The Production of Word-final Geminates in Maltese within a Communication-based Approach

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Preferential Positions

- It is well established that phonological contrasts are more likely to occur in certain positions within the word, e.g. word-initial vs. word-final.

- A range of observations support this generalization:

  – Distributional: Greater number of contrasts along a particular dimension at the beginning of the word, as opposed to the end, e.g. Shona vowel contrasts (J. Beckman 1998)

Alternations

- Neutralization of laryngeal contrasts, e.g. Polish, Russian, Korean

- Reduction/deletion, e.g. English alveolar stops (Bybee 1995, Guy 1980, Neu 1980, Jurafsky et al. 1998)

- Metathesis: Preferentially involves segments at the end of the word (Mielke & Hume 2001)

Accounting for the observations

- Optimality Theory, e.g. positionally-specified ranked constraints (Prince & Smolensky 1993, J. Beckman 1998)
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- But why such asymmetries?

- It has been suggested that the underlying motivation for these constraints relates to considerations of word recognition (Beckman 1998, Hume 1998, Mielke & Hume 2001).

"With respect to word position, it has been claimed that the left edge of the root or word is special for word recognition (Cutler et al. 1985, Halle 1992, Marslen-Wilson 1989, Marslen-Wilson & Zwitserlood 1989), since lexical access is generally achieved on the basis of the initial part of the word.

Beginnings of words also tend to be particularly robust and able to resist phonological processes (Hall 1992). Given this, for metathesis to be minimally disruptive to word recognition, it is predicted to be less prevalent at the left edge of a word (Hume 1998)."

(Hume & Mielke 2001)

But contrasts can still occur word-finally

- Despite the preference of word-initial position, there are robust patterns of contrast that occur word-finally in some languages.

- Maltese singleton vs. geminate consonants provide an example.

- While typologically rare, the contrast between singleton and geminate consonants in word-final position is pervasive.

A subset of Maltese word-final geminates: Type frequency.

Source: Maltese Language Resource Server Corpus.
(C. Borg, R. Fabri, A. Gatt & M. Rosner)

bb	48		xx	99
tt	713		ġġ	233
dd	116		mm	213
kk	216		nn	243
qq	55		rr	105
ss	982		ll	704

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Maintaining a word-final contrast

- Today, I'll present experimental evidence confirming the intuition that the contrast between word-final singleton and geminate consonants is robust.
- The strategies native speakers use to implement the contrast is of particular interest.
- As I hope to show, the strategies are consistent with insights from communication (information) theory (Shannon 1948).
- In particular, otherwise redundant information is produced in contexts of low predictability. This has the effect of providing additional information about the singleton/ geminate contrast and, by extension, enhancing the robustness of the communication system.

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Game Plan

- Overview of the ongoing study of word-final geminates in Maltese and results to date.

- How insights from communication theory can help us understand the results.

- Some speculations regarding the relative contribution of singleton/geminate contrasts to distinguishing words.

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and, of course, the participants in this study.

Methods

Speakers
- 14 native speakers (7 female, 7 male) of Standard Maltese, aged 19-23. (6 are analyzed thus far)
- Subjects were undergraduate students at the University of Malta, where the study was conducted.

Stimuli
- 32 geminate-singleton (near) minimal pairs, as well as a comparable number of fillers.

Methods

Independent variables

- Syllable number (monosyllabic, bisyllabic)
- Segment type
  - stop (t/d-tt/dd; k-kk; q-qq): 8 pairs
  - fricative (s-ss; x-xx): 3 pairs
  - affricate (ġ-ġġ): 1 pair
  - nasal (m-mm; n-nn): 1 pair each
  - liquid (l-ll; r-rr): 3 pairs

	Monosyllabic		Bisyllabic	
Stop coronal	at	att	bajjad	bajjadt
	rat	radd	għajjat	għajjatt
	bdot	dott	palat	ħallatt
velar	frak	frakk		
glottal	daq	daqq		
Fricative	ras	rass	(ma) tarax	garaxx
	qmis	miss		
Affricate	spraġ	raġġ		
Nasal	dam	damm		
	min	minn		
Liquid	ġar	ġarr		
	bħal	ħall		
	kul	kull		

Dependent variables

- **Consonant duration**:
  - stops: closure; fricatives: frication
  - affricates: closure and frication; sonorants: formant structure
- **Aspiration**: stops only
- **Duration of preceding vowel:**
  - Previous studies show vowel duration to be shorter in superheavy syllables (e.g. VCC) and longer in heavy syllables (e.g. VC) (e.g. Hume et al. 2008). Syllable structure differences are relevant for word-final singletons and geminates: syllables closed by a singleton are heavy and those closed by a geminate are superheavy.
- Data were analyzed in *Praat*.

Methods

- The words were pseudo-randomized to form 5 sets that were presented to each speaker.
- Speakers recorded words in the carrier phrase, "għid ___ erba' darbiet", which were presented to each speaker in the form of a Powerpoint presentation.
- Recordings were made in a quiet office at the University of Malta (thanks Ray!).
- Slides were automatically presented to the speaker at 3 second intervals. Speakers were given the option of pausing between each set.
- Each session lasted approximately 1 hour and subjects were paid for their participation.
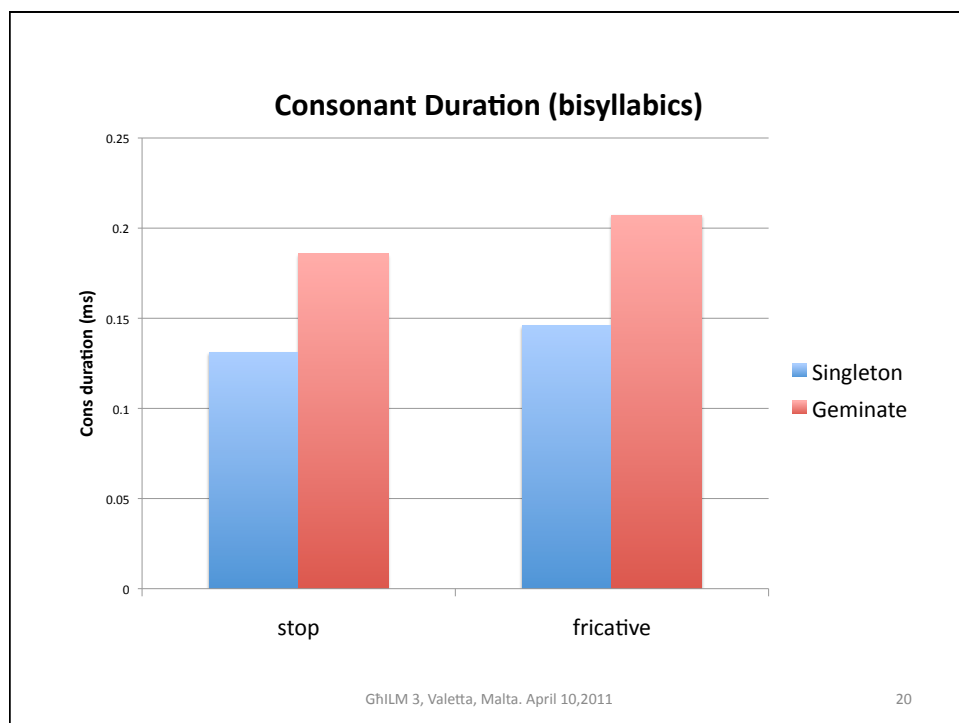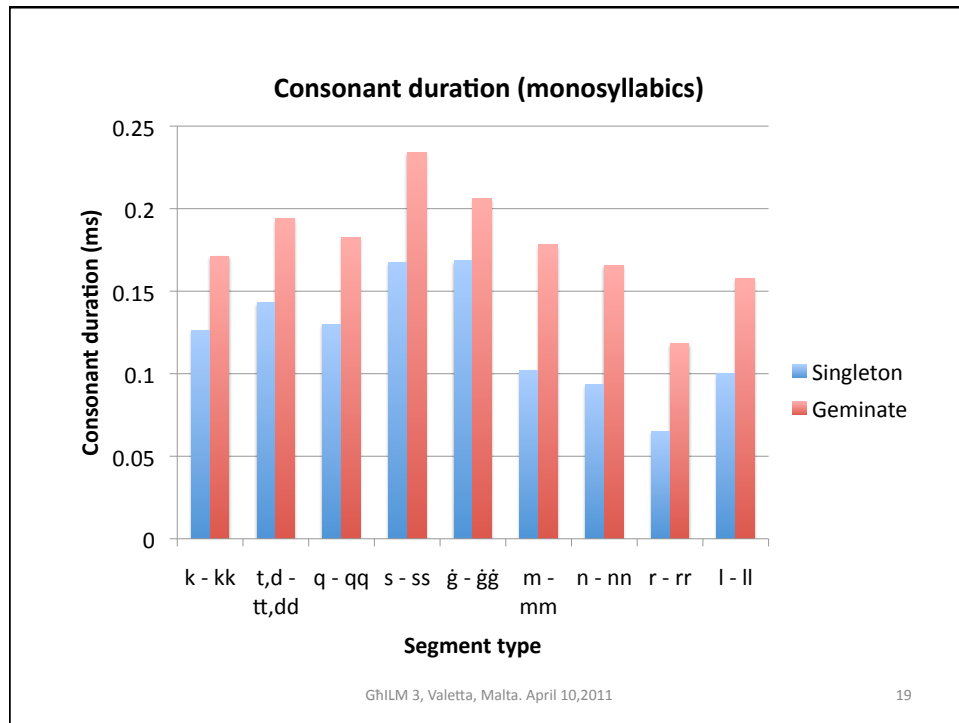
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Results for Consonants

- Aspiration was not a significant predictor of the distinction between singleton and geminates, consistent with Kraehenmann 2001 for Swiss German.

- However, consonant duration was highly significant ($p<.001$) for all segment types, regardless of whether the word was mono- or bi-syllabic.

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Consonant duration (monosyllabics)

Consonant Duration (bisyllabics)

Unpredictability

- Our results provide phonetic evidence that geminate and singleton consonants are distinctive in word-final position, implemented as a function of consonant duration.

- Consonant duration is thus an unpredictable property of word-final consonants; that is, it is not possible to predict the duration of a consonant when it occurs in word-final position.

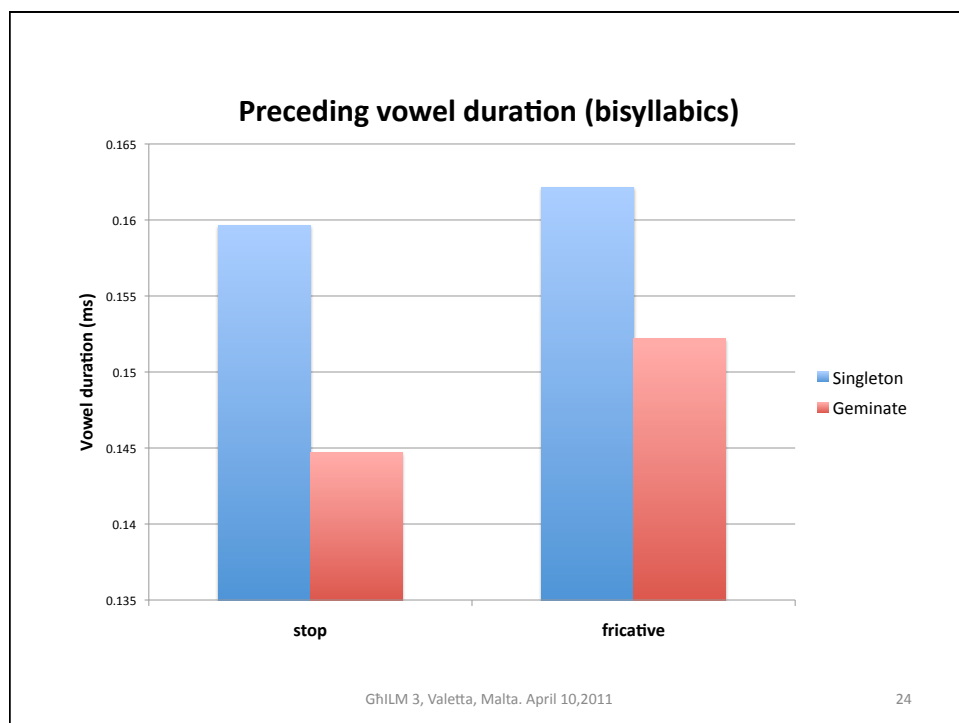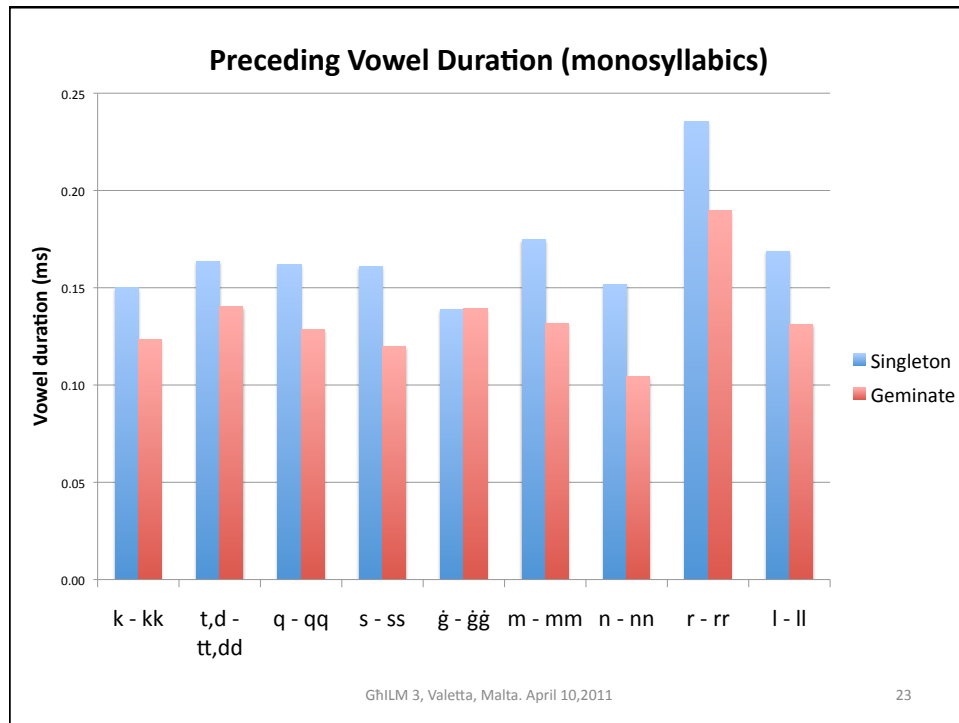## Duration of preceding vowel

- Consistent with our earlier findings, vowel duration was also a significant factor (p<.001) distinguishing singleton and geminates consonants.

- This holds with the exception of affricates (ġ vs ġġ), a point that I'll return to later.

Preceding Vowel Duration (monosyllabics)

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Preceding vowel duration (bisyllabics)

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Predictability

- While there is a systematic difference in the duration of the preceding vowel for all consonants except affricates, vowel duration is redundant, i.e. It is predictable given that singletons form heavy syllables and geminates form superheavy ones.

- If it is possible to distinguish between singleton and geminate consonants on the basis of consonant duration, why also use vowel duration? Further, the quantity of a syllable as heavy or superheavy is derivable from consonant duration.

- From an articulatory effort perspective, using two means of distinguishing the consonants or syllables would seem to require more work than using only one.

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Communicative Effectiveness

The finding that speakers use redundant information to help distinguish geminate and singleton consonants is consistent with an approach that takes communicative effectiveness into account.

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Core assumption:
Language is a system shaped by meeting the competing demands of efficiency and robustness in communication.

    Robustness: minimizing errors (increase redundancy)

    Efficiency: maximizing speed (decrease redundancy)

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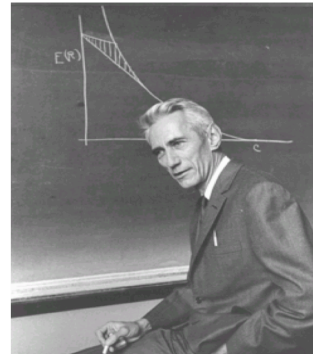   Efficiency: maximizing speed (decrease redundancy)

Speech production is simply the means by which these demands are implemented.

Communication and Information Theory

- Claude Shannon (1916-2001) developed a (the) mathematical theory of communication. Information Theory provides the necessary mathematical tools.
- While its concepts are fundamental to the field of computational linguistics, they are less familiar to theoretical linguistics.
- But see e.g. Cherry, Halle & Jakobson 1952; Hockett 1955; Broe 1996; Hale 2003; Goldsmith 1999, 2002; Aylett & Turk 2004; Hume 2006; Hall 2009; Levy & Jaeger 2007; Goldsmith & Riggle 2010; Hume et al 2011.

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Efficient and error-free communication

"The whole problem of efficient and error-free communication turns out to be that of removing from messages the somewhat inefficient redundancy which they have and then adding redundancy of the right sort in order to allow correction of errors made in transmission." (Pierce 1961:164)

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Manipulating Redundancy

E.g. Syllable duration

Phrase-medial syllables that are less predictable from lexical, syntactic, semantic, and pragmatic factors are longer than more predictable syllables (Aylett & Turk 2004).

Maltese

- Implementing **both** a vowel distinction as well as a consonant distinction for the singleton/ geminate contrast can be viewed as an example of adding the **right type of redundancy**.

- That is, it enhances the **robustness** of the consonant contrast and thus, the distinction between words. It serves to minimize communication errors.

Prediction

To the extent that vowel duration is used to enhance the robustness of the singleton/geminate contrast, the relative predictability of a given contrast may have an effect on whether or not vowel duration is used.

That is, contrasts that do little work in the language would have less of a need for the redundant property of vowel duration.

Relative contrastiveness

The degree to which an individual contrast contributes to differentiating words in a given language.
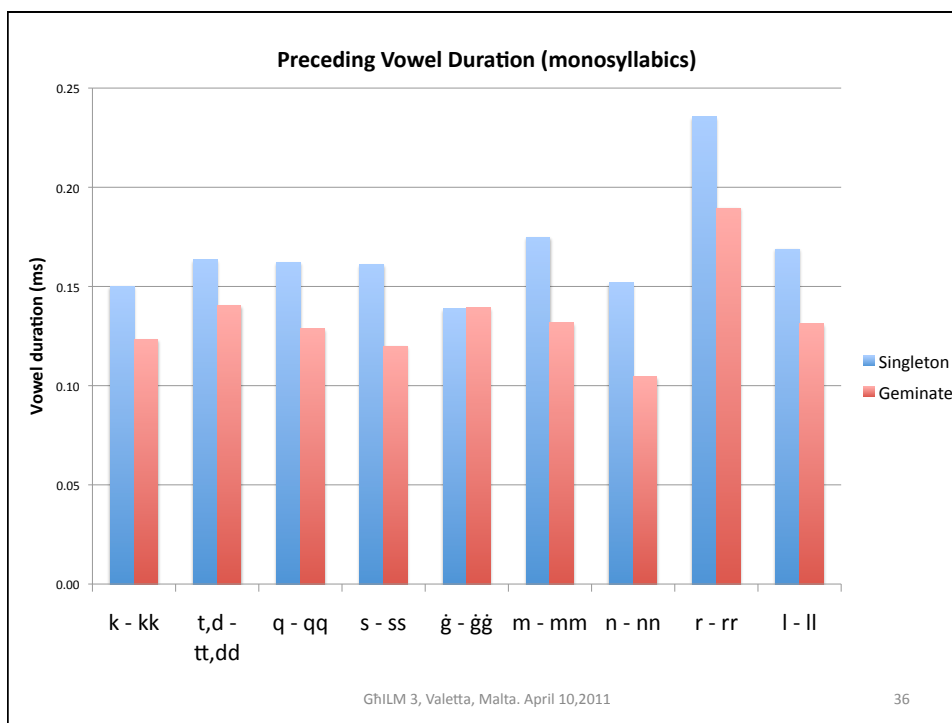
Cf. Functional load (Hockett 1955, Surendran & Niyogi 2003).

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Affricates

This approach may help elucidate the lack of a vowel duration distinction with the affricate singleton-geminate contrast *ġ-ġġ*.

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Preceding Vowel Duration (monosyllabics)

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A consonant's contribution to distinguishing words

- The amount that a given contrast contributes to distinguishing sounds can be measured in information-theoretic terms as the contrast's contribution to the entropy (uncertainty) of selecting among a set of sounds.

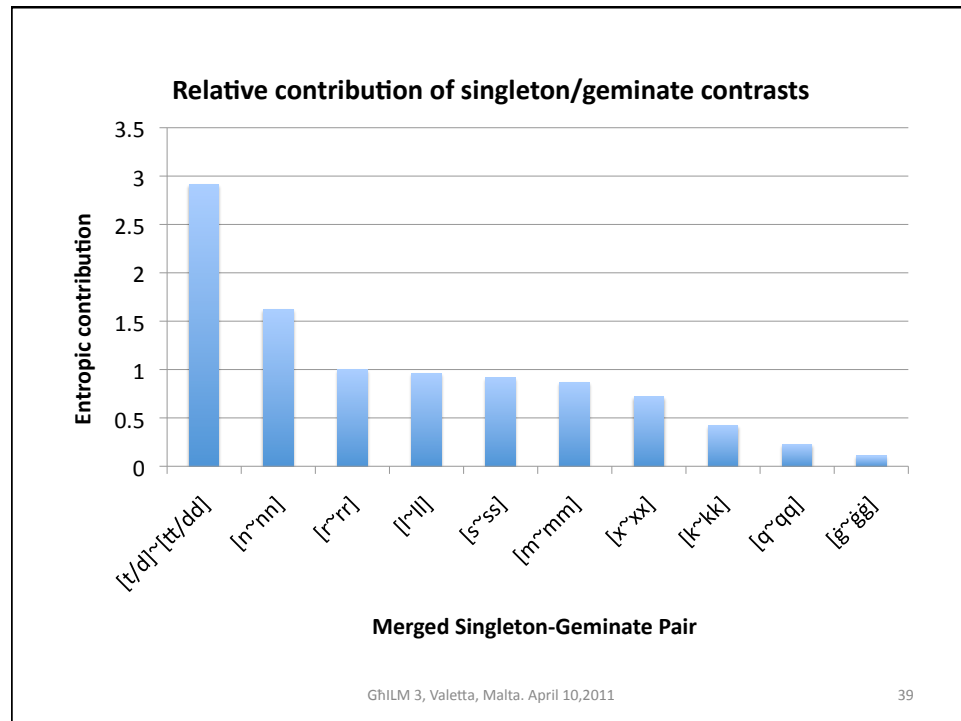- We being by calculating the entropy (H) of the set of all word-final consonants in our study: H=10.22 bits.

Computing Contrast Contribution

• We then recomputed the entropy of the consonant system, treating one singleton-geminate contrast as a single category, i.e. a given contrast was merged. The individual frequencies of each member of the merged contrast was summed. (See Wedel, in progress, Hume et al. 2011 for discussion.)

• The contribution of a contrast to the system was measured by the ***difference*** between the entropy of the entire set of word-final consonants and the entropy of the system when a given contrast is merged.

Relative contribution of singleton/geminate contrasts

Entropic contribution

Merged Singleton-Geminate Pair

Caveats

- These results can only be taken as suggestive.
- The study did not test all geminate-singleton types.
- There was only one pair of affricates (though only 1 pair of *q-qq, m-mm, n-nn, r-rr* as well and vowel duration was significant).
- The complexity of the affricate onsets differ: *spraġ-raġġ*. This probably doesn't matter but needs to be verified.
- The study should be replicated on conversational speech, providing durational measurements for both consonants and preceding vowels.
- It can extended to examine non-geminate consonant clusters in word-final position.

Conclusions

- Despite the typological rarity of word-final singleton-geminates, the contrast is pervasive in Maltese.
- Speakers implement the contrast in a variety of ways, including through consonant and vowel duration.
- Insights from communication theory may help elucidate why both predictable and redundant properties are used to distinguish the consonants.
- These insights can be formalized using the mathematical tools of information theory, making the theory rigorous and quantifiable.

Conclusions

- Today I have focussed on phonetic and phonological sources used by speakers to convey information in a message.
- However, a communication-based approach provides the mathematical means of integrating other sources of information, including those relating to intonation, semantics, syntax, pragmatics, sociolinguistics, among others.
- A communication-based approach thus has the potential for developing a truly comprehensive model of language.