CUES TO GEMINATION IN WORD-INITIAL POSITION IN MALTESE

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ABSTRACT

In this study we investigated word-initial geminates in Maltese, focusing on sub-segmental acoustic durations: constriction duration and, where appropriate, VOT; and the duration of adjacent segments: the tonic vowel duration and the duration of the inter-consonantal interval spanning the word boundary. This latter interval, between the consonant in the previous word and the singleton/geminate consonant, is measured so as to capture the presence and duration of a vocalic element, which has been referred to as epenthetic, and reportedly precedes word-initial geminates in the language. Whilst constriction duration plays an important role in distinguishing geminates from singletons (a ratio of 1.7:1), VOT does not. Moreover, although the duration of the following tonic vowel plays no role, the duration of the preceding context – the inter-consonantal interval – is a strong cue to gemination word-initially.

Keywords: acoustic cues, word-initial geminates, Maltese, duration, VOT, inter-consonantal interval

1. INTRODUCTION

Singleton and geminate consonants vary along a number of acoustic parameters. Traditionally, geminates are described as being phonetically longer than singletons [17], even though the geminate to singleton ratio seems to be language-specific, varying from 1.8:1 in Italian to 3:1 in Japanese [6].

Word-medial geminates are common across typologically different languages [6]. Maddieson [18] reports that the surrounding segments of word-medial geminates show a common typological pattern: vowels before geminates are shorter than before singletons: Italian [8], three languages of Indonesia [5] and Hindi [18] show this pattern. However, Japanese goes against this pattern: vowels before word-medial geminates seem to be longer than before singletons [14]. However, in Japanese, vowels after geminates are shorter than after singletons [13,14].

Another durational parameter for differentiating between geminates and singletons, which is also language-dependent, is voice onset time. In word-medial position in Cypriot Greek, VOT in voiceless stops is significantly longer for geminates than for singletons [1]. In Finnish, on the other hand, it is longer for singletons than for geminates [7]. Furthermore, languages such as Japanese [14], Lebanese Arabic [10] and three languages of Indonesia [5], do not show any differences in VOT at all.

Word-initial geminates are typologically rarer than word-medial geminates [16]. As in the case of word-medial geminates, constriction duration is the primary acoustic correlate for word-initial geminates (Swiss German [15], Tashlhiyt Berber [20]). Language-specific differences in VOT have also been reported in this position. In Kelantan Malay [11], for instance, VOT was significantly longer for singletons than for geminates, whereas VOT in Swiss German [15] did not differ across the two conditions.

Geminates in Maltese have received little attention to date, although the language has a singleton-geminate opposition in three positions: word-initially, word-medially, and word-finally. Our focus here is on geminates in word-initial position. Whether the geminates are truly word-initial, however, requires some qualification [2, 12], as they tend to be preceded by a vocalic element of [ɪ]-like quality, commonly referred to as an 'epenthetic vowel'.

The present study aims to contribute to the cross-linguistic specification of gemination. With respect to the consonants themselves, we investigate constriction duration and VOT; for surrounding segments, we look at the duration of the following vowel (tonic vowel) and of the inter-consonantal interval (capturing the presence and duration of a vocalic element preceding the consonant).

2. METHOD

2.1. Materials

Words were selected to allow for the comparison between singletons and geminate obstruents word-initially. *Singletons* (S) were of CVC:VC structure. Two types of geminates were chosen: *lexical geminates* (LG) and *assimilated geminates* (AG). LG are created through a morphological process that derives passive and reflexive forms in word-initial position: sabar 'to console'; ssabbar 'to be consoled'. AG are created through the addition of the definite article 'il-', which in Maltese is a pro-clitic and regressively assimilates to word-initial coronals (cf. il-bott 'the bottle', is-suq 'the market'). All target words (Table 1) contained a coronal obstruent (/t, d, s, ʃ, z/) in word-initial position. Furthermore, all target words were stressed on the penultimate syllable.

Following [2, 12], we expect lexical geminates to be preceded by a vocalic element of [ɪ]-like quality after a word ending in a consonant, but not necessarily after a word ending in a vowel. Therefore, we presented target words in two carrier phrases:

1) after /m/:
   Qalilhom <target > erba' darbiet
   'He told them <*target*> four times'
2) after /ɐ/:
   Qalilha <target> erba' darbiet
   'He told her <*target* > four times'

Table 1: Complete word list

S	LG	AG
daħħal /**d**ɐhhal/ 'to insert'	ddaħħal /**dd**ɐhhɐl/ 'to be entered'	id-daħla /ɪ**dd**ɐhla/ 'the entrance'
tallab /**t**ɐllɐb/ 'to pray'	ttallab /**tt**ɐllɐb/ 'to beg'	it-talba /ɪ**tt**ɐlbɐ/ 'the prayer'
sabbar /**s**ɐbbɐr/ 'to comfort'	ssabbar /**ss**ɐbbɐr/ 'to be consoled'	is-sabar /ɪ**ss**ɐbɐr/ 'the patience'
xaħħam /**ʃ**ɐhhɐm/ 'to fatten'	xxaħħam /**ʃʃ**ɐhhɐm/ 'to be fattened'	ix-xaħam /ɪ**ʃʃ**ɐhɐm/ 'the fat'
żarrat /**z**ɐrrat/ 'the fray'	żżarrat /**zz**ɐrrɐt/ 'to be frayed'	iż-żarda /ɪ**zz**ɐrdɐ/ 'the loose threads'

2.2. Speakers

Ten native speakers of Maltese (6 males, 4 females, ages 18-28) participated in this experiment. Participants were instructed to read each sentence at a normal speaking rate. Recordings were carried out in a soundproof booth at the University of Malta. Each target word was repeated 7 times. In total 1050 tokens were analysed (i.e. 10 speakers x 15 target words x 7 repetitions).

2.3. Measurements

The annotation was conducted using Praat [4]. The constriction duration was measured for plosives (/t, d/) from the start of the closure to the burst, and for fricatives (/s, ʃ, z/) from the start of the aperiodic noise to the start of the following vowel. VOT was measured for plosives as the lag between the consonantal burst to the onset of periodicity.

The tonic vowel was measured from the start of the formant structures to the start of the word-medial consonant. The inter-consonantal interval was measured as the portion between the last consonantal segment in the previous word (/m/ or /l/) until the start of the consonantal constriction for the singleton or geminate in the target word.

2.4. Statistical Analysis

All data were analysed using linear mixed-effect models, using R [20] and the package *lme4* [3]. All models included random intercepts for speakers and items. The fixed effects of Consonant (S, LG, AG) and Manner (i.e. *plosives* /t, d/; *fricatives* /s, ʃ, z/). were centred to reduce collinearity. We adopt a model-comparison approach, testing the goodness-of-fit of different models to determine the impact of the two independent variables; for this purpose, we report each model's Bayesian Information Criterion (BIC) together with the model chi-squared value (χ^2).

3. RESULTS

3.1. Constriction duration analysis

We built a baseline (model 1), which was made up of only the intercept and the random effects. We then investigated the contribution of the fixed effects of Consonant and Manner separately (model 2 & 3) and compared them to the baseline. Next, we built a model with both fixed effects terms (model 4) and compared it to the baseline. Finally, we compared the model 4 to a model with the two fixed effects and their interaction (model 5).The models including the fixed effects (i.e. models 2 and 3 in Table 2) have a better fit to the data than the baseline, suggesting that the duration of constriction depends on both the consonant and on manner. The model that fits the data best is model 4, as both fixed effect terms are included in the model. However, the inclusion of an interaction term did not improve the model fit, as shown by the comparison of model 5 to model 4. Note that model 4 has a reduced BIC relative to the baseline (model 1), in contrast to models 2 and 3, which are roughly on a par with the baseline model in spite of a significant difference in fit, reflected by the model chi-squared estimates.

Table 2: Model goodness of fit: Constriction Duration[1]

Model	Fixed Effects	BIC	χ^2
1	Intercept	18315	-
2	Consonant	18316	6.8835 *
3	Manner	18317	6.4755 *
4	Consonant + Manner	18312	12.621 *
5	Consonant * Manner	18319	0.4105 *ns*

As expected, the constriction duration for geminates is longer than for singletons (S: x̄=87ms, sd=35, LG: x̄=148ms, sd=31, AG: x̄=140ms, sd=32).

Table 3: Mean constriction duration (ms) consonant by manner

Segment	S	LG	AG
plosives	54 (22)	126 (24)	117 (26)
fricatives	108 (23)	162 (26)	155 (25)

3.2. VOT

VOT was calculated as the temporal interval between the release of the consonantal constriction and the onset of voicing. VOT for fully voiced stops, which is the case for Maltese, is represented by a negative value to show voicing during closure. The means of the VOT for /d/ and /t/ are represented in Table 4:

Table 4: Mean VOT duration (ms)

Segment	S	LG	AG
/d/	-49 (18)	-123 (20)	-117 (18)
/t/	33 (8)	28 (8)	29 (8)

In the case of VOT for /d/ and /t/, our model only included a term for consonant. In both cases, the models 2 (in both Table 5 & 6) that included consonant as a fixed effect did not fit the data any better than a model with just the intercept. This suggests that there was no difference in VOT between singletons, lexical geminates and assimilated geminates.

Table 5: Model goodness of fit: VOT /d/

Model	Fixed Effects	BIC	χ^2
1	Intercept	3476.3	-
2	Consonant	3479.0	3.3418 *ns*

Table 6: Model goodness of fit: VOT /t/

Model	Fixed Effects	BIC	χ^2
1	Intercept	2688.8	-
2	Consonant	2692.0	2.8229 *ns*

3.3. Tonic vowel (following singleton/geminate)

We looked at the acoustic duration of the tonic vowel after singletons and lexical geminates. We compare singletons and lexical geminates, which were designed to constitute minimal pairs.

Table 7: Model goodness of fit: Tonic Vowel

Model	Fixed Effects	BIC	χ^2
1	Intercept	10721	-
2	Consonant	10728	0.0117 *ns*
3	Manner	10728	0.6669 *ns*
4	Consonant + Manner	10735	0.0125 *ns*
5	Consonant * Manner	10742	8e-04 *ns*

None of the models with the fixed effects (models 2-5 in Table 7) explain the data any better than the model with just the intercept (model 1). This suggests that there is no difference between the duration of the tonic vowel after a singleton (x̄=91ms, sd=22) and after a lexical geminate (x̄=89ms, sd=21).

3.4. Pre-consonantal interval

In a previous study on word-initial geminates in Maltese [9] it was reported that when geminates are preceded by a consonant, there is a vocalic insertion. However, when geminates are preceded by a vowel: the study reports lengthening of this vowel before geminates. Note that this lengthening occurs across a word boundary.

3.4.1. Inter-consonantal interval after 'Qalilhom'

Speakers do not insert a vocalic element between the nasal /m/ and the following singleton. This was also verified by spectrographic inspection: nasal formants were present until the constriction of the following consonant. A vocalic element is highly frequent before both geminate types (a total of 96%). The inter-consonantal interval is similar before both lexical geminates and assimilated geminates. The

[1] In all model * indicates significant *p* values ($p<0.05$), *ns* = not significant

duration of the inter-consonantal interval was the same in both geminate types (LG: $\bar{x}$=68ms, sd=50; AG: $\bar{x}$=68ms, sd=37). This was confirmed statistically, as the model which included Consonant ($\chi^2(1)=0.0512$, $p>0.05$) or Manner ($\chi^2(1)=0.5061$, $p>0.05$) as fixed effects did not fit the data any better than the model with just the intercept.

3.4.2. Inter-consonantal interval after 'Qalilha'

The inter-consonantal interval in this subset of the data is the interval between the release of the second /l/ in 'Qalilha' (the orthographic 'h' is a silent letter) and the start of the constriction for the following consonant (singleton/geminate). The model including both fixed effects (model 4 in Table 8) captures the variation in the data best. The model suggests that the duration of the pre-consonantal interval was influenced by singleton and geminate consonants and by whether the consonant was either a plosive or a fricative. The inter-consonantal interval was shortest before singletons ($\bar{x}$=102ms, sd=44) and longest before geminates (LG: $\bar{x}$=120ms, sd=61; AG: $\bar{x}$=131ms, sd=60).

Table 8: Model goodness of fit: inter-consonantal interval after /a/

Model	Fixed Effects	BIC	χ^2
1	Intercept	10888	-
2	Consonant	10890	5.134 *
3	Manner	10891	4.7091 *
4	Consonant + Manner	10890	7.769 *
5	Consonant * Manner	10897	8e-04 *ns*

4. CONCLUSION

In this paper we have presented evidence for cues to gemination in Maltese. In measuring an array of different acoustic parameters, we investigated whether there are other parameters besides constriction duration, which serve as cues to gemination in the language. As in other languages, our results show that for geminates in word-initial position, duration is the strongest cue. Geminates are around 1.7 times longer than singletons. Even though there is no homogeneous geminate to singleton ratio cross-linguistically, the geminate to singleton ratio of 1.7:1 is on par with what has been reported for Italian [8], although this ratio has been found word-medially, the only position in which Italian has the singleton/geminate opposition.

The second durational parameter we investigated was VOT. Our results show that the VOT of voiced and voiceless stops in Maltese is not an acoustic correlate to gemination in word-initial position. The lack of an effect of gemination on VOT is also found in Japanese [14], in three languages of Indonesia [5], and in Bern Swiss German [15].

The third durational parameter we investigated was the duration of the tonic vowel after singletons and geminates. This does not function as an acoustic correlate to gemination, as the duration of the vowel was similar after both singletons and geminates.

Word-initial geminates in Maltese are special because they allow for adjustments to take place in the interval before the start of the constriction for the target consonant and thus across the word boundary. We found evidence for this in two contexts: where the preceding word ended in a nasal (*Qalilhom*) and when it ended in a vowel (*Qalilha)*. In both cases, there were longer durations of the vocalic portion of the signal (inserted after /m/ in the first case and of the vowel /ɐ/ itself in the latter) before geminates than singletons. Thus, the inter-consonantal interval is a strong cue to gemination in word-initial position in Maltese. It is possible that speakers use this interval to signal to listeners that a geminated consonant is about to occur. By doing so, speakers are ensuring that listeners can access the correct lexical item during lexical retrieval. For instance, in *daħħal* 'to insert' and *ddaħħal* 'to be entered', the only difference between these two lexical items is the geminated consonant in word-initial position. Speakers would thus be expected to enhance this lexical difference phonetically. Furthermore, this interval might suggest that word-initial geminates in Maltese are structurally similar to word-medial geminates, such that they undergo a process of resyllabification, in which the initial part of the geminate functions as a coda for a preceding syllable. The vocalic element in the inter-consonantal interval would thus be the nucleus of this syllable and have the status of a fully-fledged vowel. Finally, perception experiments on the role of the inter-consonantal interval would provide further evidence for the salience of the interval as being a strong cue for the identification of geminates.

5. REFERENCES

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