive oneself'	/tʃʊˈ**tʃ**ɐtɐ/ *ċuċata* 's.th stupid'	/ʔʊ**tʃˈtʃ**ɐtɐ/ *quċċata* 'peak'
Liquid	**/l/**	/ˈ**l**ɪbɛru:/ *liberu* 'free'	/**lˈl**ɪbɛrɐ/ *llibera* 'to set free'	/tɛˈ**l**ɐʔlʊ/ *telaqlu* 'he left him'	/tɛ**lˈl**ɐʔlʊ/ *tellaqlu* 'he raced him'
-	**/r/**	/ˈ**r**ɐbjɐ/ *rabja* 'anger'	/**rˈr**ɐbjɐ/ *rrabja* 'to get angry'	/fɛˈ**r**ɐhlʊ/ *feraħlu* 'he was happy for him'	/fɛ**rˈr**ɐhlʊ/ *ferraħlu* 'he made him happy'
Nasal	**/m/**	/ˈ**m**ɐrkɐ/ *marka* 'mark'	/**mˈm**ɐrkɐ/ *mmarka* 'to mark'	/ɛ:ˈ**m**ɪzlʊ/ *hemiżlu* 'he winked at him'	/ɛ:**mˈm**ɪzlʊ/ *hemmiżlu* 'he winked at him'

6.1.3 Participants

Twelve (6 males, 6 females) native speakers of Standard Maltese were recruited for this production study, none of whom had participated in Production Study 1. All participants in Production Study 2 were Maltese-dominant speakers. Eleven out of the twelve participants were students at the University of Malta at the time of recording. The participants were between 19 and 29 years of age (mean age = 22, median = 25).

6.1.4 Hypotheses

The duration of geminates in word-initial and word-medial position is expected to be longer than that of singletons in their respective positions. Due to the results of Production Study 1, I expect word-initial geminates to be predominantly preceded by a vocalic insertion. As I argue in the discussion of the results of Production Study 1, the vocalic insertion before word-initial geminates leads to a structure which is similar to word-medial geminates: namely a syllabic structure of VGV, where both word-initial and word-medial geminates are preceded and followed by a vowel. I predict that, since there is similarity in syllable structure, the duration of word-initial and word-medial geminates to be comparable.

In this production study, I extend the manners of articulation under investigation. It is expected for /r/ to have the longest singleton-to-geminate ratio, and this is followed by the nasals /m n/, the liquid /l/, the stops /p t k/, the fricatives /f s ʃ/ and the affricate /tʃ/. This prediction is based on the overview of duration ratio presented in Chapter 3 §3.1 for word-medial geminates. I expect word-initial singleton-to-geminate ratio to follow a similar pattern.

Voice onset time (VOT) is measured as a secondary correlate for gemination. In Production Study 1, the VOT of the voiced stop /d/ and the voiceless stop /t/ was measured. The result showed that the duration of VOT for stops does not serve as a correlate to gemination. In this study, I predict that VOT is not a correlate for gemination, but I expect to find differences in the duration of VOT in the three different places of articulation (i.e. bilabial, alveolar and velar).

6.2 Results: Constriction Duration

The results regarding the constriction duration of geminates and singletons from Production Study 2 are presented in this section. In §6.2.1, I present the overall constriction duration, which is pooled across all speakers and manner of articulation. In §§6.2.2, I explore the duration of the different manners of articulation and I statistically test which fixed effects affect constriction duration. In §6.2.3, I show whether there is a difference in terms of constriction duration between geminates/singletons in initial and in medial position. In §6.2.4, I provide the singleton-to-geminate duration ratios across all manners of articulation under investigation. In §6.2.5, I explore the constriction duration of affricates. In §6.2.6, I summarize the key findings.

6.2.1 Overall Constriction Duration

As expected, word-initial and word-medial geminates were longer than their respective singleton counterparts. Table 6.3 shows the mean durations of singletons and geminates in initial and medial position.

Table 6.3: Mean duration and standard deviations of singletons and geminates in word-initial and word-medial position, pooled across all speakers and manners of articulation

Position	Singleton	Geminate
Initial	98 (53)	158 (37)
Medial	79 (30)	146 (33)

Overall, initial geminates are 60ms longer than initial singletons, whereas initial geminates are 67ms longer than medial geminates. Furthermore, initial singletons are 19ms longer than medial singletons, whereas initial geminates are 12ms longer than medial geminates. The pooled means across all speakers and manners of articulation show that initial singletons and geminates are longer than medial singletons and geminates.

6.2.2 Constriction duration: Comparing different manners of articulation

In a number of studies on word-medial geminates, as discussed in Chapter 3 §3.1, a common pattern across many languages is for sonorants (such as liquids, nasals and approximants) and for stops to have longer geminate durations. The durations of fricatives varies in a number of these languages. In Production Study 1, stops were longer than fricatives. Table 6.4 provides the means and standard deviation of the constriction duration for fricatives, liquids, approximant and nasals and closure duration for stops. As the overall means have shown (cf. Table 6.3), initial singletons and geminates are longer than medial singletons and geminates (except for word-initial affricate geminates which are shorter than word-medial affricate geminates).

Table 6.4: Mean constriction duration and standard deviation by manner and position

Manner	**Initial**		**Medial**	
	Singleton	Geminate	Singleton	Geminate
Affricate	165 (57)	183 (31)	127 (24)	194 (26)
Fricative	116 (36)	185 (28)	104 (17)	174 (18)
Liquid	69 (28)	134 (22)	56 (15)	118 (20)
/r/	80 (31)	125 (26)	48 (18)	111 (20)
Nasal	94 (79)	148 (29)	69 (17)	135 (21)
Stops	77 (31)	143 (33)	62 (17)	135 (22)

The difference in constriction duration between geminates and singletons was overall greater in medial position than in initial position. Affricate geminates in initial position were 18ms longer than singletons, whereas affricate geminates were 67ms longer in medial position than singletons. The duration of geminate /r/ in initial position was 45ms longer than singletons, whereas the duration of geminate/r/ in medial position were 63ms than singletons. Nasal geminates in initial position were 54ms longer than singletons, whereas in medial position, nasal geminates were 66ms longer than singletons. Stop geminates in initial position were 66ms longer than singletons, whereas, in medial position, stop geminates were 73ms longer than singletons. The difference between fricative geminates and singletons in initial and medial position was comparable: 65ms in initial position and 67ms in medial position. Furthermore, the difference between liquid geminates and singletons was slightly greater in initial position (Δ=65ms) than in medial position (Δ=62ms).

Figure 6.1: Mean constriction duration and error bars mean of +/-1 standard deviation of *singletons* across all manners of articulation

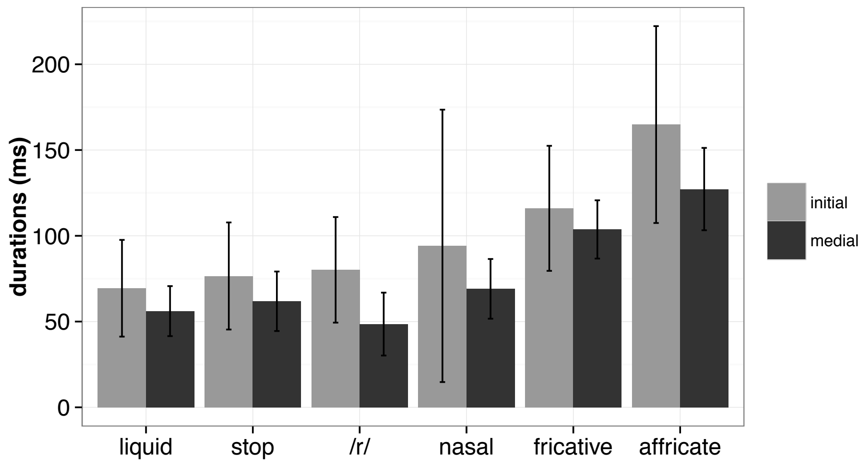
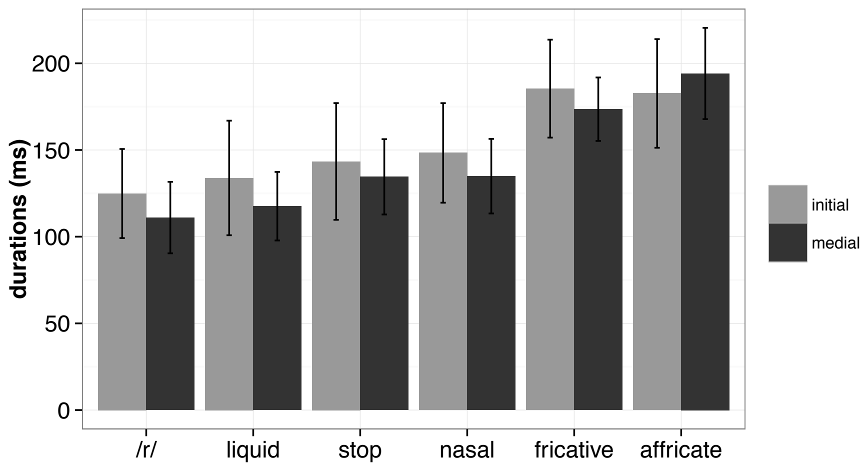


Figure 6.2: Mean constriction duration and error bars mean of +/-1 standard deviation of *geminates* across all manners of articulation



In order to investigate the contribution of the singleton/geminate, manner and word position fixed effects towards explaining the variation in the data, a model using these three variables as fixed effects was built.

As previously reported in Chapter 5 §5.2.4, all data were analysed using linear mixed-effect models and a model comparison approach was adopted. All models included random intercepts for speakers and items. Due to problems of model convergence, the models were constructed by omitting covariance from the variance-covariance matrix. Since this did not fully resolve the problem, random slopes were only included for speakers. The fixed effects of Consonant Type (S, G), Manner (i.e. plosives /p, t, k/; fricatives /f, s, ʃ/, affricate /tʃ/, liquid /l/; /r/ and nasals /m, n/) and Position (initial or medial) were centered to reduce collinearity.

A baseline (model 1), which was made up of only the intercept and the random effect was built. The contribution of the fixed effects of Consonant Type, Manner and Position were investigated separately and were compared to the baseline (i.e. models 2, 3 and 4 respectively). Given the results in Production Study 1, it is already known that a model including Consonant Type and Manner explains the data better than that with just an intercept, therefore, this model (5) was compared to a model with the three fixed effects: Consonant Type, Manner and Position (model 6). Finally, model 6 was compared to a model with the fixed effects and their interaction (model 7).

The models including the individual fixed effects (i.e. models 2, 3, 4 in Table 6.5) had a better fit to the data than the baseline, suggesting that the duration of constriction depends on all three main effects: Consonant Type, Manner and Position. The model that fit the data best was model 6, where all fixed effect terms were included in the model. A model which includes the main effects with their interactions did not improve the model fit, as shown by the comparison of model 7 to model 6. Therefore, this shows that consonant type, manner and word position play a role in explaining the differences in constriction duration.

Table 6.5: Model Comparison: Production Study 2 (*** = p < 0; ** = p < 0.001, *n.s.* = not significant)

Model	Fixed Effects	BIC	χ^2
1	Intercept	15049	-
2	Consonant Type	15008	48.248 *** (relative to model 1)
3	Manner	15024	32.72 *** (relative to model 1)
4	Position	15050	6.9576 ** (relative to model 1)
5	Consonant Type + Manner	14983	81.028 *** (relative to model 1)
6	Consonant Type + Manner + Position	14983	6.9008 ** (relative to model 5)
7	Consonant Type * Manner * Position	15009	3.5807 *n.s.* (relative to model 6)

In Table 6.6, the full model with all main effects is compared to each of the models with only one main effect. This shows that the incorporation of all three fixed effects together makes for a better goodness-of-fit than any one alone.

Table 6.6: Model Comparisons: Consonant, Manner, Position (*** = p < 0)

Model Comparisons	χ^2
Model 2, Model 6	39.681 ***
Model 3, Model 6	55.209 ***
Model 4, Model 6	81.045 ***

Model 6 (a summary of which can be found in Table 6.7) explains the data best. The summary in Table 6.7 shows that constriction duration is effected by the three fixed effects. The results for Constant Type confirms the findings of Production Study 1, Consonant Type also effected constriction duration. This confirms that singletons are shorter than geminates. In addition, Manner in Production Study 1, also played a role in describing the differences in constriction duration. This result is also present here.

Table 6.7: Summary of Model 6: Consonant + Manner + Position (*** = p < 0; ** = p < 0.001)

Fixed Effects	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	120.114	4.328	27.750	4.44e-16 ****
Consonant Type	-31.767	2.221	-14.300	<2e-16 ***
Manner	-14.906	2.124	-7.017	2.78e-10 ***
Position	-7.473	2.702	-2.765	0.00855 **

6.2.3 Word-position: Initial vs. medial

The overall mean durations in Table 6.3 indicate that initial singletons and geminates are longer than medial singletons and geminates, respectively. In order to investigate this further, the mean durations of singletons and geminates in initial and medial position were compared. In this case, statistics were run separately for singletons and geminates. The models included random intercepts for speakers and items. Random slopes were used only for speakers and not for items due to issues of convergence. The fixed effect was Position (initial, medial).

Table 6.8: Model summary for *Singletons* (*** = p < 0)

Fixed Effects	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	88.123	5.141	17.140	<2e-16 ****
Position	-9968	4.269	-2.335	0.0237 ***

Table 6.9: Model summary for *Geminates* (*** = p < 0, *n.s.* = not significant)

Fixed Effects	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	152.057	5.272	28.841	<2e-16 ***
Position	-5.470	3.511	-1.558	0.124 *n.s.*

The results (in Table 6.8) show that initial singletons were significantly longer than medial singletons ($p<0.001$; Initial Singletons: $\bar{x}$=98ms, sd=52; Medial Singletons: $\bar{x}$=79ms, sd=30; Δ=19ms). However, the durations of initial and medial geminates (in Table 6.9) were not statistically significantly different from each other as the durations did not reach significance: ($p=0.1$; Initial Geminates: $\bar{x}$=158ms, sd=37; Medial Geminates: $\bar{x}$=146ms, sd=33; Δ=12ms). This suggests that there is an interaction of Consonant Type and Position for singletons but not for geminates. Therefore, in production, initial singletons are longer than medial singletons; however, the duration of geminates in the two positions are comparable- whether this difference has a role in perception is yet to be found.

6.2.4 Duration Ratios

Following Aoyama and Reid (2006), it was expected that nasals would have the longest duration ratio, followed by stops, fricatives and liquids and approximants. Furthermore, affricates were expected to have the shortest duration ratio (cf. Aoyama and Reid 2006; Pycha 2007). In Production Study 1, duration ratios for stops were larger than for fricatives (1:2.4 for stops and 1:1.4 for fricatives). When comparing word-initial to word-medial singletons and geminates, duration ratios were larger in word-medial position (Table 6.10). On comparing the different manners of articulation, word-initial liquids had the longest duration ratio, followed by stops, approximants, fricatives, and nasals. As predicted, affricates had the shortest duration ratio. In word-medial position, approximants had the longest duration ratio, followed by liquids, stops, nasals, fricatives and affricates. Across the two word-positions, affricates had the shortest duration ratio, whereas, liquids had the longest duration ratio in word-initial position and approximants in word-medial position.

Table 6.10: Singleton-to-geminate duration ratios in initial and medial position

Manner	**Initial**	**Medial**
Affricate	1:1.1	1:1.5
Fricative	1:1.6	1:1.7
Liquid /l/	1:1.9	1:2.1
Approximant /r/	1:1.6	1:2.3
Nasal	1:1.6	1:1.9
Stops	1:1.8	1:2

6.2.5 Focus on the duration of affricate singletons and geminates

Geminate affricates are reported to have shorter durations (and in turn also duration ratios) than geminates with other manners of articulation (cf. Aoyama and Reid 2006; Pycha 2007; 2008). Few studies have investigated the affect of gemination on the stop portion of the affricate, which corresponds to the closure duration; and the frication portion, which corresponds to the aperiodic fricative noise. For instance, in Hungarian, which has geminates in medial position, gemination affects only the stop portion of affricate geminates. Pycha (2007; 2009) shows that while there is a large increase in the duration of the stop portion in geminates, there is only a small increase in the duration of the frication portion. Unlike the results presented by Pycha (2007; 2009), Faluschi & Di Benedetto (2000)'s study on affricates in word-medial geminates in Italian illustrates that both the stop and the frication portions are affected by gemination.

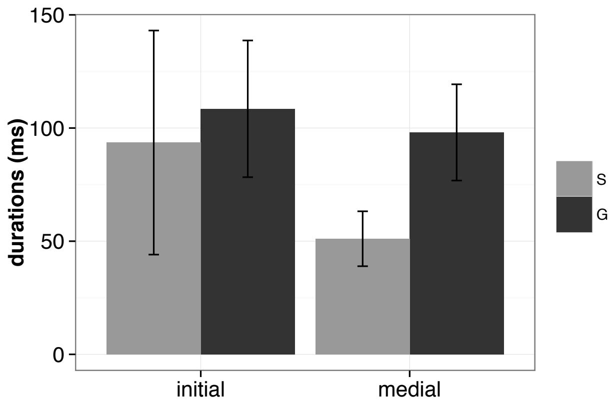
The principle aim of this analysis is to investigate how phonological length affects the duration of the stop and frication portions of the affricate in word-initial and word-medial geminates in Maltese. As shown above in Table 6.10, like all other manners of articulation, affricate geminates are longer than singletons (even though the degree to which affricate geminates are longer is less than other manners of articulation, especially in word-initial position). However, I wanted to further explore how the stop and frication portions of the affricate adjust (i.e. either increase or decrease in duration) because of gemination. To do so, the stop portion of the affricative was segmented from the release of the previous stop consonant until the start of the release burst. The fricative portion of the affricate was segmented from the onset of the aperiodic noise until the start of the vowel formants (c.f. Chapter 4).

Table 6.11: Mean duration and standard deviations for stop and frication portion in affricates

	Singleton		**Geminate**	
Position	**Stop**	**Frication**	**Stop**	**Frication**
Initial	94 (50)	70 (14)	108 (30)	74 (14)
Medial	51 (12)	75 (19)	98 (21)	96 (18)

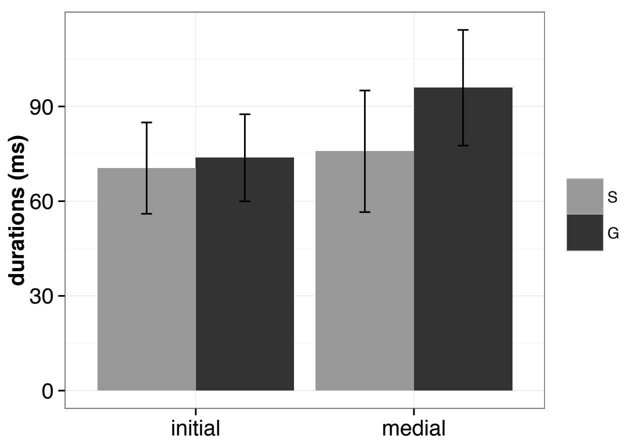
The duration of the stop portion was longer in initial position for singleton and geminates than in medial position (cf. Figure 6.3). Furthermore, the duration of the stop portion was longer in geminates than in singletons in both word-initial and word-medial position (cf. Table 6.11). There was a slight increase in the duration of the stop portion in geminates, from singletons, in initial position (Δ=14ms; duration ratio 1:1.1). However, the duration of the stop portion in geminates in medial position noticeably increased (Δ=47ms; duration ratio 1:1.9).

Figure 6.3: Mean duration and error bars mean of +/-1 standard deviation of stop portion in affricates in singletons and geminates



Gemination did not affect the frication portion in word-initial position (c.f. Figure 6.4); this is because the durations of the frication portion in singletons and geminates were comparable (frication portion in initial singletons: $\bar{x}$=70, sd=14; frication portion in initial geminates: $\bar{x}$=74, sd=14). However, there was a noticeable difference in the frication portion between singletons and geminates in word-medial position. There was an increase of 21ms in the frication portion from singletons to geminates.

Figure 6.4: Mean duration and error bars mean of +/-1 standard deviation of frication portion in affricates in singletons and geminates



In order to investigate whether the two fixed effects, i.e. Consonant Type and Position (i.e. initial or medial) contribute to explain the difference between the stop and frication portions in affricates in singletons and geminates, two separate analyses were carried out, one on the stop portion, the other on the frication portion, both involving a model comparison approach. Table 6.12 includes the model comparison for the stop portion and Table 6.14 includes the model comparison for the friction portion. The baseline model, model 1, was compared to the contribution of the fixed effects separately, model 2 and model 3, respectively. A model including Consonant Type and Position as fixed effects terms (model 4) was built. This was compared to the baseline. Model 4 was also compared to model 5 that included an interaction term.

Table 6.12: Model goodness of fit: Stop portion (*** = $p < 0$; ** = $p < 0.001$)

Model	**Fixed Effects**	**BIC**	χ^2
1	Intercept	1294.9	-
2	Consonant Type	1287.0	12.792 *** (relative to model 1)
3	Position	1292.5	7.286 ** (relative to model 1)
4	Consonant Type + Position	1284.6	20.09 *** (relative to model 1)
5	Consonant Type * Position	1281.4	8.1814** (relative to model 4)

Both fixed effects contribute in explaining the data better. The model that explains the data best is model 5 (cf. Table 6.13), when Consonant Type is in an interaction with Position. This suggests that stop portion is not only affected by whether it is a singleton or a geminate, but also whether the stop portion is in word-initial or word-medial position. This suggests that there is an impact of Position on duration, but this depends on whether there is a singleton or a geminate consonant.

Table 6.13: Summary of Model 5: Consonant Type * Position (*** = p < 0; ** = p < 0.001)

Fixed Effects	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	88.587	5.483	16.155	1.61e-09 ***
Consonant Type	-14.737	3.104	-4.749	0.000433 ***
Position	-14.046	4.188	-3.354	0.005649 **
Consonant Type * Position	-8.848	2.589	-3.417	0.005032 **

In the case of the friction portion, the contribution of Consonant Type and Position separately do not explain the data any better than the baseline. The addition of an interaction term does not explain the data better. Model 4, which includes both fixed effect terms, explains the data better than the baseline, despite the slightly higher BIC value. This suggests that friction duration is affected by whether the affricate is a singleton or a geminate and its position within the word. Word-medial affricate geminates have a longer friction portion when compared to word-initial geminates (cf. Figure 6.4).

Table 6.14: Model goodness of fit: Friction portion (*n.s.* = not significant, * = p < 0.01)

Model	Fixed Effects	BIC	χ^2
1	Intercept	1118.8	-
2	Consonant Type	1120.9	2.7585 *n.s.* (relative to model 1)
3	Position	1119.9	3.707 *n.s.* (relative to model 1)
4	Consonant Type + Position	1121.0	7.5925 * (relative to model 1)
5	Consonant Type * Position	1123.1	2.7293 *n.s.* (relative to model 4)

6.2.6 Interim Summary: Constriction duration

Geminates in word-initial and word-medial positions are longer than singleton counterparts. Constriction duration for singletons and geminates depend on both their manner of articulation and their position in the word. The singleton-to-geminate duration ratios show that in word-initial position, liquid /l/ has the longest duration ratio. This is followed by stops, /r/, nasals and fricatives. In word-medial position, a different sequence is found, /r/ has the longest singleton-to-geminate ratio, and this was followed by the liquid /l/, the stops, nasals and fricatives. In both word positions, affricates have the shortest singleton-to-geminate ratio. In terms of position, the duration of geminates in word-initial and word-medial position are comparable. This result lines up with the prediction that since word-initial and word-medial geminates in Maltese have a similar structure (where they are both preceded by a vowel), their acoustic manifestation is similar, thus, resulting in comparable durations. This contrasts with the results for singletons in word-initial position, which are discernably longer than singletons in word-medial position. These two points are picked up in the discussion (§6.5).

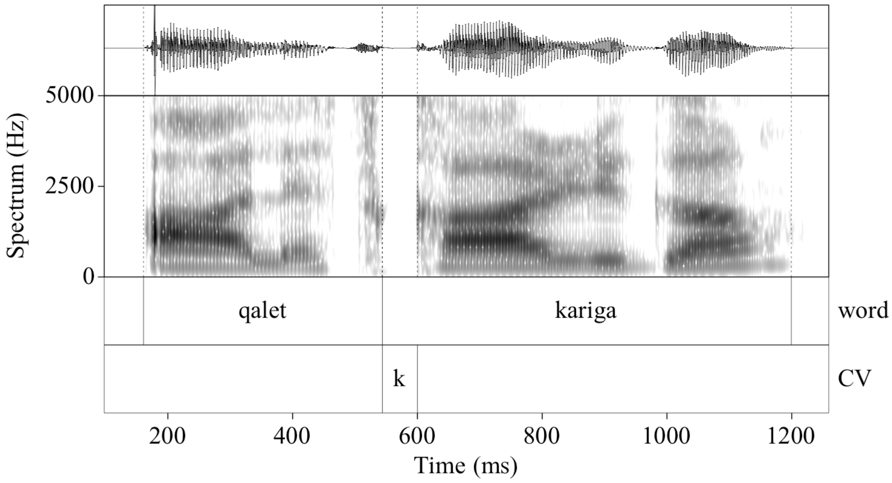
6.3 Insertions preceding word-initial geminates

Following the results in Production Study 1, where lexical and assimilated word-initial geminates were compared, a vocalic insertion was almost always present before all word-initial geminate tokens (96%). Therefore, it was expected that word-initial geminates in Production Study 2 would be preceded by a vocalic insertion. The results are presented as follows: in §6.3.1, I show the number of insertions before all speakers; in §6.3.2, I investigate the duration of the vocalic insertion and compare it to the results in Production Study 1; in §6.3.3, I count the number of glottal stop insertions before the vocalic insertion.

6.3.1 Number of vocalic insertions preceding word-initial geminates

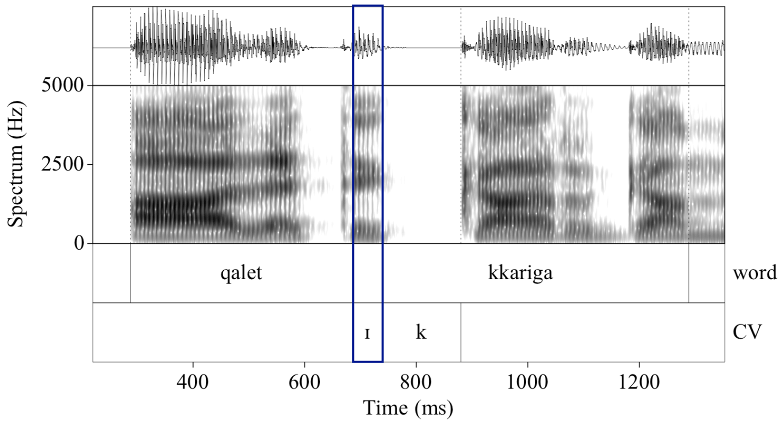
Singletons were never preceded by a vocalic insertion. There were no formant structures between the final consonant in the previous word (i.e., /t/ in '*Qalet*') and the initial consonant in the following target word, in this case /k/ in *kariga* 'charge'. Figure 6.5 shows a typical example of this.

Figure 6.5: No vocalic insertions before singleton /k/ in *kariga* 'charge'



In the case of word-initial geminates, clear vowel formants between the release of the final consonant in the previous word (i.e., /k/ in '*Qallek*') and the geminate consonant could be identified (cf. Figure 6.6). Word-initial geminates in this production study, like word-initial geminates in Production Study 1, were almost always preceded by a vocalic insertion (cf. Table 6.18), unlike singletons. Table 6.18 below shows the number of vocalic insertions per speaker; the maximum number of insertions per speaker was 33.

Figure 6.6: Segmentation of vocalic element before geminate /k/ in kkariga ‘to be charged’



Overall, speakers often inserted a vocalic element before word-initial geminates in this production study (cf. Table 6.15). The insertion of a vowel before word-initial geminates was subject to across- and within-speaker variation. Variability in the number of insertions was also found in Production Study 1.

Table 6.15: Vocalic insertions per speaker in Production Study 2

Speaker	Number of vocalic insertions
1	31 (94%)
2	17 (52%)
3	24 (73%)
4	25 (76%)
5	32 (97%)
6	33 (100%)
7	29 (88%)
8	31 (94%)
9	26 (79%)
10	29 (88%)
11	33 (100%)
12	32 (97%)

The number of insertions before each segment was investigated. This was done in order to see if any of the segments have higher numbers of vocalic insertions than others. Table 6.16 below shows the frequency of vocalic insertions by manner and segment. The maximum number of insertions was 36 per segment as these were the total number of cases where insertions could appear.

Table 6.16: Vocalic insertions per segment in Production Study 2

Manner	**Segment**	**Number of vocalic insertions**
Affricate	/tʃ/	30 (83%)
Fricative	/f/	28 (78%)
	/s/	31 (86%)
	/ʃ/	33 (92%)
Stop	/p/	34 (94%)
	/t/	32 (89%)
	/k/	31 (86%)
Nasal	/m/	32 (89%)
	/n/	31 (86%)
Liquid	/l/	29 (81%)
-	/r/	31 (81%)

The number of vocalic insertions before sonorants and obstruents was comparable. Therefore, the vocalic insertion was not conditioned by whether the geminate consonant is an obstruent or a sonorant. In Maltese, the sonorants /l m n r/ can either be syllabic in word-initial position in an onset consonant sequence (e.g. [m̩hɐːr] *mħar* 'clams') or else they can be preceded by a vowel of [ɪ]-like quality (e.g. [ɪmhɐːr] *mħar* 'clams'). However, the literature on Maltese does not discuss whether word-initial sonorant geminates are syllabic or not. Since there are no discrepancies in the frequency of occurrence between obstruents and sonorants (cf. Table 6.19), I argue that sonorants, just like obstruents, need a vowel to repair the structure. If sonorant geminates were truly syllabic, fewer insertions would be expected. This can possibly also be extended to word-initial sonorant consonant sequences, which might be preceded by the vowel [ɪ]. This would weaken the claim that the sonorants (either as singletons in an onset initial consonant sequences such as /lt, ms/ or as word-initial geminates such as /ll, mm/) in Maltese are syllabic.

6.3.2 Duration of vocalic insertion preceding word-initial geminates

In this production study, the mean duration for the vocalic insertion before word-initial geminates was 51ms (pooled in across all speakers and manners of articulation). This duration of the vocalic insertion in this production study is comparable to vocalic insertion in Production Study 1 (duration in Production Study 1 $\bar{x}$=48ms, sd=12; duration in Production Study 2 $\bar{x}$=51; sd=15). The duration of the vocalic insertion was subject to across- and within-speaker variation (cf. Table 6.17). The range of the mean duration of the vocalic insertion was between 43ms and 56ms.

Table 6.17: Duration of vocalic insertion by speaker in Production Study 2

Speaker	Duration of vocalic insertion
1	54 (11)
2	46 (8)
3	55 (15)
4	43 (14)
5	44 (15)
6	45 (8)
7	55 (13)
8	55 (14)
9	51 (9)
10	54 (15)
11	56 (11)
12	55 (25)

6.3.3 Glottal Stop Insertion before vocalic insertions before word-initial geminates

As in Production Study 1, there were a number of cases where the vocalic insertion was preceded by a glottal stop insertion. This was susceptible to both within- and across- speaker variation. In Production Study 2, there were six speakers that glottalised before the vocalic insertion that preceded word-initial geminates. However, only three were frequent glottalisers (Speakers 1, 4 and 9). Table 6.18 shows the number of glottalisation before vocalic insertion per speaker- the possible number of cases for such insertion was 33 per token.

Table 6.18: Glottalisation preceding vocalic insertion in Production Study 2

Speaker	Count of glottalisation
1	11/33 (33%)
2	3/33 (9%)
4	15/33 (45%)
5	1/33 (3%)
8	2/33 (6%)
9	9/33 (27%)

6.4 Secondary correlate: VOT in voiceless stops

VOT for the voiceless stops /p t k/ was measured for both singletons and geminates in word-initial and word-medial position. A difference in VOT in singletons and geminates was not expected, following the results in Production Study 1. However, VOT differences among the three places of articulation (i.e. bilabial, alveolar and velar) were expected. The VOT for the velar stop /k/ was expected to have the longest duration and the VOT for the bilabial stop /p/ was expected to have the shorter VOT duration (cf. Lisker and Abramson 1964; Cho and Ladefoged 1999). The data from this production study (cf. Table 6.19) shows this expected pattern: VOT was longest in the velar stop /k/, shortest in /p/ and intermediate for /t/ (this results corroborates Azzopardi's 1981 findings).

Figure 6.7 and Figure 6.8 show the mean durations of VOT in singletons and geminates respectively. The VOT of singleton /p/ in initial and medial position are only slightly longer than that of geminate /p/, a difference of 3ms. Across positions, initial singleton /p/ is 6ms shorter than medial singleton /p/ and initial geminate /p/ is 6ms shorter than medial geminate /p/. A similar result is found for /t/, where there a 2ms difference in VOT between singleton and geminate /t/ in initial position. The difference in VOT between singleton and geminate /t/ is greater in medial position, there's a difference of 10ms. Across position, the VOT of singletons in /t/ are comparable (there's only 1ms difference between initial and medial position), whereas, the VOT of geminate /t/ there's a 10ms difference between initial and medial position. In the velar stop /k/, the mean VOT duration in initial position is the same for singletons and geminates. In medial position, the mean VOT duration for singletons and geminates was also comparable, there is a difference of 1ms. Across positions, initial singletons are 5ms shorter than medial singletons; and initial geminates are 6ms shorter than medial geminates.

Table 6.19: Mean VOT and standard deviation by place of articulation

	Initial		**Medial**	
Place	**Singleton**	**Geminate**	**Singleton**	**Geminate**
Bilabial (/p/)	25 (10)	22 (7)	31 (11)	28 (9)
Alveolar (/t/)	34 (8)	32 (10)	33 (8)	23 (5)
Velar (/k/)	38 (7)	38 (9)	43 (9)	42 (10)

Figure 6.7: Mean VOT and error bars mean of +/-1 standard deviation for *singletons* by segment

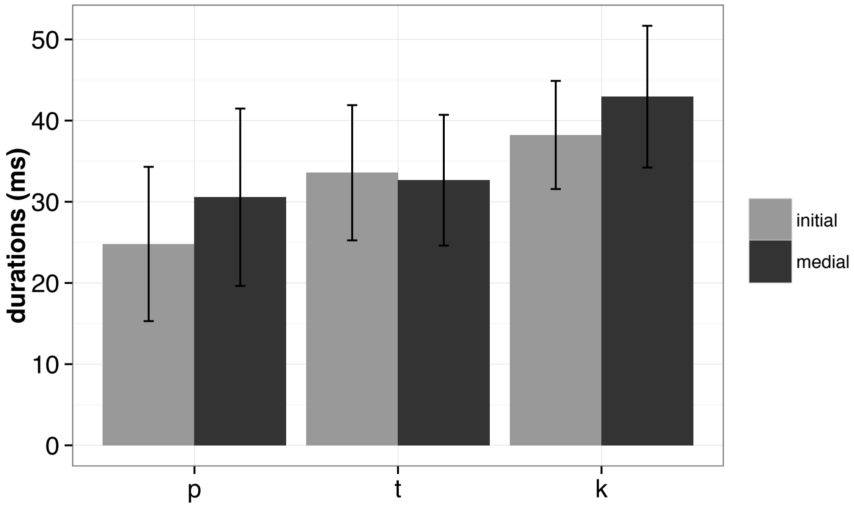
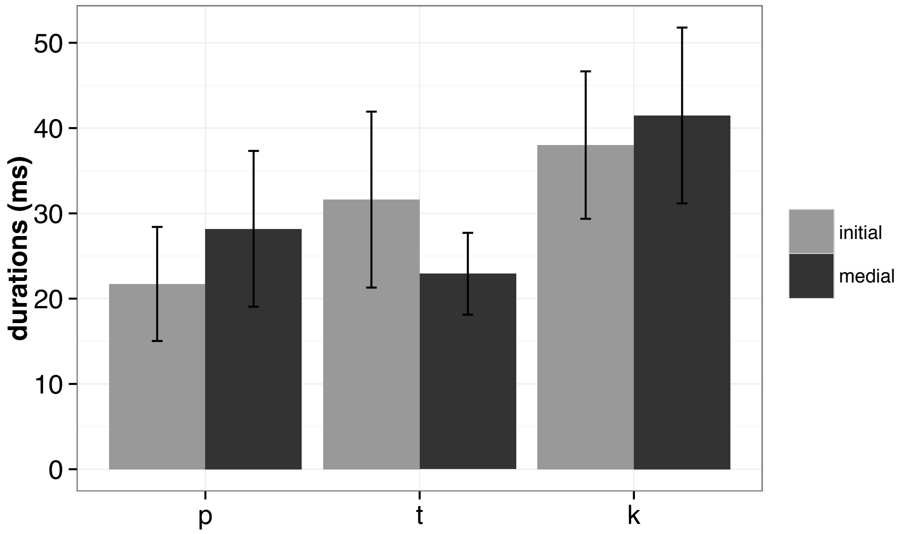


Figure 6.8: Mean VOT and error bars mean of +/-1 standard deviation for *geminates* by segment



As before, all data were analysed using linear mixed-effect models. Following Barr et al. (2013), models were built with a maximal random effects structure. However, this led to problems of convergence. As a result, the models were built by omitting covariances from the variance-covariance. The fixed effects of Consonant Type (singleton, geminate), Place (bilabial for /p/, alveolar for /t/ and velar for /k/) and Position (initial or medial) were centered to reduce collinearity.

A baseline (model 1) which was made up of only the intercept and the random effects was built. The contribution of the fixed effects: Consonant Type, Place and Position were investigated separately (i.e. model 2, model 3 and model 4). These models were compared to the baseline (cf. Table 6.20). A model including Consonant Type, Place and Position as fixed effects terms (model 5) was built. Model 5 was compared to a model with a model including the interaction of the three fixed effects terms (model 6).

Table 6.20: Model goodness of fit: VOT duration (*n.s.* = not significant, ** = $p < 0.01$)

Model	**Fixed Effects**	**BIC**	χ^2
1	Intercept	2964.6	-
2	Consonant Type	2969.1	1.5254 *n.s.* (relative to model 1)
3	Place	2960.6	10.055 ** (relative to model 1)
4	Position	2970.1	0.5299 *n.s.* (relative to model 1)
5	Consonant Type + Place + Position	2969.9	12.776 ** (relative to model 1)
6	Consonant Type * Place * Position	2989.7	4.5187 *ns* (relative to model 5)

The model including Consonant Type (model 2) and Position (model 4) as separate fixed effects did not have a better fit than the baseline. On the other hand, the model including Place (model 3) as a fixed effect had a better fit to the data than the baseline. The model including the three fixed effect terms (model 5) also has a better fit to the data than the baseline.

Table 6.21: Further model comparisons: VOT (*n.s.* = not significant, ** = p < 0.01)

Model	χ^2
Model 2, Model 5	11.251 **
Model 3, Model 5	2.7209 *n.s.*
Model 4, Model 5	12.246 **

A comparison of model 2 to model 5 and model 4 to model 5 in Table 6.21 shows that model 5 has a better fit to the data than models 2 and 4 respectively. However, the comparison of model 3 to model 5 shows that the latter model is not any better than model 3. Therefore, this suggests that place of articulation has the biggest role in explaining the differences in VOT durations.

Model 3 (cf. Table 6.22 for a summary) suggests that the duration of VOT is significantly affected by the place of articulation, where the velar stop /k/ has the longest VOT durations, the bilabial stop /p/ has the shortest VOT durations and the alveolar stop /t/ has intermediate durations.

Table 6.22: Summary of model 5: Place (*** = p < 0, ** = p < 0.001)

Fixed Effects	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	32.221	1.713	18.804	<2e-16 ***
Place	-4.028	1.189	-3.387	0.00163 **

6.5 Discussion of Production Study 1 and 2

General discussion

So far the two production studies presented in this dissertation have dealt with the production of lexical and surface word-initial geminates on the one hand, and the comparison of word-initial and word-medial geminates on the other. Constriction duration is taken to be the primary correlate of gemination in Maltese.

In Production Study 1, the production of lexical and surface word-initial geminates was compared. This comparison has shown that lexical geminates of Semitic origin (such as [ɪ**dd**ɐhhɐl] *ddaħħal* 'to be entered') and lexical geminates of non-Semitic origin (such as [ɪ**dd**ɐjljɐ] *ddajlja* 'to dial'), had comparable durations. Furthermore, when both these geminate types were compared to assimilated geminates (such as [ɪ**d-d**ɐhlɐ] *id-daħla* 'the entrance'), the durational differences were also comparable. In the case of lexical geminates of Semitic origin and assimilated geminates, a similar morpho-phonological process, i.e., regressive assimilation to the place of articulation of the stem-initial consonant, results in phonetically comparable durations. Lexical non-Semitic geminates are not derived through regressive assimilation, but the initial consonant is geminated (regardless of its place or manner of articulation). Therefore, the phonetic realization of the duration of the different types of word-initial geminates is not affected by the origin of the word. This corroborates my claim that Maltese has a single phonetic system operating on principles that apply across the board. Specifically in this case, that geminates display the same phonetic manifestations, regardless of their origin.[58]

Word- and syllable-initial singleton consonants (eg. /p/ in ˈ***p****onta* 'to point') were significantly longer than word-medial but syllable-initial consonants (e.g. /p/ in *kaˈ****p****aċi* 'ability'). One possible interpretation is that segments are longer in word- and syllable-initial position due to domain-initial strengthening (Fougeron and Keating, 1997; Keating et al. 2003), where domain refers to 'prosodic domain' not lexical domain. Speakers make a distinction, at least in terms of duration, between segments, which are word-initial and word-internal. By contrast, in the case of geminates the durations of morpho-phonological initial and word-medial geminates were similar and did not vary significantly. This can be taken as further evidence that word-initial geminates in Maltese are neither word-initial nor syllable-initial geminates; and they are not initial within the prosodic domain. It is possible that if word-initial geminates in Maltese were true word/syllable-initial geminates, longer durations would be expected (compared

[58] This can also apply to other linguistic domains of Maltese. For instance, Camilleri (2014) also argues that the morphology of Maltese should be viewed as one holistic system and should not be discussed in terms of word-origin.

to word-medial geminates, as shown for Tashlhiyt Berber by Ridouane 2007), following the principles of domain-initial strengthening.

Moving from the actual mean durations of segments to the singleton-to-geminate duration ratios, in word-medial position the duration ratio is greater than in morpho-phonological word-initial position. Pooling across all speakers and manners (in Production Study 2) word-initial geminates are about 1.6 times longer than singletons, while word-medial geminates are 1.8 times longer than singletons. Comparing these ratios to other languages, the pattern in Maltese seems to be similar to the pattern in Swiss German. Kraehenmann (2011) reports that the singleton-to-geminate duration ratio is smaller in word-initial position (1:2) than in word-medial position (1:3). On the other hand, in Tashlhiyt Berber, duration ratios increase from medial position (1:2.5) to initial (1:3). Kraehenmann (2011) argues that according to the principles of domain initial strengthening, the pattern found in Tashlhiyt Berber should be expected.

Duration ratios may vary depending on the manner of articulation. However, this issue is not specifically addressed in previous studies. First, in the literature there are a number of opposing views; for instance, Kawahara (2007) and Kawahara et al. (2011) argued that the more sonorant-like a geminate is, the more marked it is. Furthermore, Kawahara argued that sonorant geminates are dispreferred cross-linguistically. The basis of this argument stems from the relative perceptibility of such sounds. In fact, a number of phonetic studies, such as Cohn et al. (1999), Aoyama and Reid (2006), Tserdanelis and Arvaniti (2001), showed that the duration ratios for sonorants are much greater than those of obstruents. For instance, Aoyama and Reid (2006), on comparing duration ratios in a number of languages, postulated that the duration ratios for fricatives and affricates are shorter while in stops and nasals it is longer.

Table 6.23: Durations ratios for geminates[59]

Language	Manner of Articulation			
	Stops	**Fricatives**	**Nasals**	**Liquids**
Japanese (Kawahara 2015)	1:2	1:1.8	1:2/3	-
Italian (Esposito and Di Benedetto 1999)	1:2	-	1:2.4	-
Cypriot Greek (Arvaniti and Tserdanelis 2000; Tserdanelis and Arvaniti 2001)	1:1.8	1:1.3	1:2.2	1:2
Guinanng Bontok (Aoyama and Reid 2006)	1:2	1:1.6	1:2	1:1.19
Toba Batak (Cohn et al. 1999)	1:2	1:1.7	1:2	1:2
Kelantan Malay (Hamzah et al. 2010)	1:2	-	1:2.4	1:2.8
Maltese (Production Study 2)	1:2	1:1.7	1:1.9	1:2.1

Table 6.23 presents singleton-to-geminate duration ratios from typologically different languages from four manners of articulation: stops, fricatives, nasal and liquids. In a number of languages such as the ones listed in Table 6.23, sonorants and stops have high duration ratios and fricatives have lower duration ratios. Across the different languages, the duration ratios for fricatives vary from 1:1.3-1.8. However, the duration ratio for the constriction duration[60] in stops seems to be fairly consistent (i.e., varying slightly from 1:1.8-1:2). There are counter-arguments to the data presented in this table. For instance, in Buginese and

[59] Word-initial for Kelantan Malay (Hamzah et al. 2010).

[60] A variety of terms have been used in the studies in relation to what was measured for stops. Cohn et al. 1999, Arvaniti and Tserdanelis 2000 and Esposito and Di Benedetoo (1999) measured closure duration for stops in Toba Batak, Cypriot Greek and Italian respectively. Kawahara measured constriction duration for stops in Japanese. Furthermore, Hamzah et al. (2010) and Aoyoma and Reid (2006) measured duration in Kelatan Malay and Guinaang Bontok respectively.

Madurese nasals and liquids have a duration ratio of 1:1.6 and 1:1.8 respectively (Cohn et al. 1999). However, voiceless fricatives in both languages have a duration ratio of 1:1.4 (Cohn et al. 1999). These results seem to suggest that there is a tendency for duration ratio to be more stable across nasals and stops, where geminates are (almost) twice as long as singletons. Moreover, the duration ratios of fricatives are less stable across a number of different languages. Therefore, the same phonological contrast of gemination is phonetically manifested in different degrees of duration, which are both language dependent and also dependent on manner effects.

On the status of the inserted vowel

The results presented here indicate that what are traditionally described as "word-initial geminates" in Maltese are not really word-initial. As a matter of fact, such geminates are almost always preceded by a vocalic element. This was shown in both Production Study 1 and Production Study 2, where in Production Study 1 96% of word-initial geminates were preceded by a vocalic insertion and in Production Study 2 84% of word-initial geminates were preceded by a vocalic insertion. In turn, some speakers inserted a glottal stop before the vocalic insertion: 4 (out of 10) in Production Study 1 and 6 (out of 12) in Production Study 2. Therefore, I claim that "word-initial geminates" in Maltese require a whole syllable to be built up before the first part of the geminate, to which this first part of the geminate serves as a coda. In this syllable the vocalic insertion serves as a syllable nucleus and, for some speakers, the glottal stop can function as a syllable onset. Furthermore, morphological prefixes can also serve as syllable onsets to the vocalic element preceding word-initial geminates.

In view of these observations, I state that word-initial geminates in Maltese never occur syllable-initial geminates. As a result, I propose that "word-initial geminates" in Maltese should be referred to as *morpho-phonological word-initial geminates.* The phonetic realization of such geminates, as shown in Production Study 2, is very similar to word-medial geminates. There is one difference between true word-medial geminates and morpho-phonological word-initial geminates. In the case of word-medial geminates (e.g., [**tɛl**lɛf] *tellef* 'to make someone lose'), the first syllable (in bold) is a lexical syllable, which makes up a single phonological word/lexical entry. However, the first syllable (in bold) in morpho-phonlogical word-initial geminates (e.g., [**ɪt**tɛllɛf] t*tellef* 'to be made to lose') is post-lexical and it arises through the syllabification of stray consonants. A right-to-left syllabification process operates such that the vocalic insertion [ɪ] is inserted before word-initial geminates. Furthermore, the empirical data in the production studies supports the claims in the literature (cf. Azzopardi 1981, Mifsud 1995 and Hoberman and Aronoff 2003), that word-initial geminates require a preceding vowel. In addition, as predicted in Chapter 3 §3.6.3.5, the vowel insertion does not split the geminates up (since the vocalic insertion always happens before the geminates and never in between), and show that morpho-phonological word-initial geminates, even though are banned by the phonology, show geminate integrity.[61]

The results with respect to the vocalic element before word-initial geminates lead to a discussion on the status of this element. To do so, I will address whether this vowel, in light of the results from production studies 1 and 2 and the phonology of Maltese, is an 'intrusive' vowel or an 'epenthetic' vowel.

I will take Hall's (2006:387) definition of inserted vowels here. Hall (2006) defines 'epenthetic' vowels as 'phonological segments inserted in order to repair illicit structures' and 'intrusive' vowels as 'phonetic transitions between consonants'. I argue that the inserted vowel in Maltese falls more under the characterization of epenthetic vowels than intrusive vowels (followings Hall's (2006:391) descriptions). First of all, the quality of the inserted vowel before word-initial geminates (and also sonorant-initial clusters) in Maltese is always [ɪ], i.e. the quality is fixed (c.f. Azzopardi 1981). Second, and most importantly, 'the [inserted] vowel repairs a structure that is marked, in the sense of being cross-linguistically rare'. This is the case for word-initial geminates.

[61] The phonetic realization (i.e. in Production Study 1 and 2) provides further evidence for geminate integrity. There were no cases when the vocalic element was inserted between the geminates. When present, it always preceded the geminates.

The inserted vowel before word-initial geminates in Maltese is neither an intrusive vowel because it never occurs as a schwa nor does it not change according to neighbouring vowels. It is always [ɪ]. Furthermore, in comparison, there are no vocalic insertions between heterorganic clusters in Maltese. The duration of the vocalic insertion before word-initial geminates has comparable duration across speakers. Hall (2006) reports that intrusive vowels have variable duration. Finally, intrusive vowels do not repair illicit structures; rather they occur for articulatory reasons.

Therefore, according to Hall's (2006) descriptors, I claim that the inserted vowel in Maltese is an epenthetic vowel. The primary function of this vowel is to repair an illicit structure in the language, i.e. word-initial geminate. The issue of the role of the epenthetic vowel in phonological processes and even to lexical representation will be discussed in Chapter 9 §9.3, after the results of the perception experiment are presented. This is because, the perception experiment in Chapter 8, specifically addresses this question.

Moreover, in 10 out of 22 speakers (across both experiments) the epenthetic vowel was itself preceded by a glottal stop; this was also subject to within-speaker variation. The glottal stop is part of the phoneme inventory of Maltese and is found in words such as *qal* 'he said' [ʔɐːl]. However, minimal pairs such as [ʔɐːl] and [ɐːl] *għal* 'for' are being lost, as onsetless words are increasingly being preceded by a glottal stop.[62] As a matter of fact, Azzopardi (1981) commented that words beginning with a vowel, both underlyingly and in the orthography, are gradually being preceded by a glottal stop in the production of some speakers.

[62] Dr. Albert Gatt (November 2015) has brought to my attention, that words which underlying have a glottal stop are being produced without one e.g. /ʔɐːl/ → [ɐːl] 'he said'. It is argued that this might be a speaker strategy to mark his/her words as less Maltese and more English-like. Furthermore, the glottal stop is orthographically encoded in Malta by the grapheme 'q'. However, spelling mistakes are occurring in such a way that glottal-initial words are being spelt as vowel-initial, e.g. *qed* → *ed* 'still'. The evidence for this is still anecdotal and this is a topic that is subject to systematic empirical work in future.

On other correlates for gemination

In this section, I discuss a number of correlates that act (or do not act) as acoustic correlates to gemination in Maltese. I discuss the results for VOT, the duration of the tonic vowel and the inserted vowel.

VOT

The production data shows that VOT in voiceless and voiced stops does not serve as a primary or secondary correlate for gemination in Maltese in either word-initial or word-medial position. This is because there was no difference in the duration of VOT in singletons and geminates. As expected, in Production Study 1, I have shown that voiced stops (either singleton or geminate) have shorter VOT than voiceless stops. Furthermore, the results from Production Study 2 also show that VOT in singletons and geminates is comparable, but I show that VOT is longer for the velar stop /k/, less so for /t/ and shortest for the bilabial /p/.[63] This finding corroborates the pattern found in other languages (Cho and Ladefoged 1999).

Therefore, VOT in geminates in Maltese is like VOT in Japanese (Kawahara 2015), Levantine Arabic (Ham 2001), Buginese, Madurese and Toba Batak (Cohn et al. 1999) and Swiss German (Kraehenmann 2001), where it does not serve as a correlate.

The duration of the vowel after word-initial geminates/singletons

The duration of the tonic vowel does not serve as a correlate for gemination in Maltese. Few studies have measured the duration of the vowel following geminates/singletons (e.g., Idemaru and Guion 2008; Doty et al. 2007); yet again, in those studies that did, language-specific differences were found. In Japanese word-medial geminates the vowel after geminates is shorter than after

[63] VOT in word-medial geminates was longest for /k/, but shortest for /t/ and intermediate for /p/.

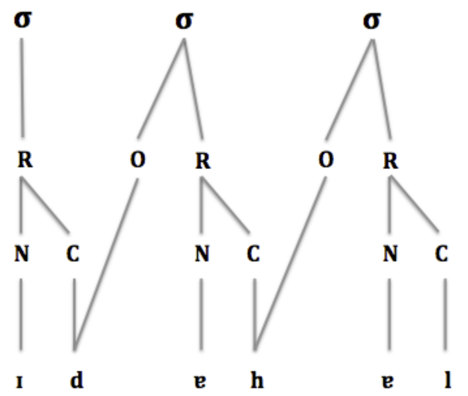
singletons (Kawahara 2015). By contrast, in Finnish word-medial geminates, the vowel after geminates and after singletons have similar durations (Doty et al. 2007). In Kelatan Malay word-initial geminates, the vowel after word-initial geminates is shorter than after singletons (Hamzah et al. 2012). In Production Study 1, the duration of the tonic vowel was measured and compared in singletons (such as [ʃ**ɐ**hhɐm] 'to fatten') and lexical geminates of Semitic origin (such as [ɪʃʃ**ɐ**hhɐm] 'to be fattened'). The duration of the stressed vowel after word-initial singletons and geminates was not statistically significant, and therefore, I conclude that in these cases the tonic vowel does not serve as a correlate to gemination.

In Production Study 3 (Chapter 7 §7.5), I compare the vowel before word-medial singletons (e.g., in [ʔ**ɐ**tɐr] *qatar* 'to drip') and geminates (e.g., in [ʔ**ɐ**ttɐr] *qattar* 'to dribble'; and word-final singletons (e.g., in [b**ɐː**t] *bagħat* 'to send') and geminates (e.g., in [ʔ**ɐ**tt] *qatt* 'never). I predict that vowel shortening to occur before geminates in both positions in a word. In addition, note that the effect of vowel shortening might be different, since, in word-final position, the vowel before singletons is a phonological vowel and the vowel before geminates is a phonological short vowel.

Word-initial gemination and resyllabification

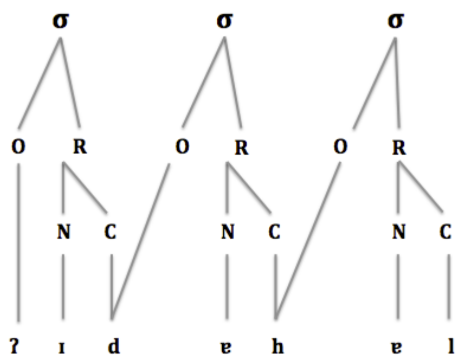
In Chapter 2 §2.5.1, I showed that there is a process of resyllabification before morpho-phonological word-initial geminates in Maltese. Here I incorporate the phonetic evidence into the phonological representation. Mainly, I argue that the vocalic insertion serves as a syllable nucleus to a preceding syllable. The coda to this syllable is the first part of the geminate, and the onset of the second syllable is the second part of the geminate (as can be seen in Figure 6.9). Some speakers insert a glottal stop before the vocalic insertion, in principle, this can serve as an onset of the first syllable (cf. Figure 6.10). This glottal stop insertion is analogous to a process found in a number of Arabic varieties, such as Classical Arabic and Quranic Arabic, where a glottal stop is inserted before words beginning with a vowel to avoid onsetless word-initial syllables (McCarthy 2005, Gadoua 2000, Haddad 2006). This could also suggest that some speakers might have lexicalized the epenthetic vowel and it is part of the mental representation of such words and as a result the epenthetic vowel is being treated as a lexical vowel, and since word/syllable initial vowels tend to be preceded by a glottal stop (c.f. Azzopardi 1981), such words are also preceded by a glottal stop. In terms of the principles of Prosodic Licensing, the insertion of a glottal stop before an epenthetic vowel does not violate this principle. The epenthetic vowel syllabifies stray consonants, i.e. the first part of the geminate. The glottal stop can serve as a simple onset to this newly created syllable.

Figure 6.9: Syllabification of vocalic insertion before word-initial geminates



ddaħħal **'to be inserted'**

Figure 6.10: Syllabification of initial epenthetic glottal stop



ddaħħal **'to be inserted'**

6.6 Conclusion

To conclude, the phonetic realization of Maltese 'word-initial geminates' shows that such geminates do not occur syllable-initially or utterance-initially. Gemination in word-initial position is licensed by a morpho-phonological process that regressively assimilates coronal sounds in Semitic verbs and nouns. The strategy for incorporating loan verbs in Maltese is through the gemination of the first consonant in the stem. As a result, this creates a word-initial geminate, which, unlike Semitic verbs and nouns, is not restricted to coronal sounds but applies to any manner of articulation in the language. I conclude that these different types of word-initial geminates should be referred to as morpho-phonological word-initial geminates, mainly because in the domain of morphology they are word-initial and are realized (phonetically) as word-medial geminates. On the phonetic surface, morpho-phonological word-initial geminates are realized with a preceding vocalic insertion. I argue that it is possible that for young [64] Standard speakers of Maltese the inserted vowel is part of the phonological representation of these words in the mental lexicon and is represented as vowel-initial. Therefore, word-initial geminates are word-initial in the morphology but are phonologically and phonetically word-medial. This analysis is reflected in the fact that the durations of geminates in morphological word-initial and word-medial positions are comparable.

In the following chapter, word-final geminates in Maltese are compared to word-medial geminates.

[64] It would be extremely interesting to compare the productions of such words and vowel initial words of different population groups: for instance, dialect speakers and older speakers in dialectal and Standard Maltese.

Chapter 7: Production Study 3 - Comparing word-final to word-medial geminates in Maltese

In this chapter, I present the third production study in this dissertation. In this production study, I compared the duration of word-final geminates to word-medial geminates across different manners of articulation.

The few studies that investigated the duration of word-final geminates have shown that a singleton/geminate contrast is maintained in such a position. However, in Swiss German (Kraehenmann 2001) and Hungarian (Ham 2001), the singleton-to-geminate duration ratio significantly decreased in word-final position (when compared to word-medial position). Ridouane (2007) reports the opposite pattern, i.e. an increase in duration ratios from word-medial to word-final position in Tashlhiyt Berber.

This chapters is structured as follows: in §7.1, I outline the methodology of this production study. In §7.2, I present the results of the production study by looking at constriction duration and duration ratios. In §7.3, a digression is made, in which word-medial geminates from Production Study 2 (Chapter 6) and this production study are compared. In §7.4, a possible secondary correlate, namely the duration of the vowel before singletons/geminates is investigated. In §7.5, a second digression is carried out, where the duration of the vowel after word-medial singletons/geminates is investigated. In §7.6, preliminary ideas on final lengthening in Maltese in monosyllables are discussed. Finally, in §7.7, the results are discussed and the chapter is concluded.

7.1 Methodology

In this section, I outline the goals for this production study in §7.1.1, this is followed by a discussion of the speech material in §7.1.2, information about the recruited participants in §7.1.3 and the hypotheses for this study in §7.1.4.

7.1.1 Goals of the experiment

In the current production study (i.e., Production Study 3), word-final geminates were compared to word-medial geminates. The results of Production Study 1 and Production Study 2 showed that the phonological contrast is phonetically manifested in word-initial and word-medial position. In addition, the durations of word-initial and word-medial geminates were comparable. On the other hand, word-initial singletons were significantly longer than word-medial singletons, which has been taken as evidence for domain-initial lengthening. Furthermore, in Production Study 2, different manners of articulation were investigated, showing that sonorants and stops have the highest duration ratios and fricatives and affricates have the lowest.

In the Production Study 3, I extend the results found in the previous two production studies by examining constriction duration in word-final position, which were also compared to word-medial geminates.

7.1.2 Speech Material

As in Production Study 2, target consonants were selected from different manners of articulation. The target consonants (singletons and geminates) in word-medial and word-final position included voiceless stops, voiceless fricatives, voiceless affricates, and liquids, as shown in Table 7.1.

Table 7.1: Manners and segments for Production Study 3

Manner	**Segment**
Stops	/p t k/
Fricatives	/f s ʃ/
Affricate	/tʃ/
Liquid	/l/
-	/r/

As in the previous production studies, the target words were presented in a carrier phrase. The carrier phrase[65] for Production Study 3 was: *Qallek* _______ *mitt darba* 'he told you ___________ a hundred times'. For both the word-medial and word-final condition and for each segment, 3 singleton and geminate pairs were chosen. Table 7.2 shows one target word example pair from each manner of articulation in word-medial and word-final position.[66] This yielded 33 word-medial singleton-geminate pairs and 33 word-final singleton-geminate pairs, for a total of 108 target words per speaker. This led to 648 tokens for word-medial target words and 648 for word-final target words, a total of 1296 tokens.

7.1.3 Participants

The participants of Production Study 3 were the same group of participants as Production Study 2. Information about the participants is found in Chapter 6 §6.1.3.

7.1.4 Hypotheses

Geminates are expected to be longer than singletons. However, given the results by Hume et al. (2014) on word-final geminates (cf. Chapter 3 §3.3.6), it is expected that the duration of word-final geminates is smaller than that of word-medial geminates. In addition, smaller duration ratios are expected. Therefore, it is expected for Maltese geminates to follow a pattern like Swiss German and Hungarian, where the singleton-to-geminate duration ratios for word-medial position are longer than word-final position.

Since Maltese has strict requirements on the structure of the rhyme in monosyllables, where the rhyme is either made up of a long vowel and a short consonant (i.e. CV:C) or of a short vowel and a geminate (CVG), it is expected that the duration of the vowel before geminates is shorter than that before singletons.

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[65] Nasals were also recorded for Production Study 3, however, these were not included in the analysis. This is because, there were problems with segmentation in word-final position, since the following word in the carrier phrase also started with the nasal /m/.
[66] A full list of examples is shown in Appendix 3

Table 7.2: Target item examples from one manner of articulation

		Word-medial		**Word-final**	
Manner	***Segment***	***Singleton***	***Geminate***	***Singleton***	***Geminate***
Stops	**/t/**	/ˈʔɐ**t**ɐr/ *qatar* 'to drip'	/ˈʔɐ**tt**ɐr/ *qattar* 'to dribble'	/bɐː**t**/ *bagħat* 'to send'	/ʔɐ**tt**/ *qatt* 'never'
Fricatives	**/ʃ/**	/ˈnɪ**ʃ**ɛf/ *nixef* 'to dry up'	/ˈnɪ**ʃʃ**ɛf/ *nixxef* 'to dry'	/ɐː**ʃ**/ *għax* 'because'	/bɐ**ʃʃ**/ *baxx* 'shallow'
Affricate	**/tʃ/**	/ˈvuː**tʃ**ɪː/ *vuċi* 'voice'	/ˈnɪ**tʃtʃ**ɐ/ *niċċa* 'niche'	/vɛrˈnɪː**tʃ**/ *verniċ* 'varnish'	/kɐpˈrɪ**tʃtʃ**/ *kapriċċ* 'caprice'
Liquid	**/l/**	/ˈʔɐ**l**ɛp/ qaleb 'to turn'	/ˈʔɐ**ll**ɛp/ *qalleb* 'to turn sth over'	/bɐː**l**/ *bagħal* 'mule'	/hɐ**ll**/ *ħall* 'vinegar'
-	**/r/**	/ˈʔɛ**r**ɛd/ *qered* 'to destroy'	/ˈʔɛ**rr**ɛd/ *qerred* 'to whimper'	/dɐː**r**/ *dar* 'house'	/dɐ**rr**/ *darr* 'cause harm'

7.2 Production Study 3: Results

In this section, I discuss the results related to constriction duration. First, in §7.2.1, I look at the overall constriction duration. Next, in §7.2.2, I compare the durations of word-medial and word-final singletons and geminates across all manners of articulation under investigation and investigate which fixed effects aid in explaining the data best. In §7.2.3, the constriction duration of singletons and geminates in the two different positions are compared. Finally, in §7.2.4, I provide the singleton-to-geminate duration ratio for word-medial and word-final position based on the results of this production study.

7.2.1 Overall Constriction Duration

As expected, geminates were longer than singletons in both word-final and word-medial positions. Table 7.3 shows the mean durations of singleton and geminates in medial and final position. The duration of singletons and geminates was longer in final position than in medial position. Singletons in word-final position were 54ms longer than singletons in word-medial position. Furthermore, geminates in word-final position were 14ms longer than geminates in word-medial position. Across all speakers and manners of articulation, geminates in word-medial position are 1.8 times longer than singletons in word-medial position, whereas geminates in word-final position are 1.22 times longer than singletons in the same position.

Table 7.3: Overall mean durations (ms) and SD of singletons and geminates

Position	**Singleton**	**Geminate**
Medial	96 (32)	169 (34)
Final	150 (51)	183 (60)

7.2.2 Comparing constriction duration across different manners of articulation

The duration of singletons and geminates in different manners of articulation were investigated and are shown in Table 7.4. The comparison of the mean durations of singletons (Figure 7.1) in word-medial and word-final positions shows that singletons are longer in word-final position than word-medial position. This also seems to be the case for word-final geminates (Figure 7.2), however, the duration of the geminate liquid /l/ in word-final position is shorter than the duration of the geminate liquid /l/ in word-medial position.

Table 7.4: Mean durations and standard deviations by manner and position

Manner	**Medial**		**Final**	
	Singleton	*Geminate*	*Singleton*	*Geminate*
Affricate	146 (28)	189 (34)	193(53)	207 (54)
Fricative	103 (18)	184 (23)	161(43)	202 (48)
Liquid	62 (11)	137 (22)	101 (40)	131 (69)
/r/	53 (24)	119 (22)	102 (48)	134 (65)
Stops	99 (18)	175 (26)	158 (40)	189 (48)

In word-final position, geminate affricates are 18ms longer than geminate affricates in word-medial position. Singleton affricates in word-final position are 47ms longer than singleton affricates in word-medial position. Geminate fricatives in word-final position were 18ms longer than geminate fricatives in word-medial position. A larger difference was found between singleton fricatives in word-final and word-medial position: singletons in word-final position are 58ms longer than singletons in word-medial position. Geminate liquids in word-final position are 6ms shorter than geminate liquids in word-medial position. However, singleton liquids in word-final position were 39ms longer than singletons in word-medial position. In word-final position, the geminate /r/ was 15ms longer than in word-medial position. A larger difference is found in singletons, the singleton /r/ in word-final position was 49ms longer than in word-medial position. Finally, word-final geminate stops were 14ms longer than word-medial geminate stops. On the other hand, word-final singleton stops were 59ms longer than word-medial singleton stops.

Figure 7.1: Mean durations and error bars mean of +/-1 standard deviation of *singletons* in final and medial position

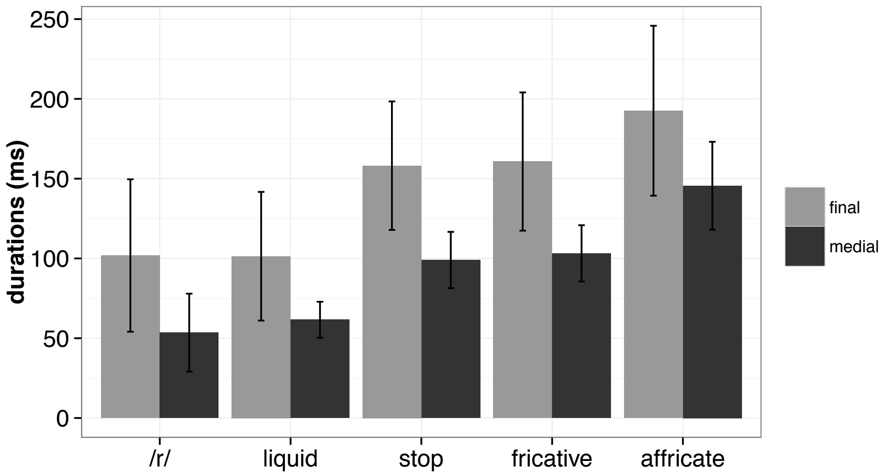
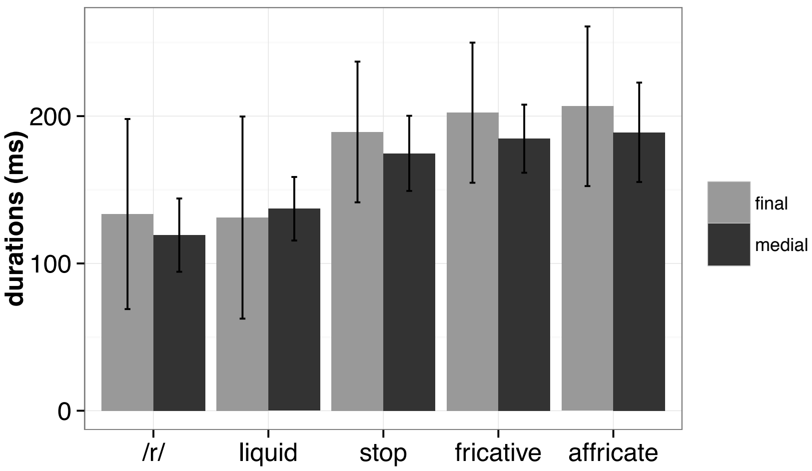


Figure 7.2: Mean durations and error bars mean of +/-1 standard deviation of *geminates* in final and medial position



In order to investigate the contribution of the singleton/geminate, manner and word position as fixed effects towards explaining the variation in the data, a model using these three variables as fixed effects was built. As in previous analyses, all data were analysed using linear mixed-effect models. Following Barr et al. (2013), models were initially fitted with a maximal random effects structure including random intercepts and random slopes for three fixed effects and their interaction. This led to problems of convergence, covariance from the variance-covariance matrix was removed, however, this also led to problems of convergence. The interaction term for slopes was removed and this also led to problems of convergence. Therefore, in this model comparison random slopes were not added. The fixed effects of Consonant Type (singleton, geminate), Manner (i.e. *plosives* /p, t, k/; *fricatives* /f, s, ʃ/, *affricate* /tʃ/, *liquid* /l/; and *approximant* /r/) and Position (medial or final) were centered to reduce collinearity.

A baseline (model 1), which was made up of only the intercept and the random effect was built. The contribution of the fixed effects of Consonant Type, Manner and Position were investigated separately and were compared to the baseline (i.e. models 2, 3 and 4 respectively). Model (5) was compared to a model with the three fixed effects: Consonant Type, Manner and Position (model 6). Finally, model 6 was compared to a model with the fixed effects and their interaction (model 7).

The models including the fixed effects (i.e. models 2, 3, 4 in Table 7.5) had a better fit to the data than the baseline, suggesting that the duration of constriction depends on all three main effects: consonant, manner and word position. The inclusion of an interaction term improved the model fit, as shown by the comparison of model 7 to model 6 (even though there is a higher BIC value). Therefore, this shows that the interaction of consonant type, manner and word position play a role in explaining the differences in constriction duration.

Table 7.5: Model Comparison: Production Study 3 (*** = $p < 0$, * = $p < 0.01$)

Model	Fixed Effects	BIC	χ^2
1	Intercept	12835	-
2	Consonant Type	12792	50.031 *** (relative to model 1)
3	Manner	12837	4.8422 * (relative to model 1)
4	Position	12824	17.778 *** (relative to model 1)
5	Consonant Type + Manner	12792	57.847 *** (relative to model 1)
6	Consonant Type + Manner + Position	12766	90.393 *** (relative to model 1)
7	Consonant Type * Manner * Position	12786	16.085 *** (relative to model 6)

Table 7.6: Production Study 3: Further model comparisons (*** = $p < 0$)

Model Comparisons	χ^2
Model 2, Model 7	56.447 ***
Model 3, Model 7	101.64 ***
Model 4, Model 7	88.701 ***
Model 5, Model 7	48.632 ***

The comparisons in Table 7.6 show that the model including the interaction of the three fixed effect terms explains the data much better than the other models. A closer look at model 7 (Table 7.7) indicates that Consonant Type, Manner and

Position contribute to explaining the differences in constriction duration. However, the strongest interaction is between Consonant Type * Position, which is explored in §7.2.3. Position effects were also previously reported in Production Study 2.

Table 7.7: Summary of Model 6: Consonant + Manner + Position (*** = p< 0, *n.s.* = not significant)

Fixed Effects	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	149.7566	6.8391	21.896	3.85e-13 ***
Consonant Type	-26.3973	2.6428	-9.988	2.2e-16 ***
Manner	-9.0751	2.5602	-3.545	0.00584 ***
Position	-16.8917	2.5608	-6.595	1.65e-09 ***
Consonant Type * Manner	-0.7783	2.5611	-0.304	0.761810 *n.s.*
Consonant Type * Position	-10.0457	2.5618	-3.921	0.000156 ***
Manner * Position	-0.2900	2.5612	-0.113	0.910056 *n.s.*
Consonant Type * Manner * Position	-0.7951	2.5621	-0.310	0.756920 *n.s.*

7.2.3 Word position: Word-medial vs. Word-final

The overall mean durations in Table 7.3 (above) show that singletons and geminates in word-final position are longer than their respective counterparts in word-medial position. As mentioned earlier, word-final singletons are 54ms longer than word-medial singletons and word-final geminates are 14ms longer than word-medial geminates. In order to investigate this further, the mean durations of singletons and geminates in medial and final position were compared. In this case, statistics were run separately for singletons and geminates. Models were initially fitted with a maximal effect structure, including random intercepts and random slopes for the fixed effect of Position (medial, final). Since this led to problems of convergence, covariance in the variance-covariance matrix was removed. The results for singletons are presented in Table 7.8 and the results for geminates are presented in Table 7.9.

Table 7.8: Model for *singletons* (*** = p< 0)

Fixed Effects	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	123.212	6.869	17.936	6.00e-15 ***
Position	-26.947	4.760	-5.661	8.53e-07 ***

Table 7.9: Model for *geminates* (*** = p< 0, *n.s.* = not significant)

Fixed Effects	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	176.149	8.038	21.914	9.77e-15 ***
Position	-6.841	4.794	-1.427	0.161 *n.s.*

Word-final singletons are statistically significantly longer than word-medial singletons (c.f Table 7.8, p<0.001; *final singletons*: x̄=150, sd=51; *medial singletons*: x̄=96, sd=32). However, word-final geminates are not statistically significantly longer than word-medial geminates (cf. Table 7.9, p=0.161; *final geminates*: x̄=183, sd=60; *medial geminates*: x̄=169, sd=34). Therefore, the results show that the duration of singletons (Table 7.8) is affected by their position in the word. Singletons in word-final position are much longer (54ms) in singletons in word-medial-position. However, geminate consonants are comparable in word-medial and word-final position. The difference between the two is only of 14ms. This confirms the results reported in Table 7.7, where Consonant Type and Position interact.

7.2.4 Duration Ratio

In Production Study 2, where word-initial and word-medial singletons and geminates were compared, it was found that in medial position affricates have the shortest duration, and the approximant /r/ has the longest duration ratio. In this study (Production Study 3), on comparing the different word positions, the duration ratios were larger in word-medial position than in word-final position (cf. Table 7.10). Therefore, the duration ratios for word-final geminates are relatively shorter compared to those in word-medial position. Also, the duration ratios for word-final geminates in this production study were much smaller than those reported in Hume et al. (2014).

Table 7.10: Duration ratios by position

Manner	**Medial**	**Final**
Affricate	1:1.3	1:1.1
Fricative	1:1.8	1:1.3
Liquid /l/	1:2.2	1:1.3
/r/	1:2.2	1:1.3

Comparing the medial singleton/geminate data in this Production Study and in Production Study 2, there are differences in terms of duration ratios. This leads to a comparison of word-medial geminates in Production Study 2 and Production Study 3.

7.3 The comparison of word-medial geminates

In order to allow for comparisons to be made between geminates in different positions in the word different prosodic conditions had to be considered. In Production Study 2 (Chapter 6), where word-initial geminates were compared to word-medial geminates, stress was on the second syllable as in (1). In Production Study 3 (this chapter), where word-final geminates were compared to word-medial geminates, stress was on the first syllable as in (2).

(1) Stress on the second syllable (Production Study 2)

/sɐ.ˈ**p**ʊn/ *sapun* 'soap'

/dʒɐ**p.ˈp**ʊn/ *Ġappun* 'Japan'

(2) Stress on the first syllable (Production Study 3)

/ˈ**p**ɐ.pɐ/ *papa* 'pope'

/ˈ**p**ɐ.ppɐ/ *pappa* 'food'

The duration ratios from Production Studies 2 and 3 (in Table 7.11) show that there are differences in word-medial geminates under different stress conditions. This difference in the data could potentially be attributed to the fact that the position of stress in the target items was different in the two studies.

Table 7.11: Singleton-to-geminate duration ratios for word-medial position in production studies 2 and 3

Manner	**Stress on the second syllable (Production Study 2)**	**Stress on the first syllable (Production Study 3)**
Affricate	1:1.5	1:1.3
Fricative	1:1.7	1:1.8
Liquid /l/	1:2.1	1:2.2
/r/	1:2.3	1:2.2
Stops	1:2	1:1.8

When stress is on the first syllable, geminates are 73ms longer than singletons (geminates: $\bar{x}$ = 169ms (34); singletons: $\bar{x}$ = 96ms (32)). When the stress is on the second syllable, geminates are 68ms longer than singletons (geminates: $\bar{x}$ = 149ms (35); singletons: $\bar{x}$ = 81ms (32)). When stressed on the first syllable geminates are 20ms longer than when they are stressed on the second syllable (geminates: stress on the first syllable: $\bar{x}$ = 169ms (34); stress on the second: $\bar{x}$ = 149ms (35)). Singletons are also longer when stress is on the first syllable than when it is on the second syllable (singletons: stress on the first syllable: $\bar{x}$ = 96ms (32); stress on the second: $\bar{x}$ = 81ms (32).

In order to investigate whether stress effects the duration of word-medial singletons and geminates, a model comparison using Stress and Consonant as fixed effects was carried out.

Following Barr et al. (2013), models were fitted a maximal random effects structure including random intercepts and random slopes for the two fixed effects and their interaction. The fixed effects of Stress (1st syllable, 2nd syllable) and Consonant (singleton, geminate) were centered to reduce collinearity.

A baseline (model 1), which was made up of only the intercept and the random effect was built. The contribution of the fixed effects of Stress and Consonant were investigated separately and were compared to the baseline (i.e. models 2 and 3 respectively). A model with the two fixed effects: Stress and Consonant Type was compared to the baseline (model 4). Finally, a model containing the two fixed effects and their interaction (model 5) was compared to model 4.

Table 7.12: Model Comparison: Effect of Stress (*** = p< 0, *n.s.* = not significant)

Model	**Fixed Effects**	**BIC**	χ^2
1	Intercept	11154	-
2	Stress	11161	0.0186 *n.s.* (relative to model 1)
3	Consonant Type	11114	47.05 *** (relative to model 1)
4	Stress + Consonant Type	11112	56.426 *** (relative to model 1)
5	Stress * Consonant Type	11118	0.2058 *n.s.* (relative to model 4)

The model including the fixed effect of Consonant Type (model 3 in Table 7.12) had a better fit to the data than the baseline, however, the model including the fixed effect of Stress (model 2) did not have a better fit to the data than the baseline. The inclusion of an interaction term did not improve the model fit, as shown by the comparison of model 5 to model 4. A comparison of model 2 to model 4; and model 3 to model 4 in Table 7.13 show that the model with Stress and Consonant Type (i.e. model 4) has a better goodness-of-fit than the individual fixed effects.

Table 7.13: Effects of Stress: Further model comparisons

Model Comparisons	χ^2
Model 2, Model 4	56.408 ***
Model 3, Model 4	9.3768 **

The fact that model 4, which includes Stress and Consonant, has a better fit than a model containing only the intercept shows that the position of stress in the syllable and whether the consonant is a singleton or geminate play a role in explaining the differences in constriction duration (cf. summary of model 4 in Table 7.14). What is interesting to note is that Stress as a fixed effect on its own, in model 3, is not significant, but when it is added to another fixed effect (in this case Consonant Type) it is significant. This can only be investigated in future work.

Table 7.14: Summary Model 4: Stress + Consonant

Fixed Effects	**Estimate**	**Std. Error**	**t value**	**Pr(>|t|)**
(Intercept)	123.369	4.255	28.991	<2e-16 ***
Stress	-8.845	2.824	-3.132	0.00223 **
Consonant	-35.282	2.746	-12.847	<2e-16 ***

Assuming that geminates are ambisyllabic, the results show that when the stress falls on the first syllable (e.g. /ˈ**p**ɐ.pɐ/ *papa* ‘pope’; /ˈ**p**ɐ.ppɐ/ *pappa* ‘food for kids’) the duration of singletons and geminates is longer than when stress falls on the second syllable (e.g. /sɐ.ˈ**p**ʊn/ *sapun* ‘soap’; /dʒɐ**p.ˈp**ʊn/ *Ġappun* ‘Japan’). Payne (2005) reports similar results for Italian, where geminates in stressed syllables were significantly longer than geminates in unstressed syllables. These results also fall within the general findings for segments to be longer in stressed position than in unstressed positions (Fry 1955; Edwards et al. 1991; de Jong & Zawaydeh 1999; Hajak & Stevens 2008).

7.4 The vowel before singletons/geminates

The duration of the preceding vowel could not be directly compared across all target words, because the preceding vowel was not always of the same quality. The preceding vowel was one of the vowels in Maltese: [iː ɪ(ː) ɛ(ː) ɐ(ː) ɔ(ː) ʊ uː]. The occurrence of which vowel occurred before each segment was controlled were possible, however, in some cases, there were not enough word types to fully control for the vowel before the segment. Nonetheless, in the majority of the target words, the preceding vowel was an /ɐ(ː)/ and this was followed by /ɪ(ː)/. In order to compare the durations of the preceding vowel, one pair from each manner of articulation was chosen which had the vowel /ɐ/ (and are listed in Table 7.15). One pair for each segment was selected, where the vowel was /ɐ/. All example pairs were monosyllabic words. Note that no affricate pairs were chosen because the vowel in the pairs did not include the vowel /ɐ/ and none of them were monosyllabic words. Therefore, the following discussion is based on 8 pairs, i.e. 16 words across all 12 speakers, a total of 192 tokens.

Before discussing the data, recall that monosyllabic words in Maltese are restricted by complimentary quantity (Chapter 2 §2.2). Monosyllabic words in Maltese have either a CV:C structure or a CVG structure. Phonological long vowels precede singletons and phonological short vowels precede geminates. Therefore, following Ham's (2001) representation, monosyllables of CVG structure are maximally bimoriac, with one mora associated to the vowel and one associated to the geminates. In the case of monosyllables of CV:C structure, they are also maximally bimoriac, however, their representation is different than CVG syllables, where the long vowels bear two moras (and the final code C does not bear a mora). As a result, one of the hypotheses is whether this phonological restriction presented in the acoustic surface.

In Production Study 1, the tonic vowel following the initial singleton/geminate was not considered to be a correlate of gemination. One possible reason for this is because of the syllable structure, C**V**GVC and G**V**GVC syllables were compared in Production Study 1. The tonic vowel was followed by a geminate in both cases. The results in Production Study 1 show that this vowel does not undergo any adjustments in relation to a preceding singleton/geminate initial contrast. In Production Study 3, different syllable structures are investigated namely: CVCV(C) and CVGV(C) for medial position and CV:C and CVG for final position.

Table 7.15: Full token list for the investigation of the vowel before singleton/geminates

Manner	Segment	Singleton	Geminate	Singleton	Geminate
Stops	/p/	/pɐ̲pa/ Papa 'pope'	/pɐ̲ppa/ *pappa* 'kid's food'	/kɐ̲ːp/ *kap* 'head'	/tɐ̲pp/ *tapp* 'tap'
	/t/	/ʔɐ̲tɐr/ *qatar* 'to drip'	/ʔɐ̲ttɐr/ *qattar* 'to dribble'	/bɐ̲ːt/ *bagħat* 'to send'	/ʔɐ̲tt/ *qatt* 'never'
	/k/	-	-	/dɐ̲ːk/ *dak* 'that'	/hɐ̲kk/ *ħakk* 'itiching'
Fricatives	/f/	/ʔɐ̲fɛl/ *qafel* 'to lock'	/ʔɐ̲ffɛl/ *qaffel* 'to lock securely'	/ɐ̲ːf/ *għaf* 'know'	/sɐ̲ff/ *saff* 'layer'
	/s/	/nɐ̲sɐb/ *nasab* 'to trap (birds)'	/nɐ̲ssɐb/ *nassab* 'to lay traps'	/nɐ̲ːs/ *ngħas* 'sleep'	/hɐ̲ss/ *ħass* 'lettuce'
	/ʃ/	/nɐ̲ʃɐr/ *naxar* 'to hang the clothes'	/nɐ̲ʃʃɐr/ *naxxar* hyp.	/ɐ̲ːʃ/ *għax* 'because'	/bɐ̲ʃʃ/ *baxx* 'shallow'
Liquid	/l/	/ɐ̲ːlɐʔ/ *għalaq* 'to close'	/ɐ̲ːllɐʔ/ *għallaq* 'to hang (s.o.)'	/bɐ̲ːl/ *bagħal* 'mule'	/hɐ̲ll/ *ħall* 'vinegar'
-	/r/	/hɐ̲rɐb/ *ħarab* 'to run away'	/hɐ̲rrɐb/ *ħarrab* 'to make s.o. run away'	/tʃɐ̲ːr/ *ċar* 'clear'	/dʒɐ̲rr/ *ġarr* 'to move'

The results in Table 7.16 indicate that the vowel before geminates in word-medial and word-final position was shorter than that before singletons (c.f. closed syllable shortening as predicted by Maddieson 1985, at least for word-medial geminates). In the word-medial case, the vowel is 17ms shorter before geminates. In word-final position, there is a restriction on the syllable structure of monosyllables, one of complementary quantity. Therefore, since the vowel before word-final singletons is phonologically long, it is expected to have a longer duration. On the other hand, the vowel before geminates is expected to be a phonologically short vowel and thus it is expected to have a shorter duration.

Table 7.16: Mean duration and standard deviations of the preceding vowel

Position	**Singleton**	**Geminate**
Medial	110 (47)	93 (29)
Final	174 (44)	135 (33)

These results were investigated further. A similar model-comparison approach as described in previous sections was adopted, where the goodness-of-fit of different models to determine the two independent variables. The fixed effects of Consonant Type (singleton, geminate) and Position (medial, final) were centered to reduce collinearity.

A baseline (model 1) which was made up of only the intercept and the random effects was built. The contribution of the fixed effects: Consonant Type and Position were investigated separately (i.e., model 2, model 3). These models were compared to the baseline. A model including Consonant Type and Position as fixed effects terms (model 4) was built. Model 4 was compared to model 2 and model 3 (in Table 7.17). Model 5 included the interaction of Consonant Type and Position, which was compared to model 4.

Table 7.17: Model Comparison: Duration of the vowel before geminates

Model	**Fixed Effects**	**BIC**	χ^2
1	Intercept	2306.3	-
2	Consonant Type	2309.1	2.687 *n.s.* (relative to model 1)
3	Position	2294.4	17.381 *** (relative to model 1)
4	Consonant Type + Position	2293.9	23.346 *** (relative to model 1)
5	Consonant Type * Position	2298.9	0.53 *n.s.* (relative to model 4)

The model that included Position (model 3 in Table 7.17) as a fixed effect had a better fit to the data than the baseline, suggesting that the duration of the tonic vowel depends on the position of the geminate/singleton in the word. However, the model including Consonant Type (model 2 in Table 7.17) did not explain the data any better than a model consisting only of the intercept.

Model 4, which includes Consonant Type and Position as two fixed effects terms, has a better fit to the data than model 1. This suggests that the duration of the tonic vowel is affected by whether the following consonant is a singleton/geminate and also by the position of that consonant in the word. In contrast, the interaction of Consonant Type and Position in model 5 did not explain the data any better than model 4.

The comparison of model 2 and model 3 to model 4 (in Table 7.18) show that model 4 has a better goodness-of-fit than the two models which include Consonant Type and Position as individual fixed effect terms. Therefore, this might suggest that Consonant and Position both effect the duration of the tonic vowel.

Table 7.18: Duration of the preceding vowel: Further model comparisons

Model Comparisons	χ^2
Model 2, Model 4	20.659 ***
Model 3, Model 4	5.9658 *

I conclude that the duration of the tonic vowel is affected by whether the following consonant is a singleton/geminate and also the position of these consonants in the word. The model that explains the data best is model 4 and it is summarized in Table 7.19.

Table 7.19: Summary Model 4: Consonant + Position

Fixed Effects	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	122.170	7.002	17.447	1.33e-15 ***
Consonant	13.462	5.184	2.597	0.0156 *
Position	-30.113	5.328	-5.652	6.07e-06 ***

Therefore, these results show that the vowel before singletons is longer than the vowel before geminates. This suggests that the requirements of the phonology on the syllable structure are taken into account in the phonetic realizations. The vowel before word-final geminates was 38ms shorter than before word-final singletons. Moreover, the vowel before word-medial geminates was 17ms shorter than before word-medial singletons. For the future, a perception study can help to identify whether this shorter duration acts as a correlate to gemination. In terms of correlates for geminates (in production) I take this vowel shortening to be a secondary correlate for gemination.

7.5 The vowel after word-medial geminates

Cross-linguistically the duration of the vowel after word-medial geminates is less studied than the vowel before geminates (Chapter 3 §3.1.4). Here, I examine the duration of the vowel after word-medial geminates. This was done for two reasons: first, to get a thorough understanding of the durational correlates for gemination in Maltese; and second, to shed more light on this understudied area. In order to do so, I created a subset from the target words in this study. These target words are listed in Table 7.20. The reason why a subset from the whole target word list was selected was to ensure a comparison of the duration of the vowel after singletons and geminates. In these target words, the vowel after the geminates was also /ɐ/. /ɐ/ was chosen, since it is the most frequent vowel in this position in the corpus. This yielded 240 tokens; i.e., 20 words from 12 speakers. All target items in this corpus were stressed on the first syllable.

Table 7.20: Word list for the investigation for the vowel after word-medial singletons/geminates (vowel in bold)

Manner	**Segment**	**Singleton**	**Geminate**
Stop	/t/	/ˈbɐt**ɐ**n/ *batan* 'to conceive an idea'	/ˈbɐtt**ɐ**n/ *battan* 'to gird a horse's belly'
		/ˈfɛt**ɐ**ʔ/ *fetaq* 'to rip apart'	/ˈfɛtt**ɐ**ʔ/ *fettaq* 'to stitch and unstitch again'
		/ˈʔɐt**ɐ**r/ *qatar* 'to drip'	/ˈʔɐtt**ɐ**r/ *qattar* 'to dribble'
Fricative	/s/	/ˈrɛs**ɐ**ʔ/ *resaq* 'to approach'	/ˈrɛss**ɐ**ʔ/*ressaq* 'to bring s.th closer'
		/ˈnɐs**ɐ**b/ *nasab* 'to trap birds'	/ˈnɐss**ɐ**b/ *nassab* 'to lay traps'
	/f/	/ˈlɛf**ɐ**ʔ/ *lefaq* 'to sob'	/ˈlɛff**ɐ**ʔ/ *leffaq* 'to sob continuously'
	/ʃ/	/ˈmɐʃ**ɐ**t/ *maxat* 'to comb'	/ˈmɐʃʃ**ɐ**t/ *maxxat* 'to comb frequently'
		/ˈnɐʃ**ɐ**r/ *naxar* 'to hang'	/ˈnɐʃʃ**ɐ**r/ *naxxar* 'hyp.'
-	/r/	/ˈmɐr**ɐ**d/ *marad* 'to fall ill'	/ˈmɐrr**ɐ**d/ *marad* 'to cause s.o. to fall ill'

The duration of the vowel after singletons ($\bar{x}$ = 102ms (27)) and geminates ($\bar{x}$ = 99ms (31)) are comparable. A linear mixed effects model with Consonant (singleton, geminates) as a fixed effect showed that this difference between these two vowels is not significant (BIC = 2362.7, χ^2 = 0.2604, p = 0.6, compared to a baseline: BIC = 2357.4).

7.6 Final lengthening

The results in §7.2.1 indicated that singletons in word-final position are discernably longer than singletons in word-medial position (under the same prosodic conditions). Furthermore, the duration of the vowel is also discernably longer in final position than in medial position. I argue that the longer durations of singletons in final position are due to domain final lengthening (cf. Cambier-Langeveld 1997, Jun and Fougeron, 2000 and Turk & Shattuck-Hufnagel 2007). Therefore, singleton consonants are phonetically longer in pre-boundary position. Note that the duration of geminates was not significantly different in the two positions (c.f. §7.2.4). This might suggest that there is some sort of limit of how long geminates can be on the acoustic surface.

Cambier-Langeveld (1997) argued that final lengthening in Dutch is restricted to the final syllable and the final rhyme of that syllable. Moreover, Turk & Shattuck-Hufnagel (2007) reported that the effect of final-lengthening in American English is strongest in the rhyme, in both monosyllabic words and polysyllabic words, where the lengthening starts off in the nucleus. Therefore, I investigated the duration of the nucleus and the following consonant. Note that Maltese provides a very interesting case, unlike American English or Dutch, as it imposes complimentary quantity in monosyllabic words. The addition of a long vowel and a singleton was on average 320ms (72), and the addition of the short vowel and the geminate was on average 316ms (73). Therefore, this suggests that the duration of the rhyme in word-final position is comparable, despite the fact the rhymes are made up of different syllable constituents.

Unfortunately a comparison of the rhyme in word-medial and word-final position cannot be made here. This is because in word-medial position singletons constitute an onset and not a coda, therefore a CVCV syllable is syllabified as CV.CV. In addition, these constitute bisyllabic words and cannot be used to compare to the monosyllabic word-final words.

The mean durations of the rhyme in word-final position, despite having different subsyllabic constituents, are comparable. Therefore, an interesting question is what is the exact location of final-lengthening in monosyllabic words. Does it start off in the nucleus or in the coda consonant? In order to do this, a comprehensive study using bisyllabic and monosyllabic words has to be carried out. In addition, I propose two possible areas that could be investigated later on. First, what are the implications of these results on rhythm in Maltese or in languages that have complimentary quantity, what about in other languages? Second, an interesting follow-up question is related to perception. Which subsyllabic constituent do native speakers rely on? Does manipulating and neutralizing the duration of the vowel and/or the consonant lead to a mismatch in a word-identification task?

7.7 Discussion

Overall, word-final gemination in typologically different languages has been investigated to a lesser degree compared to word-medial and/or word-initial position. In the review of the empirical studies presented in Chapter 3 §3.3 word-final geminates, like word-medial and word-initial geminates, manifested constriction duration as the primary correlate. In most cases, word-final obstruents were investigated much more than word-final sonorants. Hume et al. (2014) differs in this respect as they looked at both sonorants and obstruents.

In this study, gemination in word-final position has longer durations than singletons, albeit to a lesser degree when compared to word-medial geminates (under similar prosodic conditions). Some of the duration ratios reported in this study differ from those reported in Hume et al. (2014). Table 7.21 shows a comparison of the duration ratios in both studies.

Table 7.21: Comparing duration ratios of word-final geminates in Maltese

Manner	Hume et al. (2014)	This Study
Fricatives	1:1.3	1:1.3
Affricates	1:1.1	1:1.1
Stops	1:1.4	1:1.2
Liquids	1:1.9	1:1.3

First, the duration ratios of fricatives and affricates are comparable in both studies. However, the duration ratio of stops and liquids are different. In the current study, stops are slightly shorter than in Hume et al. (2014). It is crucial to mention that Hume et al. (2014) measured closure duration for stops, and in this study the whole duration of the stop was measured.

On the other hand, there is a substantial difference between the duration ratios of liquids in both experiments, where liquids are noticeably longer in Hume et al. (2014). One possible explanation for this difference might be the method of presentation used in the two studies. In this experiment, the word following the target word started with the nasal /m/, whereas in Hume et al. (2014) the word started with the vowel /ɛ/. It might be possible that liquids maintain their acoustic realizations in word-final position when the following word starts with a vowel, but its duration might be affected when the following word starts with a consonant. This does not happen in word-medial position. Liquids in word-medial position have longer duration ratios than in word-final position. However, liquids in word-medial position are immediately followed by a vowel and not a consonant – the syllabic structure for word-medial geminates was as follows: CVGV(C)- (i.e. there is always a vowel after the liquid). In light of this finding, a comparison can be made with Kraehnmann's (2001) results. Kraehenmann (2001) reported a decrease in duration for word-final geminate stops in Swiss German. Furthermore, Kraehenmann (2001) reported that word-final geminate stops are neutralized when they were followed by another obstruent, but not when they were followed by a sonorant.

In this production study, I examined whether the vowel before geminates shortens as predicted by Maddieson (1985). In the case of medial geminates, the vowel before geminates was 17ms shorter than that before singletons. The extent to which this decrease in vowel duration serves as a cue in perception still needs to be examined. The vowel before word-final geminates was shorter than that before singletons. This was expected since the vowel before word-final singletons are phonologically long vowels and the vowel before word-final geminates are phonologically short vowels. Furthermore, the addition of the rhyme (i.e. of the long vowel and the singleton; and the short vowel and the geminate) shows that the durations are comparable. This was taken as evidence for final-lengthening in Maltese, where possibly the rhyme is the domain of final-lengthening.

This chapter marks the final production study in this dissertation. The following chapter, Chapter 8, investigates the role of the epenthetic vowel in the perception of word-initial geminates.

Chapter 8: The perception of the vocalic insertion before word-initial geminates

The perceptual role of the vocalic insertion before word-initial geminates in Maltese, with respect to lexical representation is investigated in the following study. To start with, an overview of a number of empirical studies that investigated the perception of the geminate/singleton contrast in word-initial position is presented in §8.1. This serves as a guide to the perception experiment on morphological word-initial geminates and the role of the preceding vowel in Maltese in §8.2, where I lay out the goals and the overall methodology of the experiment. In §8.3, I examine the results from this experiment by looking at correctness rates. In §8.4, I sum up the results.

8.1 The perception of word-initial geminates

The critical issue for the perception of word-initial geminates is how can word-initial voiceless stops be perceived when the durational cue is not there? In the case of fricatives, frication is present in the acoustic signal, but in voiceless stops closure duration might be mistaken for silence. The studies presented here corroborate this fact; namely, that word-initial geminates are better perceived when they are fricatives or voiced stops rather than voiceless stops.

8.1.1 Cypriot Greek

In a production study on word-initial geminates in Cypriot Greek, Muller (2001) established that VOT was a significant correlate to word-initial geminate stops, where VOT was longer for geminates than for singletons. In addition, constriction duration in fricatives was longer for geminates than for singletons. Subsequently, Muller (2001; 2003) investigated whether native speakers of Cypriot Greek can discriminate between word-initial singletons and geminates. The initial syllables of words were used as tokens in this perception experiment. Listeners had to identify word-initial singletons and geminates in a forced choice word identification task. For example, participants heard the syllable [t:el] and had to decide if this word was either *telaron* 'cloth frame' (i.e., containing a singleton /t/ in word-initial position) or *t:eliazo* 'fence in' (i.e., containing a geminate /t/ in word-initial position).[67] Participants were able to correctly identify whether the token had a singleton or a geminate in over 92% of the tokens presented. Thus, Muller (2003) concluded that listeners are able to distinguish initial geminates from singletons. Furthermore, it seems that listeners identify stops in phrase-initial position much better than fricatives in the same position. Stops in phrase-initial position were correctly identified in 98% of the tokens, whereas fricatives in the same position were correctly identified in 67% of the tokens. The rate of correct identification in phrase-medial position is similar for stops (around 97%) but it increased for fricatives (82%). Therefore, listeners were able to identify the singleton/geminate contrast. Voiceless stops were correctly identified in both phrase-initial and phrase-medial positions. Also, stops are better perceived than fricatives. In light of this result, looking at the production and the perception data, Muller (2001:51) suggested that "constriction duration [for voiceless stop] is not the most salient cue marking geminate status". She argued that VOT is employed by speakers and listeners to distinguish length of initial stops.

8.1.2 Arabic

Obrecht (1965) reported a similar result to Muller (2001) for word-initial fricatives in Arabic. Obrecht (1965) tested whether native speakers of Arabic (Jordanian and Lebanese) could identify word-initial singleton /ṣ/or geminate /ṣṣ/ in pairs of words such as /ṣabiy/ *boy* and /ṣṣabiy/ *the boy*, where the latter example turns out to have an assimilated geminate in word-initial position. The stimuli for the perception experiment were created from an original token, and closure durations were increased by 20ms from 80ms to 200ms. Obrecht (1965) reported that the stimulus at 80ms was identified well by all speakers (i.e. 100%) and was identified as a singleton. However, the stimulus with the longest duration (i.e. 200ms) was judged as a geminate consonant only 70.37%.

[67] These two examples were taken from Muller 2001:42.

8.1.3 Tashlhiyt Berber

Ridouane and Hallé (2011) investigated whether native speakers of Tashlhiyt Berber can distinguish between words with initial geminates as in *tut* 'she hit' and *ttut* 'forget him'.[68] Ridouane and Hallé (2011) reported that the voiced stops and fricatives were correctly identified at near ceiling level (97% and 95% respectively). However, voiceless stops were identified only above chance level with 62% correct identification. Furthermore, reaction times were slowest for voiceless stops, compared to voiced stops and fricatives. In addition, Ridouane and Hallé (2011) also indicated that the context in which target words were present affected the performance of the participants, so much so that voiceless stops were best identified in the focused condition (70%) and less so in the carrier phrase condition (55%). When words were in isolation, they held an intermediate between the focused condition and the carrier phrase condition. On the other hand, in a similar experiment on similar stimuli but played to French listeners, the opposite result was reported in Hallé and Ridouane (2011). French listeners, who do not have the phonemic contrast of gemination in their language, were able to identify Tashlhiyt Berber word-initial voiced stops and fricatives geminates much better than word-final voiceless stop geminates.

8.1.4 Interim summary

In §8.1, I provided an overview of the results on a number of different perception experiments. With respect to word-initial geminates, the main issue is whether geminate voiceless stops can be distinguished from singleton counterparts in phrase-initial position. The results from Cypriot Greek (Muller 2001) and Tashlhiyt Berber (Ridouane and Hallé 2011) gave contradicting evidence. Muller (2001) reported that native speakers of Cypriot Greek can identify voiceless stops much better than fricatives in word-initial position. On the other hand, Ridouane and Hallé (2011) reported that voiced stops and fricatives were better perceived than voiceless stops by native speakers of Tashlhiyt Berber.

[68] Examples were taken from Ridouane and Hallé 2011:1692.

8.2 The perception of word-initial geminates in Maltese

In this section I discuss a perception study on the word-initial geminates in Maltese. In this experiment, an AX discrimination task was used, where participants listened to pairs of words and had to decide whether these words sounded the same or different. This section is divided up as follows: in §8.2.1, I identify the goals of the experiment. In §8.2.2, the experimental design is outlined. In §8.2.3, the predictions are presented. In §8.2.4, I discuss the procedure employed to collect the data. In §8.2.5, I give some information in relation to the participants of the experiment.

8.2.1 Goals of the experiment

Given the results of Production Study 1 and also Production Study 2, word-initial geminates (regardless if they are lexical or surface geminates) are almost always preceded by a vocalic insertion of [ɪ]-like quality. This is at least almost always true when the preceding word ends in a consonant. It is also predicted (Hobermann and Aronoff 2003) that the vowel before word-initial geminates is always present at the start of a phonological phrase, however, this has not been empirically tested. Yet, little is known on the role of the vowel before word-initial geminates in Maltese in perception. In this experiment, the role of the vocalic insertion before word-initial geminates is investigated.

8.2.2 Materials and design

In this experiment, three conditions were used. In the V (vowel before word-initial geminates) condition, target words had the vocalic insertion before the word-initial geminate. In the G (geminate) condition, nothing preceded the word-initial geminate. Finally, in the S (singleton) condition, target words had a word-initial singleton. These three conditions were matched and the *identity* and *test* conditions in Table 8.1 were created. A Latin square design was used to have an equal distribution of words in each condition. The identity conditions are expected to be used as a baseline for comparison of the test conditions.

Table 8.1: Conditions (and examples) of the perception experiment

Identity	**V - V (VV)** [**ɪss**ɐffɐr - **ɪss**ɐffɐr]	**G - G (GG)** [**ss**ɐffɐr - **ss**ɐffɐr]	**S – S (SS)** [**s**ɐffɐr - **s**ɐffɐr]
Test	**V – S (VS)** [**ɪss**ɐffɐr - **s**ɐffɐr]	**V - G (VG)** [**ɪss**ɐffɐr - **ss**ɐffɐr]	**G - S (GS)** [**ss**ɐffɐr - **s**ɐffɐr]

Target words consisting the word-initial segments /t, d, s, ʃ/ were selected. For each segment 18 target words (expect for 17 target words for /t/) were selected. This yielded 71 target words pairs. Target words were all verbal forms taken from *ġabra* (Camilleri 2013) and had a similar syllable structure for word-initial singletons and geminates: **G**VGC/**G**VCCVC and **C**VGC/**C**VCCVC. 71 filler items, which had a similar syllable structure to the target words, were also added to the stimuli list. In order to record the target words and the filler items, a male Maltese-dominant native speaker (age 25) read the words in the carrier phrase in (1). Recordings were carried out in a sound-attenuated booth at the Institute for Linguistics-Phonetics, University of Cologne.

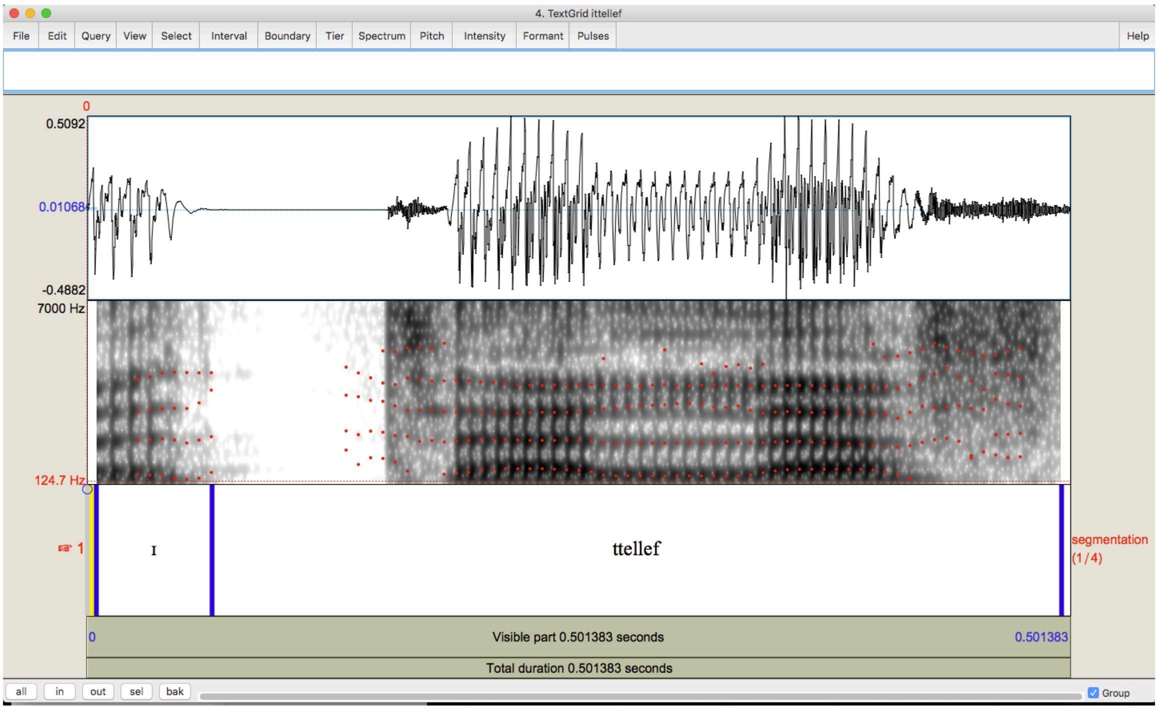
(1) **Qalilhom**	__________	mitt darba
HE TOLD THEM	__________	**A HUNDRED TIMES**

The native speaker read only one version of the target words, which included the inserted vowel and the word-initial geminate such as: [**ɪtt**ɛllɛf] 'to cause to lose'. These words were segmented in Praat (Boersma & Weenink 2015) and were extracted using a Praat script. The target word was spliced in order to come up with the word-initial geminate forms without the inserted vowel (i.e., the G-words in Table 8.1, e.g., [**tt**ɛllɛf]) and the singleton form (i.e., the S-words in Table 8.1, e.g., [**t**ɛllɛf]). An example of one set of words for each segment is given in Table 8.2.[69] The criteria implemented for splicing was the same for all the target words. In order to create word-initial geminate forms without the inserted vowel (i.e., G), the vowel formants were used as a guide to splice off the vowel. If the vowel formants continued into the closure (or constriction) duration, and the

[69] The full list of the stimuli and their glosses is in Appendix 4

vowel could still be heard, then the vowel was spliced off after the end of the vowel formants trail in Figure 8.1 (as shown by the thick line after the vowel [ɪ]).

Figure 8.1: Splicing off the vocalic insertion [ɪ] from the target word [ɪttɛllɛf] 'to cause to lose'



The duration ratios from Production Study 1 (cf. Chapter 5) were used in order to establish the duration of the singleton segments. The singleton-to-geminate duration ratios for the four segments are listed in (2) below.

(2) Duration ratios

/t/ = 1:2.19

/d/= 1:2.44

/s/= 1:1.42

/ʃ/= 1:1.35

Table 8.2: An example of the stimuli for the perception study from each of the segments

Condition	**/t/**	**/d/**	**/s/**	**/ʃ/**
V(owel)	[**ɪtt**ɛllɛf] *ttellef* 'to be made to lose'	[**ɪdd**ɐbbɐr] *ddabbar* 'to be temporarily patched up'	[**ɪss**ɐbbɐr] *ssabbar* 'to be comforted'	[**ɪʃʃ**ɐbbɐt] *xxabbat* 'to climb'
G(eminate)[70]	[**tt**ɛllɛf]	[**dd**ɐbbɐr]	[**ss**ɐbbɐr]	[**ʃʃ**ɐbbɐt]
S(ingleton)	[**t**ɛllɛf] *tellef* 'to cause s.o. to lose'	[**d**ɐbbɐr] *dabbar* 'to manage to acquire'	[**s**ɐbbɐr] *sabbar* 'to console'	[**ʃ**ɐbbɐt] *xabbat* 'to cause s.th. to climb'

Given the six possible combinations from the three conditions (i.e., V-V; G-G; S-S; V-G; G-S; V-S), six counterbalanced lists were created. Each list consisted of three pairs of words for each segment and every list consisted all the words in the list. Since a Latin square design was used, all words were presented to the participants, in different conditions in each list. Note that participants were presented with pairs of words, for instance in the V-G condition, one possibility was [ɪttɛmtɛm] - [ttɛmtɛm].

8.2.3 Predictions

In this experiment, native speakers had to decide whether pairs of words (in the conditions in Table 8.1) sounded the same or different. For the identity conditions (i.e., where the word pairs were exactly the same: VV, GG, SS), it is predicted that participants will respond to these words as being the same. For all the test conditions (i.e., VG, VS, GS), it is predicted that participants will respond to these pairs of words as sounding different. For each of the test conditions, the following predictions were made. For the VS pairs (such as ***iss****affar* – ***s****affar*), the initial segments in the word are phonetically different; also the tokens correspond to two different lexical items. Therefore, I predict that these pairs

[70] The words in the G (geminate) condition have the same meaning as the V (vowel) condition.

will be perceived as being different and they should be perceived as a word having a geminate and another having a singleton. For the VG pairs (such as ***iss****affar* – ***ss****affar*), I predict that these two tokens will be perceived as being different. Based on the outcomes of the production studies 1 (Chapter 5) and 2 (Chapter 6), I predict that participants will not be able to distinguish between GS pairs (such as ***ss****affar* – ***s****affar*).

With respect to the segments used in this experiment, the following predictions were made. Since constriction duration is more readily available on the acoustic surface for fricatives than for stops, I predict that fricatives should be better perceived in word-initial geminates when the inserted vowel is not present. During the voiced stop /d/, there is voicing during closure; however, this is less audible than the frication in the fricative. Following the results presented by Ridouane and Hallé (2011) for Berber, I predict that when the vocalic element is missing, voiced stops will be perceived as accurately as fricatives. On the other hand, during the voiceless stop /t/, closure duration will not be perceptually available and therefore, this will be much more difficult to perceive when the vocalic element is absent. Therefore, it is expected that the fricatives (/s ʃ/) will be perceived much better than the stops (/t d/), and within the stops themselves, the voiced stop /d/ will be perceived much better than the voiceless stop /t/. Notwithstanding any of these predictions, I claim that when present the inserted vowel before word-initial geminates is the strongest cue for identifying word-initial geminates. When absent, it is possible that the nature of the fricatives will help the identification of word-initial geminates. This result is in line with previous findings on the perception of word-initial geminates in Tashlhiyt Berber (Ridouane and Hallé 2011). Note, however, that Muller (2003) reported the opposite pattern: word-initial voiceless stops were better identified than fricatives.

8.2.4 Procedure

Participants were tested individually in a quiet room at the University of Malta. Participants heard the speech stimuli through professional quality headphones. This experiment was run in DMDX (Forster & Forster 2003). On each AX trial, participants were presented with three sound files: a bell sound indicating that the trial was going to start, followed by a 1000ms silence, followed by two auditory stimuli in sequence. The first and second stimuli were separated by a 500ms silence. Participants had to decide whether the two stimuli sound the same or different, by pressing keys on the keyboard. After the second stimulus, the word *Wieġeb* 'answer' flashed on the screen and participants had 2000ms to answer. Before running the actual experiment all participants were given a six-item practice session.

8.2.5 Participants

Sixty (37 females, 23 males) native speakers of Maltese were recruited for this experiment, none of which had participated in the Production Studies 1, 2 and 3. Most participants used Maltese more than English, but there were participants who reported the used of both languages. As in the production studies, participants answered the same linguistic questionnaire (based on Twist (2006); cf. Appendix 1) as the other participants in the production studies. Participants were asked which languages they use at home and with friends; and also which language they feel most comfortable in. 88% of the participants reported that they use only Maltese at home, 3% English at home and 8% use both languages at home. 75% of the participants reported that they use only Maltese with friends, 10% reported that they use English with friends and 15% reported that they use both languages with friends. Most participants (i.e. 78%) feel most comfortable in Maltese, 12% feel most comfortable in English, whereas 10% feel comfortable using both languages. The participants were between 19 and 47 years of age at the time of testing. The mean age was 25, and the median age was 24.

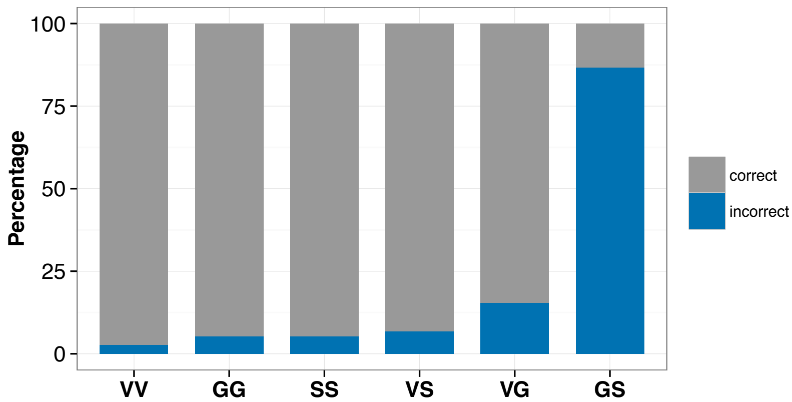
8.3 Results

The results of the perception experiment are discussed here. In §8.3.1, I present the correctness rates for the six conditions and in §§8.3.2-8.3.3 I investigate whether the difference in the correctness rates is statistically significant.

8.3.1 Correctness rates

In the identity conditions (i.e. GG: ***ss****affar* 'to be whistled' – ***ss****affar* 'to be whistled'; SS: ***s****affar* 'to whistle' – ***s****affar* 'to whistle'; VV: ***iss****affar* 'to be whistled' – ***iss****affar* 'to be whistled'), participants correctly identified the pairs of words as being the same. The highest correctness rate was for VV, where VV pairs were correctly identified in 97% of the tokens. GG and SS followed VV, where participants correctly identified such pairs as being the same in 96% of the tokens. This result confirms the predictions made above, where participants perceived GG (e.g., ***ss****affar* – ***ss****affar)*, SS (e.g., ***s****affar* – ***s****affar)* and VV (e.g., ***iss****affar* – ***iss****affar)* pairs as being the same. Figure 8.2 shows the correctness rate for each condition.

Figure 8.2: Percentage correctness rates, correct here is defined as the correctly identified in the pairs as being the same or different



In the test conditions, there is a clear split in the data as a function of whether there is vowel or not. In the VG (e.g., ***iss****affar* – ***ss****affar*) and VS (e.g., ***iss****affar* – ***s****affar*) conditions, participants perceived these pairs as being different.

Participants identified VS pairs as being different in 93% of the data. This result was much better than that for VG pairs, as participants perceived these pairs as being different in 86% of the data. Even though this correctness rate is lower than that for VS pairs, it is still a very good rate and it is above chance level. In the other test condition, GS (e.g., ***ss****affar* – ***s****affar*), in 87% of the data, participants perceived the pairs as being the same, and in 13% they perceived the pairs as being different. This suggests that native speakers of Maltese could not distinguish between true word-initial geminates and word-initial singletons. Before delving into the implications of these results, the role of Condition and Segment (i.e. /t d s ʃ/) on the data is investigated.

All data were analysed using Logit Mixed Models, using R and the function *glmer* in the package *lme4* (Bates et al. 2015) to test for a binominal dependent (i.e. correct/incorrect). Random slopes for speakers and items were added, but the model had problems with convergence. Covarience was removed and the models still had issues of convergence. Therefore, random slopes were only added for speaker. The fixed effects of Condition (GG, SS, VV, GS, VS, VG), and Segment (/t d s ʃ/) were centered to reduce collinearity. A model-comparison approach was adopted, where the goodness-of-fit of different models was tested to determine the impact of the two independent variables; for this purpose, the model's Bayesian Information Criterion (BIC) together with the model chi-squared value (χ^2) are reported.

A baseline (model 1), which was made up of only the intercept and the random effect, was built. The contribution of the fixed effects of Condition and Segment were investigated separately and were compared to the baseline (i.e., models 2 and 3 respectively). Model 4 including the two fixed effects Condition and Segment was built and was compared to model 1. Model 5 included the interaction of the two fixed effects and this was compared to model 4.

The model including Condition as a fixed effect (i.e. model 2 in Table 8.3) had a better fit to the data than the baseline; however, the model including Segment as a fixed effect (i.e., model 3 in Table 8.3) did not. In model 4, the addition of the two fixed effects explain the data much better than the just the intercept.

Table 8.3: Model Comparison: Correctness (*** = p < 0; *n.s.* = not significant)

Model	**Fixed Effects**	**BIC**	χ^2
1	Intercept	2484.0	-
2	Condition	2481.5	10.829 *** (relative to model 1)
3	Segment	2492.3	0.8592 *n.s.* (relative to model 1)
4	Condition + Segment	2489.8	10.874 ** (relative to model 1)
5	Condition * Segment	2498.2	0.0122 *n.s.* (relative to model 4)

Table 8.4: Further model comparisons: Correctness

Models	χ^2
Model 2, Model 4	0.0454 *n.s.*
Model 3, Model 4	10.843 ***

Model 4 has a better goodness-of-fit than model 3, but not better than model 2. This suggests that the addition of Segment does not explain the data any better. Therefore, this suggests that Condition is the strongest contributor to the results. The inclusion of an interaction term did not improve the model fit, as shown by the comparison of model 5 to model 4. In Table 8.5, I present a summary of Model 2.

Table 8.5: Summary of Model 2: Condition (*** = p < 0)

Fixed Effects	**Estimate**	**Std. Error**	**z value**	**Pr(>|z|)**
(Intercept)	-2.1412	0.2395	-8.939	< 2e-16 ***
Condition	-0.7615	0.2213	-3.441	0.000579 ***

8.3.2 A closer look at the test conditions

The three test conditions had distinct accuracy rates. VS pairs (e.g. [ɪssɐffɐr] ‘to be whistled’ - [sɐffɐr] ‘to whistle’) were almost always identified as different (93%) and VG pairs (e.g., [ɪssɐffɐr] ‘to be whistled’ - [ssɐffɐr] ‘to be whistled’) were almost always identified as being different (86%). However, GS pairs (e.g., [ssɐffɐr] ‘to be whistled’ - [sɐffɐr] ‘to whistle’) had the lowest correctness rate as GS pairs were only identified as being different 13% of the time. Here, I investigate whether the difference among these three conditions are statistically different or not. In order to assess this, each *test condition* was compared to every other. In order to achieve this, a Logit Mixed Model was constructed (using *lme4* Bates et al. 2015) with *Test Condition* as a fixed effect. The *Test Condition* was dummy-coded, so that each level was compared to a fixed reference level. In this case, VG (e.g., [ɪssɐffɐr] ‘to be whistled’ - [ssɐffɐr] ‘to be whistled’) was chosen as the reference level and the correctness percentages of VS (e.g. [ɪssɐffɐr] ‘to be whistled’ - [sɐffɐr] ‘to whistle’) and GS (e.g., [ssɐffɐr] ‘to be whistled’ - [ssɐffɐr] ‘to whistle’) were compared to the reference level. The correctness percentages for VG were statistically different from those for VS (VG: 86%, $z = -13.356$; VS: 93%, $z = -5.121$, $p = 0.001$). Also, the correctness percentages for VG were statistically different from those for GS (VG: 86%, $z = -13.356$; GS: 13%, $z = 22.645$, $p = 0.001$).

8.3.3 Segments play no role

Following the discussion in §8.1, it was expected that in the GS pairs, fricatives would be better perceived than voiced stops. Voiceless stops would be perceived the worst. However, in this experiment, the participants perceived true word-initial geminates words as word-initial singletons words (i.e., they did not distinguish between [*ssaffar* – *saffar*]). This also holds across all segment types. Participants had low accuracy rates regardless of the segment type, as these two words were perceived as being the same. Therefore, they did not do better in one segment type over another type. This is confirmed by the fact that Segment as a fixed effect term did not contribute in explaining the data any better than a model with just the intercept (cf. Table 8.3).

8.4 Discussion

The results of this perception study, pattern quite well with the results of Production Studies 1 and 2, where it was shown that word-initial geminates in Maltese almost always require a preceding vocalic insertion. This led to the research questions for this perception experiment, namely, 1) what role does this vocalic insertion have in perception? 2) Can word-initial geminates without a preceding vowel be perceived as distinct from singletons? The results of this perception study bear out my predictions, as do the production results presented in the preceding chapters, as the vowel before word-initial geminates has been shown to play a very important role in perception. The data show that there is a split in the results of this perception experiment, where native speakers of Maltese correctly discriminated between vowel-word-initial geminates and singletons (VS pairs: *issaffar* - *saffar*), as well as between vowel-word-initial geminates and non-vowel-word-initial geminates (VG pairs: *issaffar* - *ssaffar*). However, in the other test condition, GS (e.g., *ssaffar* – *saffar*), native speakers of Maltese identified these tokens as being the same and not different.

The fact that GS pairs were identified as being the same and not different is very revealing. If word-initial gemination were present in the phonology of Maltese, native speakers would have perceived the two words as being different. This is the case for Tashlhiyt Berber (Ridouane and Hallé 2011) and Cypriot Greek (Muller 2001). In fact, in those languages, native speakers produce word-initial geminates (i.e., without preceding vocalic insertions) and even perceive them. Additionally, the results show that word-initial gemination without the preceding vocalic insertion in Maltese is perceived as being perceptually similar to a word-initial singleton.

Based on these findings, I argue that word-initial gemination in Maltese does not exist, and that this holds in both production and perception. In production, word-initial geminates are almost always preceded by a vocalic insertion and in perception word-initial geminates (i.e., without preceding insertions) are perceived as singletons. Note that it is very difficult to say how native speakers of Maltese perceived the second item in the VS and VG pairs. Given the GS pair results, I assume that the participants treated the S and G tokens in the pairs as singletons. However, given the nature of the experiment this is not possible to find this out. In addition, one can argue that pairs like *issaffar* and *ssaffar* (i.e., VG pairs) are variants of the same lexical item, especially considering that a vocalic insertion before word-initial geminates was not present in 4% of the data in Production Study 1 and not present in 14% of the data in Production Study 2. If this idea were to be pursued further, I would expect participants to decide that such words are the same and not different. Nonetheless, I believe that this hypothesis cannot be entertained as the results show that participants overwhelmingly decided that these words are different.

Implications for processing models

According to these results (and also the results for word-initial geminates in production studies 1 and 2), I claim that the vowel before word-initial geminates is phonological, and part of their lexical representation. Native speakers of Maltese rely on this vowel as a cue to word recognition. Therefore, native speakers have phonological knowledge of this vowel, since when it is present, they are able to differentiate between word-initial geminate vs singleton consonants, but when it is absent, a word-initial geminate is perceived as a singleton consonant. These results fit with models of lexical representation such as the Cohort Model (Marslen-Wilson & Tyler 1980; Marslen-Wilson 1984) and the Shortlist A Model (Norris 1994). In the Cohort model, word identification is based on activation of a number of possible candidates determined by word-initial matching of the incoming speech signal based on the start of a spoken word. To illustrate, hearing [ɪssɐffɐr] *ssaffar* 'to be whistled' could potentially activate [ɪssɐhhɐn] *ssaħħan* 'to be warmed up', [ɪssɐbbɐt] *ssabbat* 'to bang', and [ɪssɛwwɐ] *ssewwa* 'to be repaired', all of which match the word onset [ɪss…]. As the speech signal unfolds over time, mismatching activated candidates are rejected as potential target words, as they do not match the phonemes in the target word. Word recognition occurs when the speech signal matches one unique word from the cohort, at what is termed the lexical Uniqueness Point (UP). The UP could in fact occur relatively early, when enough information has been perceived in the speech signal to uniquely identify a single lexical candidate. Furthermore, in the event that the phoneme is not perceived, then the target word may not be activated since only candidates consistent with the input would be considered as potential lexical representations. I claim that this is what happens in GS pairs. A word-initial geminate (without the vowel) such as [ssɐffɐr] *ssaffar* 'to be whistled' activates competitors such as [sɐffɐr] *saffar* 'to whistle', [sɐhhɐn] *saħħan* 'to warm up', [sɐbbɐt] *sabbat* 'to bang', [sɛwwɐ] *sewwa* 'to repair'. These competitors are activated since true word-initial geminates in Maltese are not part of the sound system or the lexical representations of the language. Therefore, a word-initial geminate not preceded by a perceivable vowel is interpreted as a singleton, which activates singleton-initial words to the exclusion of geminate-initial words. In a discrimination task, like the one presented in this chapter, participants will respond by identifying these words as the same. However, when the vowel before word-initial geminates is present, the right set of candidate lexical representations is activated, and listeners have no problems in discriminating the sequence of the vowel-word-initial geminates from singletons.

In the Shortlist model of word recognition a similar process ensues. An initial phoneme is taken as the input and according to this input a shortlist of candidates is selected, and these candidates are in competition for selection and recognition. As more phonemic information is made available, the shortlist is updated and non-matching candidates are rejected until the correct candidate is chosen. In relation to this experiment, both models make similar predictions with respect to lexical competitors. I argue that only through the vowel [ɪ] can word-initial geminates be activated. As a consequence, this vowel cannot be added on the fly as the result of phonetic transitions from one consonant to another. When this vowel is absent, words containing segments with longer durations in word-initial position are judged as singletons by native speakers.

Therefore, native speakers of Maltese are insensitive to word-initial constriction duration and use their phonological knowledge and phonotactic information in word recognition.

In the next chapter, I provide final remarks in light of outcomes of the experimental work undertaken in this dissertation by considering the implications of the results of the three production studies and this perception experiment on the phonology of Maltese, and more specifically on the representation of geminates in Maltese.

Chapter 9: General discussion and conclusion

This chapter aims at bringing together the results from both the production studies and the perception study. In §9.1, I recapitulate the discussion in relation to the duration of geminates in different positions in the word by looking at the manners of articulation and their duration ratios. In §9.2, the findings on secondary correlates for gemination in Maltese are reviewed. In §9.3, I provide further evidence that the vowel before word-initial geminates is a phonological vowel. In §9.4, I propose a moraic representation for word-initial, word-medial and word-final geminates. In §9.5, I summarize the main points of the dissertation and conclude.

9.1 The duration of geminates

In this dissertation, I set out to discover the acoustic and perceptual correlates for geminates in Maltese. In the first production study (Chapter 5), I investigated the duration of lexical and surface geminates in Maltese. This starting point was driven by their reportedly controversial status, and I hypothesized that word-initial geminates are, in fact, non-initial as they are preceded by a vowel of [ɪ] quality. The results confirm this hypothesis. Word-initial geminates are neither phonetically or phonologically word-initial. I argued that it is possible that they are word-initial in another linguistic domain such as in the morphology (in Chapter 6). In addition, I reported that the duration of lexical Semitic and non-Semitic geminates are not statistically significant different from each other. In addition, there is also no statistical significant difference between the duration of geminates derived from the assimilation of the definite article as well as both lexical geminate types. Therefore, in the case of lexical geminates, the etymological origin of the verb does not have an effect on the duration of the geminate. Furthermore, evidence from a perception experiment (Chapter 8) showed the importance native speakers give to the epenthetic vowel in order to perceive word-initial geminates.

The fact that word-initial geminates are preceded by a vocalic insertion led me to look for differences between word-initial and word-medial geminates (in Production Study 2, Chapter 6). In fact, the results show that in terms of duration there is no difference between word-initial and word-medial geminates. In Production Study 3 (Chapter 7), I considered the differences between word-final and word-medial geminates.

As expected, the results showed that there are differences in the singleton-to-geminate duration ratios across different manners of articulation. Following the results from Production Study 2 (Chapter 6), I propose the hierarchy of the duration of word-initial geminates in (1) and of word-medial geminates in Maltese in (2).

(1) Word-initial geminate duration ratio hierarchy[71]
Affricates > fricatives, /r/, nasals > stops > liquids

(2) Word-medial geminate duration ratio hierarchy
Affricates > fricatives > nasals > stops > liquids > /r/

Affricate geminates have the shortest duration ratio and this is stable across the two positions. Except for /r/, there is a similar pattern in the rest of the manners, where there is an increase in the duration of fricatives, nasals, stops and liquids. The distinct duration ratios of /r/ in the two-word positions are quite surprising. It is generally reported that for /r/ there is a change in quality from a singleton as an approximant or tap to a geminate trill. This is a common alternation in a number of languages such as Italian and Malayalam (cf. Banner-Inouye 1995; Ladefoged and Maddieson 1996; and Cohn and Ham 1998).

Moreover, differences in the duration ratios are also present in the comparison of word-final and word-medial geminates. In (3) and (4) I propose the hierarchies for geminates in word-final and word-medial position respectively, following the results in Production Study 3 (Chapter 7).

[71] In the hierarchies (1) – (4), '>' means "greater duration than" and a ',' refers to a similar duration ratio.

(3) Word-final geminate duration ratio hierarchy

Affricates > stops > fricatives, liquids, /r/

(4) Word-medial geminate duration ratio hierarchy

Affricates > fricatives, stops > liquids, /r/

A similar pattern is found across the two sets of findings (bearing in mind that the target words were under different stress conditions). Affricates in (1) – (4) had the shortest duration. The liquid /l/ and /r/ had the longest durations in (1) – (4). Fricatives, stops and nasals had intermediate durations.

9.2 Secondary Correlates to gemination

In the three production studies, two secondary correlates were investigated. These were VOT (in Production studies 1 and 2, Chapters 5 and 6, respectively) and the duration of the tonic vowel (in Production studies 1 and 3, Chapters 5 and 7, respectively). In this section, I summarize these findings.

9.2.1 VOT

As discussed in Chapter 6 §6.5.3.1, VOT in voiced and voiceless stops was investigated in word- initial and word-medial singletons/geminates. In both production studies 1 and 2, it was found that *<u>VOT does not serve as a correlate</u>* to gemination in word-medial and word-initial position. As expected, VOT was shorter for voiced stops than for voiceless stops. Also, unsurprisingly, VOT was longest in the velar stop /k/, shortest in the bilabial stop /p/ and intermediate in the alveolar stop /t/.

9.2.2 The duration of the tonic vowel

Maddieson (1985) predicts that vowels before geminates should be shorter than vowels before singletons. This has been referred to as closed syllable shortening (e.g., Maddieson 1985; Cohn et al. 1999) or even compensatory shortening (e.g., Esposito and Di Benedetto 1999). The review on the duration of the vowel before word-medial geminates illustrates that different languages can, as predicted, shorten the vowel (as in Italian), or lengthen the vowel (as in Japanese), or else make no adjustments to the duration of the vowel (as in Turkish; cf. Chapter 3 §3.1.3 for a review).

In Production Study 3 (Chapter 7), I investigated the duration of the tonic vowel (i.e. the stressed vowel) before word-final and word-medial geminates as in (5).

(5) Tonic vowels (in bold) in word-final and word-medial contexts

(a) Word-final

/k**ɐː**p/ *kap* ‘boss’

/t**ɐ**pp/ *tapp* ‘tap’

(b) Word-medial

/ˈp**ɐ**.pɐ/ *papa* ‘pope’

/ˈp**ɐ**.ppɐ/ *pappa* ‘food’

The results elucidate the fact that in word-medial geminates the duration of the vowel before geminates is on average 17ms shorter than the vowel before singletons. By contrast, the duration of the vowel before word-final geminates is 39ms shorter than the vowel before word-final singletons. In the latter case, there is a phonological distinction as the vowel before word-final singletons is a phonologically long vowel, whereas the vowel before word-final geminates is a phonologically short vowel. Therefore, this result was expected. Whether these compensations serve as a correlate to discriminate word-medial or word-final geminates from singletons in perception still needs to be empirically tested.

Moreover, in Production Study 1 (Chapter 5), I compared the duration of the tonic vowel after word-initial geminates and singletons (as in [ˈs**ɐ**bbɐr] *sabbar* ‘to comfort’; [ɪsˈ**sɐ**bbɐr] s*sabbar* ‘to be comforted’). The duration of this vowel after singletons was not statistically significantly different from the duration of the vowel after geminates. Note that the consonant following the tonic vowel was a word-medial geminate in both cases.

I would like to draw a comparison between these results by using three sets of words and the results of the duration of the tonic vowel. Recall that in Chapter 3, I illustrated the prevalence of gemination in root-and-pattern morphology. I believe that this has implications for the phonetic realization of the duration of the tonic vowel.

In root-and-pattern morphology, from a base form such as [sɐ**b**ɐr] *sabar* 'to console', a Pattern II form can be derived involving a word-medial geminate, e.g. [sɐ**bb**ɐr] *sabbar* 'to comfort'. I claim that on comparing pairs such as *sabar* and *sabbar*, the vowel before word-medial singletons is longer than the vowel before word-medial geminates. This claim was supported by results from Production Study 3 (Chapter 7). Furthermore, a Pattern II form (e.g., ***s**a**bb**ar*) is used to derive Pattern V forms, where word-initial geminates are created in [+coronal, – sonorant]-initial roots, as in [**ss**ɐ**bb**ɐr] s*sabbar* 'to be comforted'. In these cases (e.g., *sabbar* and *ssabbar*), the duration of the vowel is comparable. The results show the tonic vowel has comparable durations in the two contexts; i.e., after a word-initial singleton geminate. I propose that vowel shortening operates *before* word-medial geminates and not *after* word-initial geminates. In order to strengthen this claim, I crosschecked this result with non-Semitic pairs such as [ˈm**ɐ**rkɐ] *marka* 'a mark' and [mˈm**ɐ**rkɐ] *mmakra* 'to mark' and in such pairs, the duration of the tonic vowel is also comparable (vowel after singletons: $\bar{x}$=100; sd=32; vowel after geminates: $\bar{x}$=94; sd=28). What is interesting is that in the Semitic pairs (such as *sabbar* 'to comfort' and *ssabbar* 'to be comforted'), the tonic vowel is followed by word-medial geminates, however, in the non-Semitic pairs (*marka* 'a mark' and *mmarka* 'to mark'), the tonic vowel is followed by a consonantal cluster. It would be of great interest to measure and compare the vowel before a word-medial singleton and a word-medial consonantal cluster and examine whether this leads to vowel shortening before word-medial consonantal clusters. To sum up, I conclude that vowel shortening of the tonic vowel only occurs in word-medial and word-final position.

9.2.3 The vowel after word-medial geminates/singletons

In Chapter 7, I compared the duration of the vowel after word-medial singletons and geminates (e.g., singleton: /ˈfɛ*t*ɐʔ/ *fetaq* ‘to rip apart’; geminate: /ˈfɛ*tt*ɐʔ/ *fettaq* ‘to stitch and unstitch again’). The duration of the vowel after word-medial singletons and geminates are not statistically significantly different from each other. This suggests that the vowel after word-medial singletons/geminates does not serve as a correlate to geminate. In this respect, Maltese is similar to Punjabi (Hussain 2015) where the duration of the vowel after geminates was comparable from the duration of the vowel after singletons. Therefore, *the vowel after word-medial geminates does not serve as a correlate to gemination*.

9.2.4 Summary: Vowel duration

To summarize, taking word-medial geminates as the starting point, the tonic vowel (i.e. the stressed vowel) before geminates is shorter than the tonic vowel before singletons in production. This is also the case in word-final geminates. The tonic vowel after word-initial geminates has comparable duration to the vowel after word-initial singletons. In addition, the unstressed vowel after word-medial geminates and word-medial singletons are comparable. The perceptual role of vowel duration as a correlate to gemination in word-medial and word-final position still needs to be investigated.

9.3 On the status of the vowel before word-initial geminates

In Chapter 6 §6.5, I give a preliminary analysis with respect to the status of the vocalic insertion before word-initial geminates. In this section, I examine whether this vowel can be considered as an intrusive, an epenthetic, or a lexical vowel. Recall from Chapter 6 §6.5, where I employed Hall’s (2006) diagnostics to identify the vowel before word-initial geminates as an epenthetic vowel. Here, I employ Hall’s (2006) diagnostics to strengthen my earlier claims and to show that the vowel before word-initial geminates is not an intrusive vowel.

Hall (2006) treats intrusive vowels as phonologically invisible and provides the diagnostics in (6).

(6) Properties for intrusive vowels (Hall 2006: 391)

(a) The vowel's quality is either schwa, a copy of a nearby vowel, or influenced by the place of the surrounding consonants.

(b) If the vowel copies the quality of another vowel over an intervening consonant, that consonant is a sonorant or guttural.

(c) The vowel generally occurs in heterorganic clusters.

(d) The vowel is likely to be optional, have a highly variable duration or disappear at fast speech rates.

(e) The vowel does not seem to have the function of repairing illicit structures. The consonant clusters in which the vowel occurs may be less marked, in terms of sonority sequencing, than clusters which surface without vowel insertion in the same language.

Epenthetic vowels are visible to phonological patterns and Hall (2006) provides four diagnostics which are listed in (7).

(7) Properties of epenthetic vowels (Hall 2006: 391)

(a) The vowel's quality may be fixed or copied from a neighboring vowel. A fixed quality epenthetic vowel does not have to be schwa.

(b) If the vowel's quality is copied, there are no restrictions as to which consonants may be copied over.

(c) The vowel's presence is not dependent on speech rate.

(d) The vowel repairs a structure that is marked, in the sense of being cross-linguistically rare. The same structure is also likely to be avoided by means of other processes within the same language.

Applying these properties to the vowel before word-initial geminates in Maltese, I argue that the vowel, according to the properties in (6) it is not an intrusive vowel, but that the properties of epenthetic vowels in (7) describe the vowel before word-initial geminates best. First of all, the vowel before word-initial geminates is always [ɪ], therefore, the quality is always fixed: it is neither a schwa nor a copy vowel. The vowel before word-initial geminates is also expected to occur in phrase-/utterance-initial position. There is nothing there to be copied from in that case. Ergo it cannot be a copy vowel. Second, the vowel occurs before geminated consonants, which are definitely not heterorganic clusters. However, as shown in Chapter 2 §2.3, the vowel [ɪ] can occur before heterorganic clusters, such sibilant-initial clusters. The vowel [ɪ] before sibilant-initial clusters occur as the definite article alternates from [ɪl] before to [l-ɪ], as in [ɪl-fsi:t] *il-fsied* ‘the cuddles’ but [l-ɪsfɪdɐ] *l-isfida* ‘the challenge’. Third, the vowel occurs before a relatively marked structure; namely, word-initial geminates, which only occur in a few languages (cf. Davis 2011, Kraehenmann 2011). Therefore, following these properties, the vowel before word-initial geminates meets more properties from Hall’s (2006) criteria for epenthetic vowels than for intrusive vowels. One speculation that I would like to advance is that this vowel is phonologically visible for the syllabification of word-initial geminates, yet this syllable fails to attract stress here (more on this below). However, the same vowel appears in other contexts in Maltese and attracts stress. When the second consonant in a Semitic root is a sonorant, an epenthetic vowel is inserted before the sonorant in plural non-perfective forms (Fabri 2009). Compare the non-perfective forms of *kiteb* ‘to write’ and *tilef* ‘to lose’ in Table 9.1.

Table 9.1: Non-perfective forms of *kiteb* and *tilef*

	kiteb ‘to write’		*tilef* ‘to lose’	
Person	Sing	Plural	Sing	Plural
1	/nɪktɛb/	/nɪktbʊ/	/nɪtlɛf/	/nɪtɪlfʊ/
2	/tɪktɛb/	/tɪktbʊ/	/tɪtlɛf/	/jɪtɪlfʊ/
3M	/jɪktɛb/	/jɪktbʊ/	/jɪtlɛf/	/jɪtɪlfʊ/
3F	/tɪktɛb/		/tɪtlɛf/	

Following Fabri (2009), I propose that the following forms lead to the following syllabic structures in (8a) for *kiteb* and (8b) for *tilef*.

(8) Syllable structures

(a) *kiteb* ‘to write’

Singular: CVC.CVC /nɪk.tɛb/

Plural: CVC.CCV[72] /nɪk.tbʊ/

(b) *tilef* ‘to lose’

Singular: CVC.CVC /nɪt.lɛf/

Plural: CV.CVC.CV /nɪ.tɪl.fʊ/

The singular verbal forms have the same syllabic structure (CVC.CVC). However, in *tilef* ‘to lose’, where the second consonant of the root is one of the sonorant consonants, in this case, the liquid /l/, a vocalic insertion is present in the plural. In this context, the vowel preceding the sonorant is an epenthetic vowel (Fabri 2009). Fabri (2009) suggests that this vowel is inserted since sonorant + obstruent sequences (such as /lf/ in *tilef*) are sonority-violating onsets. However, what Fabri (2009) does not mention is that this is also what happens in sonorant-initial words, as discussed in Chapter 2 §2.4.1. Therefore, besides the fact that sonorant-obstruent sequences violate sonority and are not allowed in onset position in Maltese, they seem to be always preceded by an epenthetic vowel regardless of their position within a prosodic word. Therefore, sonorant-obstruent sequences are intact but a preceding vowel causes different syllabification, where the epenthetic vowel serves as a syllable nucleus, the sonorant serves as a coda of that previous syllable, and the obstruent serves as an onset for the following syllable. Also important is the fact that the vowel before the sonorant consonant is not always of the same quality but it can also be realized as [ɐ] and [ɔ] (c.f. Table 9.2). However, the phonological conditions for this vowel allomorphy have not been spelled out for Maltese. Fabri (2009), following Aquilina (1963), gives a list of the possible vocalic sequences in verbal forms and the epenthetic vowel that occurs in the non-perfective forms.

[72] This follows from my discussion of syllabification in Maltese in Chapter 2 §2.4, where the onset is maximized, following the Maximum Onset Principle.

Table 9.2: Epenthetic vowels in plural non-perfective forms (based on Fabri 2009: 13)

	Base vowel	Epenthetic vowel	Singular Non-perfective forms	Plural Non-perfective forms
1	ɛ - ɛ	ɪ	[nɛʔrɛd] *neqred* 'I complain'	[nɛʔ**ɪ**rdʊ] *neqirdu* 'we complain'
2	ɪ - ɛ	ɪ	[nɪslɛf] *nislef* 'I lend'	[nɪs**ɪ**lfʊ] *nisilfu* 'we lend'
3	ɐ - ɛ	ɪ	[nɐʔlɛb] *naqleb* 'I turn s.th over'	[nɐʔ**ɪ**lbʊ] *naqilbu* 'we turn s.th over'
4	ɪ - ɐ	ɪ	[nɪtlɐʔ] *nitlaq* 'I leave'	[nɪt**ɪ**lʔu] *nitilqu* 'we leave'
5	ɔ - ɔ	ɔ	[nɔhlɔm] *noħlom* 'I dream'	[nɔh**ɔ**lmʊ] *noħolmu* 'we dream'
6	ɪ - ɔ	ɔ	[nɪtlɔb] *nitlob* 'I pray'	[nɪt**ɔ**lbʊ] *nitolbu* 'we pray'
7	ɐ - ɐ	ɐ	[nɐhrɐʔ] *naħraq* 'I burn s.th'	[nɐh**ɐ**rʔu] *naħarqu* 'we burn s.th'

According to Sutcliffe (1936), Maltese phonology includes a rule that an unstressed /ɛ/ become /ɪ/ when stressed. Therefore, the allomorphs in (1) –(3), in Table 9.2, in the plural non-perfective can be explained by this rule. In contrast, Fabri (2009) does not acknowledge this vowel allomorphy, but rather argues that the vowel is a vocalic insertion due to syllabification. Sutcliffe (1936) also claims that unstressed /ɐ/ can become /ɪː/ when stressed, as in /ˈɐh.nɐ/ *aħna* 'we' - /ɐh.ˈnɪːʃ/ *aħniex* 'we aren't'; however, in cases such as (4), in Table

9.2, the vowel changes from /ɐ/ to /ɪ/. In contrast, in case (7), in Table 9.2, the vowel /ɐ/ does not change to /ɪ/. There might be a partial rule for vowel raising when the two vowels in the singular non-perfective forms are different and in context of [ɪ, ɛ, ɐ] (i.e., in (2) – (4)), but this does not occur when the two vowels in the word are the same (i.e., in (5) and (7)). One exception to this generalization is (6), where the words have two vowels and the vowel before the sonorant is [ɔ], so there is no vowel raising.

What is interesting about the Maltese plural non-perfective forms (i.e., in 1-7 in Table 9.2) is that this newly built syllable attracts stress. Stress in Maltese is assigned to the rightmost heavy syllable, where a heavy syllable is defined as a short vowel and a consonant, or a long vowel/diphthong (Vella 1995). Compare the two examples in (9) below.

(9) Stress assignment
(a) [ˈ**nɪk.**tbʊ] *niktbu* ‘we write’
(b) [nɪˈ**sɪl**fʊ] *nisilfu* ‘we lend’

Stress in (9b) is assigned to a syllable whose nucleus is formed from an epenthetic vowel. Therefore, stress assignment rules take the epenthetic vowel into account. The literature reports that epenthetic vowels can partake in phonological processes. For instance, Blevins and Pawley (2010) show that in Kalam, syllables with epenthetic vowels also seem to attract stress.

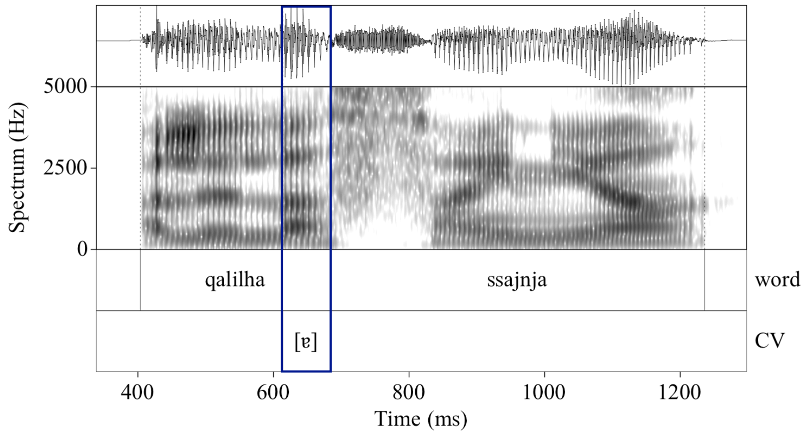
For Maltese, these facts seem to support the claim that such a vowel is phonologically motivated and it not just an artifact of articulation. This raises the question of the lexical representation of such vowels and, as a consequence, of these words. For instance, is this vowel inserted on the fly, or is it part of the phonological knowledge, and even phonotactic knowledge of native speakers of Maltese? Ogasawara (2006) showed that Japanese speakers use their phonotactic knowledge about the application of an allophone in relation to its contexts, where she investigated perception of reduced vowels between two voiceless consonants (e.g. [ak(i)kan] ‘empty can) and fully voiced vowels next to a voiced obstruent consonant (e.g. [tedʒina] ‘magic’).

On the basis of the results of the vowel before word-initial geminates in Maltese, I argue that the vowel is part of the lexical representation and it is phonological; therefore, the term *epenthetic* is incorrect, and *lexical vowel* might be a more appropriate term. I suggest that a natural next step is to investigate how native speakers of Maltese perceive vowels before sonorant sequences - this will shed light on how they are lexically represented and in turn will help us understand better whether such vowels are lexical, epenthetic, or intrusive.

Ideally, a number of different methods should be used; for instance, it could be fruitful to look at the production of such words by using an articulograph, following proposals by Hall (2006), in order to shed more light on the true nature of such vowels. I claim that, given the results of production studies 1 and 2 (Chapter 5 and 6, respectively) and the perception experiment (Chapter 8), the vowel before word-initial geminates is a lexical vowel, just like in other words, which traditionally are considered as having a lexical [ɪ] vowel; e.g., [ɪˈtɐljɐ] *Italja* ‘Italy’, [ɪˈzi:t] *iżid* ‘he adds’, [ɪˈʃɐndɐr] *ixandar* ‘he broadcasts’. Note that these are comparable to words such as [ɪtˈtɐllɐb] *ittallab* ‘to beg’, [ɪzˈzɐrrɐt] ‘to fray’ and [ɪʃˈʃɔkjɐ] ‘to shock’, where stress falls on the penultimate syllable, and the initial vowel, being in the leftmost syllable, does not attract stress. In terms of syllable structure, in a word such as [ɪˈtɐljɐ] *Italja* ‘Italy’, the first syllable just consists of a vowel nucleus, whereas in words such as [ɪtˈtɐllɐb] *ittallab* ‘to beg’, the first syllable consists of a vowel nucleus and the first part of the geminate, which serves as a coda. I also propose that the duration of these vowels should be compared. Bosch and de Jong (1997) report that epenthetic vowels in Barra Gaelic tend to be longer than lexical vowels in the same position (as in the comparison of the lexical form: [ar**a**n] ‘bread’ and the epenthesised form /arm/ → [ar**a**m] ‘army’).

So far, I have reported that the vowel before word-initial geminates almost always occurs. Yet the presence of a vowel before word-initial geminates was conditioned by the preceding context. In Production Study 1 (Chapter 5), I investigated the presence or absence of this vowel when the preceding word ended in a vowel. I reported that a glottal stop insertion can occur between the final vowel of the previous word and the vowel before word-initial geminate. This glottal stop insertion was interpreted as a possible strategy for breaking up a vowel hiatus across a word boundary as reported for English (Redi and Shattuck-Hufnagel 2001) and dialects of Italian (Stevens et al. 2002; Di Napoli 2015) to name a few. The glottal stop insertion before the vowel preceding word-initial geminates in this data was also present when the previous word ended in a consonant. Note that the glottal stop insertion was subject to across- and within-speaker variation. Focusing on the data when the pre-target word ended in a vowel in 'qalilha' from Production Study 1, out of 1060 tokens from Production Study 1, where a preceding vowel occurred before a word-initial geminate, glottal stop insertion was present in 14% of the data. As a consequence, I claimed that this insertion constitutes an optional syllable onset. However, glottal stop insertion across a word-boundary was not the only strategy speakers used for hiatus resolution. In the large majority of cases (60% of the tokens) an auditory and spectrographic analysis showed that the final vowel [ɐ] from the pre-target word [ʔɐlɪlɐ] 'he told her' was present but the [ɪ] before word-initial geminates was not. An example of this is shown in Figure 9.1.

Figure 9.1: No [ɪ] vocalic insertions before the word-initial geminate [ss] in [ssɐjnjɐ] 'to sign'[73]



This result by itself leads to a compelling discussion with regards to the status of the vowel before word-initial geminates. If it is argued that the vowel before word-initial geminates is in fact an inserted vowel, then one can argue that when the previous contexts ends in a vowel, insertion is blocked or does not occur. This is one route one could opt for to explain these results. In contrast, if my arguments that the vowel before word-initial geminates is phonological are correct, then in a preceding vowel-final context, the vowel before word-initial geminates is elided. Note that in the pre-target word /ʔɐ.lɪ.lɐ/, the final vowel /ɐ/ is a third person feminine clitic, therefore, eliding this vowel would lead to a loss of morphological information.

Casali (1996) argues that elision of the second vowel in a vowel sequence is less common than the elision of the first vowel cross-linguistically. In addition, he makes the generalization that at a boundary between two lexical words the first vowel is elided. Exceptions to this cross-linguistic generalization are found in Yoruba (Pulleybank 1988), where the vowel /i/ is elided at a boundary between two lexical words. This seems to be the case in Maltese as well. Nevertheless, a more thorough investigation could shed more light on the underpinnings of this, for instance by comparing what happens across a word boundary when the vowel is of another quality; e.g., /ʔɐ.lɪ.lɐ ɔhlɔm/ 'he told her dream' and also with

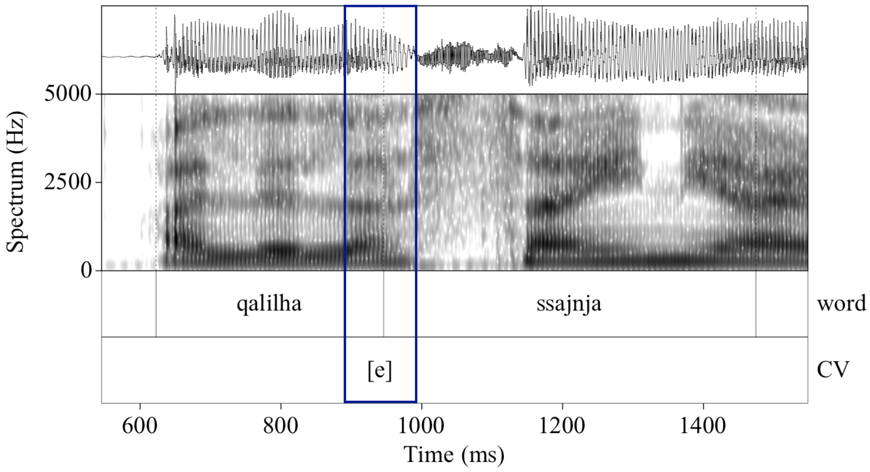
[73] In Figures 9.1-9.3, the word tier show orthographic words and not phonetic transcriptions.

other /ɪ/-initial words; e.g., /ʔɐ.lɪ.lɐ ɪtɐljɐ/ 'he told her Italy'. Note that in other contexts, the vowel [ɪ] is subject to a glide formation [j], when the preceding word ends in a vowel, as in (10).

(10) Glide formation
[mɐr**k ɪ**ħɔbb] *Mark iħobb* 'Mark loves'
[sɐndr**ɔ j**ħɔbb] *Sandro jħobb* 'Sandro loves'

Furthermore, vowel coalescence was also present, where the non-high vowel /ɐ/ and the high vowel /ɪ/ form a vowel similar to [e] (c.f. Casali 2011 cites Xhosa as a language that does this too). Coalescence was examined auditorily and spectrographically and it was present in 17% of the tokens (c.f. Figure 9.2).

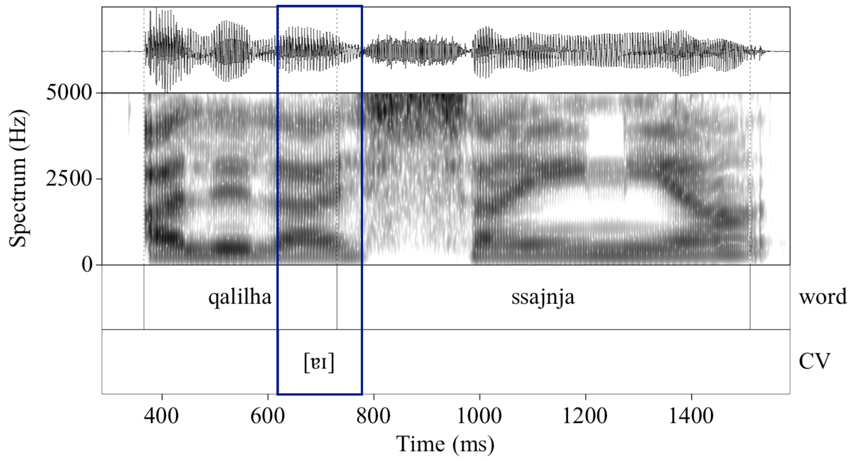
Figure 9.2: Vowel coalescence of [ɐ] and [ɪ] before the word-initial geminate [ss] in [ssɐjnjɐ] 'to sign'



In 9% of the data, the vowel hiatus, i.e. the vowel sequence [ɐ] – [ɪ] across a word boundary occurred freely (cf. Figure 9.3). Casali (2011) reports that vowel hiatus occur freely in Hawaiian.

Casali (2011:1442) showed that multiple hiatus resolution strategies can occur within a language and also that "multiple strategies apply in the same morphosyntactic context, targeting different vowel sequences." However, the above cases from Maltese show that multiple strategies in fact apply within the same context. To sum up the results, if the vowel is considered to be a lexical vowel, elision of the vowel [ɪ] occurs in most cases (60%), followed by vowel coalescence (17%), followed by glottal stop insertion (14%) and vowel hiatus is left to occur freely in 9% of the tokens. The interpretation of multiple strategies as evidence for hiatus resolution (and the allowance for vowel hiatus to occur freely) implies that the vowel before word-initial geminates is phonological.

Figure 9.3: Vowel hiatus before the word-initial geminate [ss] in [ssɐjnjɐ] 'to sign'



9.4 Representation

In the following section, I address some specific issues for word-initial geminates and word-medial geminates; and word-final and word-medial in relation to their representation.

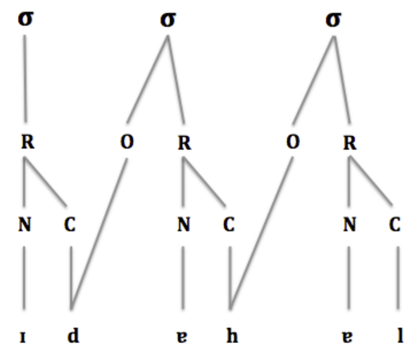
9.4.1 Word-initial geminates and word-medial geminates in Maltese

The core issue of this dissertation was the status of word-initial geminates in Maltese. In Chapters 2 and 3, I discussed how the literature claims that word-initial geminates are never realized as word-initial and are always preceded by an epenthetic vowel. I addressed this discussion by presenting, for the first time, empirical evidence to partially support the claims in the literature. Word-initial geminates are almost always preceded by a vocalic insertion when the previous words end in a consonant. Furthermore, the realization of a vocalic insertion before word-initial geminates was subject to variation across- and within-speakers. Namely, in Production Study 1, the vocalic insertion was present before word-initial geminates in 96% of the tokens. In Production Study 2, the vocalic insertion was present before 86% of the word-initial geminates token. Therefore, there was a 10% decrease from Production Study 1 to Production Study 2. Nonetheless, these percentages are definitely above chance, and so I conclude that word-initial geminates are almost always preceded by a vocalic insertion. When the previous word ends in a vowel, multiple resolutions are at play. The phonetic insertion of a vowel before word-initial geminates matches the phonological account I presented in Chapter 2 §2.4.1. I argued that underlyingly word-initial geminates in Maltese are stray consonants, which according to Prosodic Licensing can either be resolved through epenthesis or deletion in their surface forms. It is clear that phonetic duration is preserved; therefore, phonological length is also preserved. Evidence from production studies 1 and 2, show that the duration of word-initial geminates is longer than that of singletons, and I concluded that word-initial geminates are not subject to deletion (or Stray Erasure).

Based on these findings I conclude that word-initial geminates in Maltese can never occur as syllable-initial geminates, and as a result this leads to a process of resyllabification. Word-initial geminates which are preceded by a vowel are syllabified as follows (as in Figure 9.4):

- the vowel serves at the nucleus to a preceding syllable
- the first half of the geminate serves as a coda to that syllable
- the second half of the geminate serves as an onset to the following syllable.

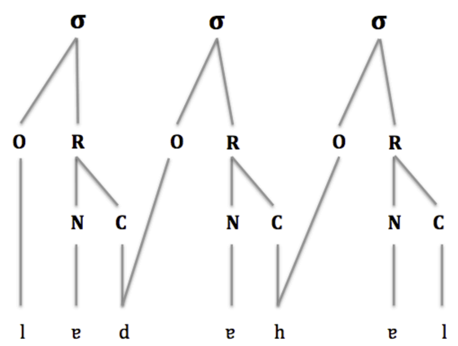
Figure 9.4: Syllabification of word-initial geminates



ddaħħal **'to be inserted'**

However, when the vowel before word-initial geminates is not present, and the preceding word ends in a consonant, I propose that the first half of the geminate serves as a coda to the previous syllable. Therefore, there is resyllabification across a word-boundary. This is shown in Figure 9.5. A process of across word-boundary resyllabification occurs in French, where word-final consonants syllabify as onsets with a following word-initial vowel (Encrevé 1988).

Figure 9.5: Syllabification of word-initial geminates preceded by a word-ending in a vowel

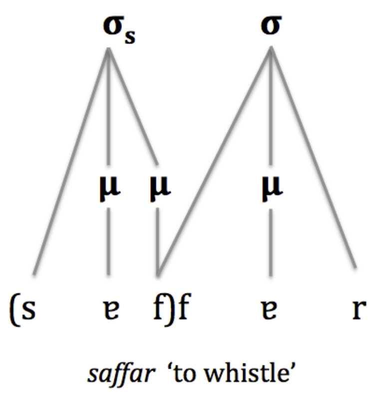


[ɐ.li.lɐ#d.dɐh.hɐl] *Qalilha ddaħħal* 'to be inserted'

Hitherto, I have used an Onset-Rhyme model to describe the syllabification of geminates in word-initial and word-medial position. By using such a model I was able to establish the positions of such geminates within a syllable. Subsequently, I address the phonological representation of singletons and geminates through moraic theory. Before doing so, some issues related to stress assignment in

Maltese are illustrated. Stress assignment in Maltese operates on moraic trochees constructed from left to right, with stress tending to fall on the rightmost heavy syllable. A heavy syllable is defined as either consisting of a short vowel and a coda (which can include a the first half of a geminate) or a long vowel or a diphthong (Vella 1995). This leads to the assumption that in Maltese there is a bimoraic constraint on feet (e.g., the 'Ft-Bin' constraint in Optimality Theory; e.g., Prince 1997, Kiparksy 2005) and as a result, degenerate feet consisting of only one mora are banned. Coda consonants are considered to be extrametrical. For word-medial geminates, as in /sɐffɐr/ *saffar* 'to whistle', I propose the representation in Figure 9.6. This representation follows other representations of word-medial geminates (e.g., Hayes 1989; Davis 1999, 2011; Davis and Ragheb 2014).

Figure 9.6: Moraic word-medial geminates in Maltese[74]



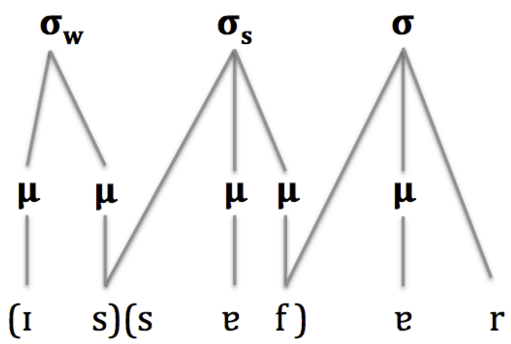
Under such a representation, the first syllable /sɐf/ is bimoraic (the vowel and the geminate both have a mora) and therefore can be footed on its own. The second syllable /fɐr/ only has one mora, which is assigned to the vowel. The coda consonant /r/ is extrametrical. Therefore, stress is assigned to the penultimate syllable: /ˈsɐffɐr/ 'to whistle'.

I propose a similar representation for morpho-phonological word-initial geminates in Maltese, in which the geminates are also assigned a mora (as in

[74] In Figure 9.6 and 9.7, bracketing around a syllable indicate foot grouping. The symbol S and W indicate 'strong' and 'weak' feet. Strong feet are stressed (following Hayes 1995). If a syllable has not bracketing around it, this indicates that this syllable does not constitute a foot.

Figure 9.7). In addition, I propose that the vowel before morpho-phonological word-initial geminates also bears a mora. Given the evidence from production and perception I argue that this vowel is not a mere phonetic artifact, but rather that it is phonological and also part of the lexical representation of word-initial geminates.

Figure 9.7: Moraic representation for morpho-phonological word-initial geminates



ssaffar 'to be whistled'

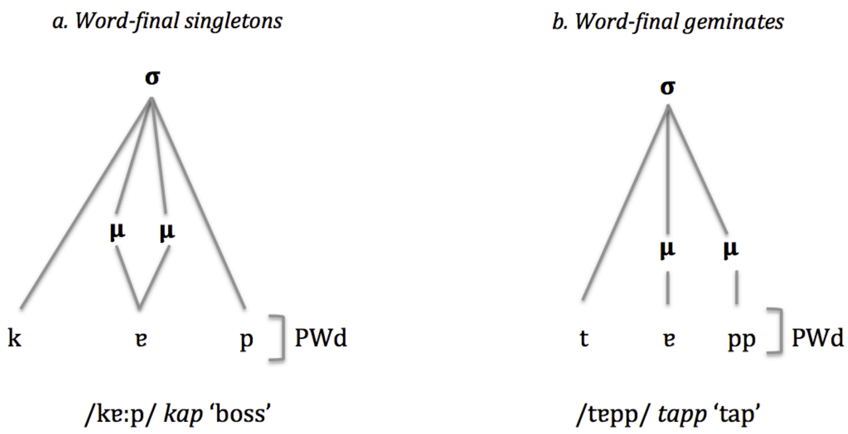
In a word such as /ɪssɐffɐr/ *issaffar* 'to be whistled', the first syllable is bimoraic, where the vowel /ɪ/ bears a mora and the first part of the geminate also bears a mora, creating a bimoraic foot. Nevertheless, this syllable can never be assigned stress as Maltese tends to assign stress to the rightmost footed syllables and not to the leftmost footed syllables. Stress, therefore, falls on the next bimoraic foot, which happens to also contain a (part of a) geminate: /ɪs'sɐffɐr/ *issaffar* 'to be whistled'.

Some considerations have to be made for when the preceding word ends in a vowel. As shown in §9.3, multiple strategies are used for vowel hiatus. This might lead to the proposal of a different phonological representation. With respect to glottal stop insertion as a strategy for vowel hiatus, I discussed that this would serve as an onset to the [ɪ]-initial syllable. This does not affect the moraic structure proposed in Figure 9.7, as onsets do not tend to be moraic. In such cases, the glottal stop can be linked directly to the syllable node. In the cases of vowel elision, where /ɪ/ before morpho-phonological geminates is elided, the mora associated to this vowel is also deleted. This would lead to a similar representation in Figure 9.7, where morpho-phonological geminates are still underlyingly moraic. In addition, in the cases in which vowel hiatus occurs, the representation is unaffected. For vowel hiatus, I adopted the same representation I proposed for morpho-phonological word-initial geminates in Figure 9.7. This is because the vowel before morpho-phonological word-initial geminates is unaffected by the presence of a previous vowel. In vowel coalescence, the same representation in Figure 9.7 still holds, however, the surface realization of the vowel hiatus results in vowel coalescence. Therefore, the phonological representation should be followed by a rule in which a non-high vowel and a high vowel coalesce to form a non-high vowel; e.g., /ɐ/ + /ɪ/ = [e].

9.4.2 Word-final and word-medial geminates

The results illustrate that the geminate/singleton contrast was also maintained in word-final position, even though word-final geminates had smaller durations than word-medial geminates (Production Study 3 in Chapter 7). In terms of representation, I follow Ham's (2001) proposal, where word-final geminates are represented as word-final moraic consonants (c.f. Figure 9.8).

Figure 9.8: Representation of word-final singletons and geminates



Under this representation, the word-final singleton does not bear a mora and is extrametrical (c.f. Figure 9.8a). Thus, it is directly attached to the syllable mode.

Also, in Figure 9.8a, the vowel is a phonological long vowel and bears two moras. In Figure 9.8b, the vowel is a short vowel and bears one mora. The word-final geminate also bears a mora but it is not extrametrical. It is important to point out that Kiparsky (2003:156-157) proposed a different analysis for word-final singletons for Maltese and other C-dialects of Arabic. Kiparsky (2003) analysed the word-final singleton as mora bearing; however, this is not attached to the syllable node, but to a higher prosodic constituent, such as the prosodic word. Nonetheless, Kiparsky (2003:157) suggested that mora-bearing word-final singleton codas "do not count towards syllable weight or foot size".

In my account, rhymes in monosyllables are bimoraic, so in CV:C syllables, the vowel bears two moras and in CVG syllables, the vowel and the geminate each bear a mora. Recall from Chapter 7 §7.6 that the duration of the rhyme is both syllable types are comparable: V:C rhyme: $\bar{x}$ = 320ms (72); VG rhyme: $\bar{x}$ = 316ms (73). One possible interpretation is that if a syllable bears two moras, their manifestation of duration are comparable, regardless of which segments they are associated with. Broselow et al. (1997) suggested that moraic structure is reflected in phonetic timing in Hindi, Malayalam and Arabic. Furthermore, they argued that segments dominated by two moras have longer durations than those dominated by one mora. This also seems to be case in Maltese, given the data from word-final and word-medial geminates/singleton. Let's compare the following three syllabic structures: CV, CVVC, CVG in (11).

(11) Syllable types

CV: /**pɐ**.pɐ/ *papa* 'kid's food': bears one mora on the vowel

CVVC: /kɐːp/ *kap* 'boss': bears two moras on the vowel

CVG: /tɐpp/ *tapp* 'tap': bears one mora on the vowel and one mora on the geminate

In a CV syllable, which is monomoraic, the duration of the vowel corresponds to the duration of one mora, which on average is 110ms. In a CVVC syllable, which is bimoraic and the vowel bears the two moras, the duration of the phonologically long vowel is on average 174ms. I extend Broselow et al.'s (1997) claim and argue that one segment bearing two moras is longer than one segment bearing one mora. This is also the case when the CVVC and CVG syllables are compared: a bimoraic nucleus ($\bar{x}$ = 174ms (44)) is longer than a monomoraic nucleus ($\bar{x}$ = 135ms (33)). However, this does not seem to pattern with Broselow et al.'s (1997:63) generalization that "phonemically long vowels are about twice the length of a comparable phonemically short vowel". The difference here is 39ms. In addition, if the duration of moras is examined across syllable constituents, the durations are discernably different. In the CVVC bimoraic syllable, the vowel is the only syllable constituent that bears moras, and its duration is 174ms. In contrast, in a CVG final syllable, where the vowel and the geminate bear a mora each, the rhyme's duration is significantly larger. I argue that without any doubt the segmental material directly influences the duration of the mora. The fact that there is a geminate corresponds an increase in the duration of segments, and by default, the duration of the mora.

9.5 Conclusion

In this section, I summarize the main findings of this dissertation. In Chapter 1, the aims of this dissertation were presented. The theoretical underpinnings related to syllable structure and gemination were addressed.

Chapter 2 examined the syllable structure of Maltese, explaining the complexity of the possible syllable types in Maltese by looking at possible onsets and codas. A description of the possible onsets and codas was provided through sonority; however, this leaves numerous unanswered questions since Maltese allows for an unprecedented number of violations. Thus, I recommend examining the syllable structure of Maltese by employing other theoretical frameworks (e.g., using articulatory data).

Chapter 3 provided a cross linguistic review of gemination. First, it established the phonetic correlates of word-medial geminates, and compared them to word-initial and word-final position. In typologically different languages, the strongest correlate for geminates, as expected, is constriction duration. Other phonetic correlates can be manifested, but these are language-specific. This was followed by a discussion on the phonological representation for geminates. A segmental approach and a moraic analysis were presented; as well as arguments for and against these representations. Finally, gemination in Maltese was address by looking at the phonological distribution of gemination in different positions in the word. In addition, the intricate interplay between morphology and phonology, which results in gemination in initial, medial and final positions was explained.

Chapter 4 provided the general methodological procedure employed throughout the production studies of the dissertation.

The first production study, which compared lexical and surface word-initial geminates in Maltese, was presented in Chapter 5. Unsurprisingly, geminates are longer than singletons. However, gemination does not effect any of the secondary correlated investigated, namely, VOT and tonic vowel duration. Yet, (as became even more apparent in the subsequent chapters) the strongest correlate for word-initial gemination in Maltese is a vowel insertion before word-initial geminates, when the preceding word ends in a consonant. Note that a glottal stop insertion preceding the vowel is also present. On the other hand, when the preceding word ends in a vowel, the inter-consonantal interval is longer before geminates than singletons. The constriction duration results showed that lexical geminates are comparable to surface geminates, and that geminates originating in Semitic words and non-Semitic words also have comparable durations.

In Production Study 2, in Chapter 6, geminates and singleton across a number of different manners of articulation were compared in word-initial and word-medial position. Constriction duration for word-initial and word-medial geminates was comparable across the different manners of articulation. As in Production Study 1, word-initial geminates were almost always preceded by a vowel, and in some cases, this vowel was preceded by a glottal stop. VOT in voiceless stops does not serve as a correlate to gemination. The discussion in

Chapter 6 was motivated by the findings in production studies 1 and 2. I also propose that word-initial geminates should be referred to as *morpho-phonological word-initial geminates.*

Chapter 7 compared the production of word-final and word-medial geminates. The results show that the duration of word-final geminates are discernably shorter than word-medial geminates. Furthermore, the vowel before geminates is shorter than the vowel before singletons in both final and medial positions. The compensatory quantity on monosyllables in Maltese (i.e., CV:C and CVG syllables) results in comparable durations in the rhyme.

The perception of the vowel before morpho-phonological word-initial geminates was explored in Chapter 8. Native speakers of Maltese are not sensitive to a true word-initial geminate/singleton contrast (e.g. /#dd/, /#d/) and perceive such words as being the same. However, they can easily identify pairs of words which have a vowel before morpho-phonological word-initial geminates. I proposed that these results are in line with theories of lexical processing, and I argued that the vowel before morpho-phonological word-initial geminates is lexical and that it is crucial for the identification of such geminates.

This chapter presented a general discussion of the results of this dissertation and embedded them in a larger phonological context. I summarized the findings in relation to constriction duration of geminates/singletons in initial and medial position; and final and medial position. A summary of secondary correlates for gemination in Maltese was presented. Next, I proposed a reanalysis of the vowel before morpho-phonological word-initial geminates, where I argued that this vowel is phonological. Finally, I advanced a moraic representation of geminates in Maltese.

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Appendix 1: Linguistic background questionnaire (based on Twist 2006)

Please answer the following questions about your language background.

1. What is your occupation? ____

2. In which town or region did you grow up? ___________________________

3. In which town or region do you now live? ____________________________

4. What language(s) were spoken often in the home where you grew up? (In this and subsequent questions, if you tick multiple languages, please specify the approximate percentage of time applicable to each language. For instance, if Maltese was spoken most of the time in your childhood home, but some English was also spoken, you could indicate Maltese: 90% and English:10%)

   a. Maltese________%
   b. English________%
   c. Other (please specify) ______________________________%

5. What type of primary school did you attend?
   a. State
   b. Church
   c. Independent

6. What was the primary language spoken in this school? Please indicate all that apply.

   a. Maltese________%
   b. English________%
   c. Other (please specify) ______________________________%

7. What type of secondary school did you attend?

a. State

b. Church

c. Independent

8. What was the primary language spoken in this school? Please indicate all that apply.

a. Maltese________%

b. English________%

c. Other (please specify) ______________________________%

9. Did you attend university?

a. No

b. Yes

Please list number of years attended _____

Highest degree obtained ____________________________________

Course of study____

If your university training was in a country other than Malta, please specify the institution and languages used: ____

10. In which language(s) do you usually speak to the following people?

a. Father ___________________

b. Mother___________________

c. Grandparents_______________

d. Siblings__________________

e. Children__________________

f. Friends___________________

g. Co-workers________________

h. Customer/clients/other business contacts________________________

11. In which language(s) are the newspapers and magazines you read regularly?

a. Maltese_______%

b. English_______%

c. Other (please specify) ___________________________%

12. In which language(s) are the television programs you watch regularly?

a. Maltese_______%

b. English_______%

c. Other (please specify) ___________________________%

13. Please list all languages you speak and rate your overall proficiency in each:

a. Maltese: Excellent Good Not Bad Bad
b. English: Excellent Good Not Bad Bad
c. Other _____: Excellent Good Not Bad Bad
d. Other _____: Excellent Good Not Bad Bad
e. Other _____: Excellent Good Not Bad Bad

14.What is the longest period of time you have spent continuously outside of Malta?

a. Never been outside Malta

b. One week or less

c. Less than one month

d. Two to five months

e. Six months to a year

f. Longer than one year

15. Which language(s) did you use most during this absence? ___________________

16. On average, how much time do you spend outside of Malta per year?

a. None

b. One week or less

c. Less than one month

d. Less than six months

e. More than six months

17. Which language(s) do you use most during these absences?

____

Appendix 2

Production Study 2: Target words containing word-initial / word-medial segments.

The target words for production study 2 were chosen from *ġabra* (Camilleri 2013) and from Aquilina (2006) *Concise Maltese English English Maltese dictionary.* In most of the word-medial geminate cases, the target words contain the suffix *–lu*, which means 'to/for him'. This was not added in the translation of the words as the translations sounded odd. Nonetheless, these are actual words in Maltese.

	WORD-INITIAL		**WORD-MEDIAL**	
Segment	**Singleton**	**Geminate**	**Singleton**	**Geminate**
/p/	/ˈpɐtpɐt/ *patpat* 'to gossip'	/pˈpɐkjɐ/ *ppakja* 'to pack'	/sɐˈpuːn/ *sapun* 'soap'	/dʒɐpˈpʊn/ *Ġappun* 'Japan'
	/ˈpɔntɐ/ *ponta* 'a sharp end'	/pˈpɔntɐ/ *pponta* 'to point'	/kɐˈpɐtʃɪ/ *kapaċi* 'capable'	/pɛpˈpɪnɐ/ *Peppina* 'name'
	/ˈpɐrtɪ/ *parti* 'part'	/pˈpɐrkjɐ/ *pparkja* 'to park'	/tɐˈpɪtɪ/ *tapiti* 'carpets'	/tɐppɪːrɪ/ *tappieri* 'manhole'

/t/	/ˈtɐllɐb/ *tallab hyp*	/tˈtɐllɐb/ *ttallab* ‘to beg for s.th’	/fɛˈtɐhlʊ/ *fetaħlu* ‘he opened’	/fɛtˈtɐhlʊ/ *fettaħlu* ‘he kept on opening’
	/ˈtɛllɐʔ/ *tellaq* ‘to race’	/tˈtɛllɐʔ/ *ttellaq* ‘to be raced’	/fɛˈtɐʔlʊ/ *fetaqlu* ‘he stitched’	/fɛyˈtɐʔlʊ/ *fettaqlu* ‘he stitched and unstitched again’
	/ˈtɛllɐː/ *tella’* ‘to raise’	/tˈtɛllɐː/ *ttella* ‘to be raised	/hɐˈtɐrlʊ/ *ħatarlu* ‘he elected’	/hɐtˈtɐrlʊ/ *ħattarlu* ‘he was elected’
/k/	/ˈkɐwzɐ/ *kawża* ‘cause’	/kˈkɐwzɐ/ *kkawża* ‘to cause’	/bɐˈkɐrlʊ/ *bakarlu* ‘he anticipated’	/bɐkˈkɐrlʊ/ *bakkarlu* ‘he got up early’
	/ˈkɐrɪgɐ/ *kariga* ‘post’	/kˈkɐrɪgɐ/ *kkariga* ‘to harge’	/rɪˈkɪblʊ/ *rikiblu* ‘he rode’	/rɪkˈkɪblʊ/ *rikkiblu* ‘it was ridden’
	/ˈkɔnfɛrmɐ/ konferma ‘confirmation’	/kˈkɔnfɛrmɐ/ *kkonferma* ‘to confirm’	/hɐˈkɪmlʊ/ *ħakimlu* ‘he ruled’	/hɐkˈkɪmlʊ/ *ħakkimlu* ‘he governed’

/m/	/ˈmɐrkɐ/ *marka* ‘mark’	/mˈmɐrkɐ/ mmarka ‘to mark’	/sɛˈmɐlʊ/ *semalu* ‘he listened’	/sɛmˈmɐlʊ/ *semmalu* ‘he made him hear’
	/ˈmɪrɐ/ *mira* ‘aim’	/mˈmɪrɐ/ *mmira* ‘to aim’	/sɐˈmɐtlʊ/ *samatlu* ‘he scaled’	/nɛmˈmɪslʊ/ *nemmislu* ‘he looked at girls’
	/ˈmu:tɐ/ *muta* ‘muteness’	/mˈmu:tɐ/ *mmuta* ‘to make silent’	/ɛ:ˈmɪzlʊ/ *hemiżlu* ‘he attached’	/ɛmˈmɪzlʊ/ *hemmiżlu* ‘it was attached’
/n/	/ˈnɐʔʔɐs/ *naqqas* ‘to reduce’	/nˈnɐʔʔɐs/ *nnaqqas* ‘to be reduced’	/hɐˈnɐʔlʊ/ *ħanaqlu* ‘he strangled’	/hɐnˈnɐʔlʊ/ *ħannaqlu* ‘he strangled slowly’
	/ˈnɔ:tɐ/ *nota* ‘note’	/nˈnɔ:tɐ/ *nnota* ‘to notice’	/kɪˈnɪslʊ/ *kinislu* ‘he swept’	/dɛnˈnɪslʊ/ *dennislu* ‘he dimmed’
	/nɪfs/ *nifs* ‘breath’	/nˈnɪfsɪ/ *nnifsi* ‘myself’	/dɪˈnɪblʊ/ *diniblu* ‘he sinned’	/ʃɛnˈnɐʔlʊ/ *xennaqlu* ‘he aroused an appetite’
/f/	/ˈfɐnfrʊ/ *fanfru* ‘pilot fish’	/fˈfɐngɐ/ *ffanga* ‘to eat too much’	/nɐˈfɐrlʊ/ *nafarlu* ‘he took fright of s.th’	/nɐfˈfɐrlʊ/ *naffarlu* ‘he startled’
	/ˈfɪrmɐ/ *firma* ‘signature’	/fˈfɪrmɐ/ *ffirma* ‘he signed’	/nɛˈfɐʔlʊ/ *nefaqlu* ‘he spent’	/nɛfˈfɐʔlʊ/ *neffaqlu* ‘he made so spend’
	/ˈfɔrmɐ/ *forma* ‘form’	/fˈfɔrmɐ/ *fforma* ‘to form’	/nɪˈfɪdlʊ/ *nifidlu* ‘he pierced’	/nɪfˈfɪdlʊ/ *niffidlu* ‘he pierced forcefully’

/s/	/ˈsɐbbɐr/ *sabbar* ‘to console’	/sˈsɐbbɐr/ ssabbar ‘to be comforted’	/ʔɐˈsɐmlʊ/ *qasamlu* ‘he broke’	/ʔɐsˈsɐmlʊ/ *qassamlu* ‘he distributed’
	/ˈsɐbbɐt/ *sabbat* ‘to bang’	/sˈsɐbbɐt/ *ssabbat* ‘to be banged’	/bɐˈsɐrlʊ/ *basarlu* ‘he predicted’	/bɐsˈsɐrlʊ/ *bassarlu* ‘he forecasted’
	/ˈsɪkkɛt/ *sikket* ‘to silence’	/sˈsɪkkɛt/ *ssikket* ‘to be silenced’	/kɪˈsɪrlʊ/ *kisirlu* ‘he broke’	/kɪsˈsɪrlʊ/ *kissirlu* ‘he broke to pieces’
/ʃ/	/ˈʃɐhhɐm/ *xaħħam* ‘to fatten’	/ʃˈʃɐhhɐm/ *xxaħħam* ‘to become fat’	/bɐˈʃɐrlʊ/ *baxarlu* ‘he told’	/bɐʃˈʃɐrlʊ/ *baxxarlu* ‘he announced’
	/ˈʃɛbbɐh/ *xebbah* ‘to liken’	/ʃˈʃɛbbɐh/ *xxebbah* ‘to be likened’	/kɪˈʃɪflʊ/ *kixiflu* ‘he uncovered’	/kɪʃˈʃɪflʊ/ *kixxiflu* ‘he made s.o. disclose s.th’
	/ˈʃɐmmɐr/ *xammar* ‘to fold back’	/ʃˈʃɐmmɐr/ *xxammar* ‘to be folded back’	/nɪˈʃɪflʊ/ *nixiflu* ‘he became dry’	/nɪʃˈʃɪflʊ/ nixxiflu ‘he dried’

/l/	/ˈlɪbɛrʊ/ *liberu* ‘free’	/lˈlɪbɛrɐ/ *llibera* ‘to make s.o. free’	/sɐˈlɐblʊ/ *salablu* ‘he crucified’	/sɐlˈlɐblʊ/ *sallablu* ‘he crucified’
	/lɪmɪtʊ/ *limitu* ‘limit’	/lˈlɪmɪtɐ/ *llimita* ‘to limit’	/tɛˈlɐʔlʊ/ *telaqlu* ‘he left’	/tɛlˈlɐʔlʊ/ *tellaqlu* ‘he took part in a race’
	/ˈlɪkwɪdʊ/ *likwidu* ‘liquid’	/lˈlɪkwɪdɐ/ llikwida ‘to liquefy’	/dɐˈlɐmlʊ/ *dalamlu* ‘it got dark’	/dɐlˈlɐmlʊ/ *dallamlu* ‘he made it dark’
/r/	/ˈrɐbjɐ/ *rabja* ‘anger’	/rˈrɐbjɐ/ *rrabja* ‘to get angry’	/dɐˈrɐblʊ/ *darablu* ‘he injured’	/dɐrˈrɐblʊ/ *darrablu* ‘he stroke’
	/ˈrɛtʃtɐ/ *reċta* ‘a play’	/rˈrɛtʃtɐ/ *rreċta* ‘he acted’	/bɐˈrɐmlʊ/ *baramlu* ‘he twisted’	/bɐrˈrɐmlʊ/ *barramlu* ‘he twisted vigorously’
	/ri:t/ *rit* ‘rite’	/rˈrɪd/ *rrid* ‘I want’	/fɛˈrɐhlʊ/ *ferаħlu* ‘he was glad’	/fɛrˈrɐhlʊ/ *ferraħlu* ‘he made s.o. happy’

/tʃ/	/ˈtʃɐhhɐd/ *ċaħħad* ‘to deprive s.o. of s.th’	/tʃˈtʃɐhhɐd/ ċċaħħad ‘to deprive onself’	/bɐˈtʃɪr/ *baċir* ‘dock’	/vɐtʃˈtʃɪn/ *vaċċin* ‘vaccine’
	/ˈtʃɛkkɛn/ *ċekken* ‘to make smaller’	/tʃˈtʃɛkkɛn/ *ċċekken* ‘to be humiliated’	/pɐːˈtʃɪ/ *paċi* ‘peace’	/kɛtʃˈtʃɪ/ *keċċi* ‘to send away’
	/ˈtʃɐrrɐt/ *ċarrat* ‘to tear’	/tʃˈtʃɐrrɐt/ *ċċarrat* ‘to be torn’	/tʃʊˈtʃɐtɐ/ *ċuċata* ‘s.th silly’	/ʔʊtʃˈtʃɐtɐ/ *quċċata* ‘peak’

Appendix 3

Target words used in production 3. The containing word-medial / word-final segments.

The target words for Production Study 3 were chosen from *ġabra* (Camilleri 2013) and from Aquilina (2006) *Concise Maltese English English Maltese dictionary.*

	WORD-MEDIAL		WORD-FINAL	
Segment	**Singleton**	**Geminate**	**Singleton**	**Geminate**
/p/	/ˈpɐp̠ɐ/ *papa* 'pope'	/ˈpɐp̠p̠ɐ/ *pappa* 'food'	/tɪːp/ *tip* 'type'	/zɪpp/ *żipp* 'zipper'
	/ˈkɔp̠rɪ/ *kopri* 'cover'	/ˈkɔp̠p̠jɐ/ *koppja* 'couple'	/kɐːp̠/ *kap* 'boss'	/tɐp̠p̠/ *tapp* 'tap'
	/ˈrɐp̠ɐ/ *Rapa* 'surname'	/ˈmɐp̠p̠ɐ/ *mappa* 'map'	/kɪrˈkɔːp̠/ *Kirkop* 'name of town'	/kɔp̠p̠/ *kopp* 'a catching net'
/t/	/ˈʔɐt̠ɐr/ *qatar* 'to drip'	/ˈʔɐt̠t̠ɐr/ *qattar* 'to drip'	/bɐːt̠/ *bagħat* 'he sent'	/ʔɐt̠t̠/ *qatt* 'never'
	/ˈbɐt̠ɐn/ *batan* 'to breed'	/ˈbɐt̠t̠ɐn/ *battan* 'to grid the belly of a horse'	/vɔːt̠/ *vot* 'vote'	/bɔt̠t̠/ *bott* 'bottle'
	/ˈfɛt̠ɐʔ/ *fetaq* 'to unstitch'	/ˈfɛt̠t̠ɐʔ/ fettaq 'to stitch and unstitch again'	/siːt̠/ *sit* 'site'	/sɪt̠t̠/ *sitt* 'six'

/k/	/ˈsɪkɛt/ *siket* ‘to be silent’	/ˈsɪkkɛt/ *sikket* ‘to silence’	/ˈdɐːk/ *dak* ‘that (m.)’	/hɐkk/ *ħakk* ‘to scratch’
	/ˈbɪkɛm/ *bikem* ‘to become mute’	/ˈbɪkkɛm/ *bikkem* ‘to dumbfound’	/lɔːk/ lok ‘place’	/ʃɔːkk/ xokk ‘shock’
	/ˈnɪkɛb/ *nikeb* ‘break off direction’	/ˈtʃɛkkɛn/ *ċekken* ‘to make small’	/dɪːk/ *dik* ‘that (f.)’	/zɪkk/ *żikk* ‘used to mean petty’
/f/	/ˈʔɐfɛl/ *qafel* ‘to close’	/ˈʔɐffɛl/ qaffel ‘to lock repeatedly’	/tɐːf/ *taf* ‘you know’	/kɛff/ *keff* ‘to hem’
	/ˈlɛfɐʔ/ *lefaq* ‘to sob’	/ˈlɛffɐʔ/ *leffaq* ‘to sob frequently’	/suːf/ suf ‘wool’	/gɔff/ *goff* ‘rudely’
	/ˈrɪfɛs/ *rifes* ‘to tread upon’	/ˈrɪffɛs/ *riffes* ‘to tread on s.th. repeatedly’	/ɐːf/ *għaf* ‘to know’	/sɐff/ *saff* ‘layer’
/s/	/ˈkɪsɛb/ *kiseb* ‘to acquire’	/ˈkɪssɛb/ *kisseb* ‘to obtain’	/rɐːs/ *ras* ‘head’	/rɐss/ *rass* ‘to press’
	/ˈnɐsɐb/ *nasab* ‘to trap’	/ˈnɐssɐb/ *nassab* ‘to lay traps’	/bɪːs/ *bies* ‘to kiss’	/bɪss/ *biss* ‘only’
	/ˈrɛsɐʔ/ *resaq* ‘to approach’	/ˈrɛssɐʔ/ *ressaq* ‘to bring s.th. closer’	/nɐːs/ *ngħas* ‘sleepy’	/hɐss/ *ħass* ‘to feel’

/ʃ/	/ˈnɪʃɛf/ *nixef* ‘to dry up’	/ˈnɪʃʃɛf/ *nixxef* ‘to dry’	/ɐːʃ/ *għax* ‘because’	/bɐʃʃ/ baxx ‘shallow’
	/ˈnɐʃɐr/ *naxar* ‘to hang’	/ˈnɐʃʃɐr/ *naxxar* ‘hyp.’	/miːʃ/ *mhix* ‘isn’t’	/lɪʃʃ/ *lixx* ‘smooth’
	/ˈmɐʃɐt/ *maxat* ‘to comb’	/ˈbɛʃʃɐʔ/ *bexxaq* ‘to leave ajar’	/ɛːʃ/ *għex* ‘to live’	/bɛʃʃ/ *bexx* ‘to spray’
/l/	/ˈɐːl̲ɐʔ/ *għalaq* ‘to close’	/ɐl̲l̲ɐʔ/ *għallaq* ‘to hang’	/dʒɛːl̲/ *ġegħel* ‘to compel’	/dɛl̲l̲/ *dell* ‘shade’
	/ˈhɐl̲ɛb/ *ħaleb* ‘to milk’	/ˈhɐl̲l̲ɛb/ *ħalleb* ‘to milk cows milk’	/bɐːl̲/ *bagħal* ‘mule’	/hɐll/ *ħall* ‘vinegar’
	/ˈʔɐl̲ɛb/ *qaleb* ‘to turn’	/ˈʔɐl̲l̲ɛb/ *qalleb* ‘to turn s.th. over’	/nɪˈkɔːl/ *Nikol* ‘name’	/uːˈkɔll/ *ukoll* ‘as well’
/r/	/ˈʔɛr̲ɛd/ *qered* ‘to destroy’	/ˈʔɛr̲r̲ɛd/ *qerred* ‘to whimper’	/dɐːr̲/ *dar* ‘house’	/dɐːr̲r̲/ *darr* ‘cause harm’
	/ˈmɐr̲ɐd/ *marad* ‘to become sick’	/ˈmɐr̲r̲ɐd/ *marrad* ‘to cause s.o. to fall in’	/dɔˈlɔːr̲/ *Dolor* ‘name’	/ɪˈdʒɔːr̲r̲/ *iġorr* ‘he moves’
	/ˈhɐr̲ɐb/ *ħarab* ‘to run away’	/ˈhɐr̲r̲ɐb/ *ħarrab* ‘to make s.o. run away’	/tʃɐːr̲/ *ċar* ‘clear’	/dʒɐr̲r̲/ *ġarr* ‘to carry’

/tʃ/	/ˈvɪt̠ʃɪ/ *viċi* ‘vice’	/ˈbɪt̠ʃt̠ʃɐ/ *biċċa* ‘a piece’	/sɔːt̠ʃ/ *soċ* ‘short for member’	/pɐˈpɔt̠ʃt̠ʃ/ *papoċċ* ‘slippers’
	/ˈvʊt̠ʃi/ *vuċi* ‘voice’	/ˈnit̠ʃt̠ʃɐ/ *niċċa* ‘niche’	/vɛrˈnɪːt̠ʃ/ *ver'niċ* ‘varnish’	/kɐpˈrɪt̠ʃt̠ʃ/ *kap'riċċ* ‘caprice’
	/ˈbɐt̠ʃɪ/ *Baci* ‘choclate brand’	/ˈbɔt̠ʃt̠ʃɐ/ *boċċa* ‘marble’	/fɛˈlɪːt̠ʃ/ *Feliċ* ‘name’	/wɪt̠ʃt̠ʃ/ *wiċċ* ‘face’

Appendix 4

List of words and glosses for the perception experiment in Chapter 8. Glosses taken from the online open access lexicon *ġabra*[1] (Camilleri 2013).

/t/	/d/	/s/	/ʃ/
[ɪttɛllɛf] / [ttɛllɛf] *ttellef* 'to be made to lose'	[ɪddɐbbɐr] / [ddɐbbɐr] *ddabbar* 'to be temporarily patched up'	[ɪssɐbbɐr] / [ssɐbbɐr] *ssabbar* 'to be comforted'	[ɪʃʃɐbbɐt] / [ʃʃɐbbɐt] *xxabbat* 'to climb'
[tɛllɛf] *tellef* 'to cause s.o. to lose'	[dɐbbɐr] *dabbar* 'to manage to acquire'	[sɐbbɐr] *sabbar* 'to console'	[ʃɐbbɐt] *xabbat* 'to cause s.th. to climb'
[ɪttɐffɐ] / [ttɐffɐ] *ttaffa* 'to subside'	[ɪddɐhhɐn] / [ddɐhhɐn] *ddaħħan* 'to be covered with smoke'	[ɪssɐbbɐt] / [ssɐbbɐt] *ssabbat* 'to be banged'	[ɪʃʃɐmmɐr] / [ʃʃɐmmɐr] *xxammar* 'to roll up one's sleeves'
[tɐffɐ] *taffa* 'to alleviate'	[dɐhhɐn] *daħħan* 'to emit smoke'	[sɐbbɐt] *sabbat* 'to bang'	[ʃɐmmɐr] *xammar* 'to roll up one's sleeves'

[1] http://mlrs.research.um.edu.mt/resources/gabra

[ɪttɐmɐ] / [ttɐmɐ] *ttama* ‘to hope’	[ɪddɐmdɐm] / [ddɐmdɐm] *ddamdam* ‘to be filled with loud noise’	[ɪssɐddɐt] / [ssɐddɐt] *ssaddad* ‘to become rusty’	[ɪʃʃɐhʃɐh] / [ʃʃɐhʃɐh] *xxaħxaħ* ‘to get cozy’
[tɐmɐ] *tama* ‘hope’	[dɐmdɐm] *damdam* ‘to resound’	[sɐddɐt] *saddad* ‘to rust’	[ʃɐhʃɐh] *xaħxaħ* ‘to get cozy’
[ɪttɐppɐn] / [ttɐppɐn] *ttappan* ‘to become less transparent’	[ɪddɐllɐm] / [ddɐllɐm] *ddallam* ‘to grow dark’	[ɪssɐffɐ] / [ssɐffɐ] *ssaffa* ‘to be cleansed’	[ɪʃʃɐhhɐm] / [ʃʃɐhhɐm] *xxaħħam* ‘to become fat’
[tɐppɐn] *tappan* ‘to make less transparent’	[dɐllɐm] *dallam* ‘to obscure’	[sɐffɐ] *saffa* ‘to cleanse’	[ʃɐhhɐm] *xaħħam* ‘to fatten’
[ɪttɐʔʔɐp] / [ttɐʔʔɐp] *ttaqqab* ‘to be pierced’	[ɪddɐrrɐs] / [ddɐrrɐs] *ddarras* ‘to be displeased’	[ɪssɐffɐr] / [ssɐffɐr] *ssaffar* ‘to be whistled’	[ɪʃʃɐmmɛm] / [ʃʃɐmmɛm] *xxammem* ‘to sniff’
[tɐʔʔɐp] *taqqab* ‘to pierce’	[dɐrrɐs] *darras* ‘to displease’	[sɐffɐr] *saffar* ‘to whistle	[ʃɐmmɛm] *xammem* ‘to sniff’
[ɪttɐjjɐr] / [ttɐjjɐr] *ttajjar* ‘to be flown’	[ɪddɛffɛs] / [ddɛffɛs] *ddeffes* ‘to poke one’s nose’	[ɪssɐjjɐr] / [ssɐjjɐr] *ssajjar* ‘to be cooked’	[ɪʃʃɐppɐp] / [ʃʃɐppɐp] *xxappap* ‘to be dipped’
[tɐjjɐr] *tajjar* ‘to make s.th fly’	[dɛffɛs] *deffes* ‘to push s.th. in’	[sɐjjɐr] *sajjar* ‘to cook’	[ʃɐppɐp] *xappap* ‘to douse in water’

[ɪttɐrrɐʃ] / [ttɐrrɐʃ] *ttarraf* ‘to be hinted at’	[ɪddɐndɐn] / [ddɐndɐn] *ddandan* ‘to show off’	[ɪssɐkkɐr] / [ssɐkkɐr] *ssakkar* ‘to lock oneself in’	[ɪʃʃɐndɐr] / [ʃʃɐndɐr] *xxandar* ‘to be broadcast’
[tɐrrɐʃ] *tarraf* ‘to hint at’	[dɐndɐn] *dandan* ‘to bring up s.th. gently’	[sɐkkɐr] *sakkar* ‘to shut’	[ʃɐndɐr] *xandar* ‘to advertise’
[ɪttɐwwɐl] / [ttɐwwɐl] *ttawwal* ‘to be lengthened’	[ɪddɐʔʔɐs] / [ddɐʔʔɐs] *ddaqqas* ‘to assume the right proportions’	[ɪssɐmmɐr] / [ssɐmmɐr] *ssammar* ‘to be nailed’	[ɪʃʃɐʔʔɐʔ] / [ʃʃɐʔʔɐʔ] *xxaqqaq* ‘to split’
[tɐwwɐl] *tawwal* ‘to lengthen’	[dɐʔʔɐs] *daqqas* ‘to proportion’	[sɐmmɐr] *sammar* ‘to nail’	[ʃɐʔʔɐʔ] *xaqqaq* ‘to split’
[ɪttɛftɛf] / [ttɛftɛf] *tteftef* ‘to be handled using fingers’	[ɪddɐrdɐr] / [ddɐrdɐr] *ddardar* ‘to feel nausea’	[ɪssɛbbɐħ] / [ssɛbbɐħ] *ssebbaħ* ‘to be made beautiful’	[ɪʃʃɐrrɐb] / [ʃʃɐrrɐb] *xxarrab* ‘to get wet’
[tɛftɛf] *teftef* ‘to nibble’	[dɐrdɐr] *dardar* ‘to turn s.o.’s stomach’	[sɛbbɐħ] *sebbaħ* ‘to make beautiful’	[ʃɐrrɐb] *xarrab* ‘to wet’
[ɪttɐʔʔɐl] / [ttɐʔʔɐl] *ttaqqal* ‘to be made heavier’	[ɪddɐwwɐr] / [ddɐwwɐr] *ddawwar* ‘to made to turn’	[ɪssɐlvɐ] / [ssɐlvɐ] *ssalva* ‘to be saved’	[ɪʃʃɐwwɐt] / [ʃʃɐwwɐt] *xxawwat* ‘to be burnt’
[tɐʔʔɐl] *taqqal* ‘to make s.th. heavy’	[dɐwwɐr] *dawwar* ‘to turn’	[sɐlvɐ] *salva* ‘to save’	[ʃɐwwɐt] *xawwat* ‘to scald’

[ɪttɛllɐ] / [ttɛllɐ] *ttella'* 'to be raised'	[ɪddɛjjɛn] / [ddɛjjɛn] *ddejjen* 'to run into debt'	[ɪssɛddɐʔ] / [ssɛddɐʔ] *sseddaq* 'to be proved true'	[ɪʃʃɛbbɐħ] / [ʃʃɛbbɐħ] *xxebbah* 'to be likened'
[tɛllɐ] *tella'* 'to raise'	[dɛjjɛn] *dejjen* 'to sell on credit'	[sɛddɐʔ] *seddaq* 'to render'	[ʃɛbbɐħ] *xebbah* 'to liken'
[ɪttɛllɐʔ] / [ttɛllɐʔ] *ttellaq* 'to be raced'	[ɪddɛllɛk] / [ddɛllɛk] *ddellek* 'to be covered in liquids'	[ɪssɛffɐʔ] / [ssɛffɐʔ] *sseffaq* 'to grow dense'	[ɪʃʃɛjjɛr] / [ʃʃɛjjɛr] *xxejjer* 'to flap'
[tɛllɐʔ] *tellaq* 'to race'	[dɛllɛk] *dellek* 'to grease'	[sɛffɐʔ] *seffaq* 'to cause to become thick'	[ʃɛjjɛr] *xejjer* 'to wave goodbye'
[ɪttɛnnɐ] / [ttɛnnɐ] *ttenna* 'to be repeated'	[ɪddɛffɛn] / [ddɛffɛn] *ddeffen* 'to ground'	[ɪssɛfsɛf] / [ssɛfsɛf] *ssefsef* 'to be sucked'	[ɪʃʃɛllɛf] / [ʃʃɛllɛf] *xxellef* 'to become chipped'
[tɛnnɐ] *tenna* 'to repeat'	[dɛffɛn] *deffen* 'to grind pottery'	[sɛfsɛf] *sefsef* 'to suck'	[ʃɛllɛf] *xellef* 'to chip'
[ɪttɐllɐp] / [ttɐllɐp] *ttallab* 'to beg'	[ɪddɛnnɛs] / [ddɛnnɛs] *ddennes* 'to become opaque'	[ɪssɛllɛf] / [ssɛllɛf] *ssellef* 'to borrow'	[ɪʃʃɛmmɛʃ] / [ʃʃɛmmɛʃ] *xxemmex* 'to sun onself'
[tɐllɐp] *tallab* 'hyp.'	[dɛnnɛs] *dennes* 'to dim'	[sɛllɛf] *sellef* 'to lend'	[ʃɛmmɛʃ] *xemmex* 'to sun'
[ɪttɛrtɐʔ] / [ttɛrtɐʔ] *ttertaq* 'to be shredded'	[ɪddɐjjɛf] / [ddɐjjɛf] *ddgħajjef* 'to be weakened'	[ɪssɛllɛm] / [ssɛllɛm] *ssellem* 'to be greeted'	[ɪʃʃɛrrɐʔ] / [ʃʃɛrrɐʔ] *xxerraq* 'to cause to choke (ref.)'
[tɛrtɐʔ] *tertaq* 'to shred'	[dɐjjɛf] *dgħajjef* 'to weaken'	[sɛllɛm] *sellem* 'to salute'	[ʃɛrrɐʔ] *xerraq* 'to cause s.b. to choke'

[ɪttɛrtɛr] / [ttɛrtɛr] *tterter* ‘to be made to shiver’	[ɪddɛwwɐ] / [ddɛwwɐ] *ddewwa* ‘to be cured’	[ɪssɛmmɐ] / [ssɛmmɐ] *ssemma’* ‘to eavesdrop’	[ɪʃʃɛnnɐʔ] / [ʃʃɛnnɐʔ] *xxennaq* ‘to long for’
[tɛrtɛr] *terter* ‘to shiver’	[dɛwwɐ] *dewwa* ‘to cure’	[sɛmmɐ] *semma’* ‘to make one hear’	[ʃɛnnɐʔ] *xennaq* ‘to arouse a longing’
[ɪttɛmtɛm] / [ttɛmtɛm] *ttemtem* ‘to start stuttering’	[ɪddɛndɛl] / [ddɛndɛl] *ddendel* ‘to be hung’	[ɪssɛrrɛp] / [ssɛrrɛp] *sserrep* ‘to be meandering’	[ɪʃʃɛwwɛʃ] / [ʃʃɛwwɛʃ] *xxewwex* ‘to be incited’
[tɛmtɛm] *temtem* ‘to stutter’	[dɛndɛl] *dendel* ‘to hang’	[sɛrrɛp] *serrep* ‘to meander’	[ʃɛwwɛʃ] *xewwex* ‘to incite’
	[ɪddɛjjɐʔ] / [ddɛjjɐʔ] *ddejjaq* ‘to be annoyed’	[ɪssɔlvɐ] / [ssɔlvɐ] *ssolva* ‘to be solved’	[ɪʃʃɛrrɛt] / [ʃʃɛrrɛt] *xxerred* ‘to scatter’
	[dɛjjɐʔ] *dejjaq* ‘to annoy’	[sɔlvɐ] *solva* ‘to solve’	[ʃɛrrɛt] *xerred* ‘to scatter’

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May 2014 — Galea, L., Grice, M., Hermes, A., & Muecke, D., 'Lexical and surface geminates in Maltese'; poster presentation at 10th International Seminar of Speech Production, Cologne.

PUBLICATIONS

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