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Research Article

Not all geminates are created equal: Evidence from Maltese glottal consonants

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ABSTRACT

Many languages distinguish short and long consonants or singletons and geminates. At a phonetic level, research has established that duration is the main cue to such distinctions but that other, sometimes language-specific, cues contribute to the distinction as well. Different proposals for representing geminates share one assumption: The difference between a singleton and a geminate is relatively uniform for all consonants in a given language. In this paper, Maltese glottal consonants are shown to challenge this view. In production, secondary cues, such as the amount of voicing during closure and the spectral properties of frication noises, are stronger for glottal consonants than for oral ones, and, in perception, the role of secondary cues and duration also varies across consonants. Contrary to the assumption that gemination is a uniform process in a given language, the results show that the relative role of secondary cues and duration may differ across consonants and that gemination may involve language-specific phonetic knowledge that is specific to each consonant. These results question the idea that lexical access in speech processing can be achieved through features.

1. Introduction

Many languages distinguish short and long consonants and those languages are not necessarily related (e.g., Finnish, Italian, Japanese, and Maltese). It is generally accepted that long consonants, or geminates, are longer than short consonants, or singletons. This difference in duration is the primary distinction made in production and used in perception (for a recent overview, see Table 1 in Hamzah, Fletcher, & Hajek, 2016). However, there is considerable discussion regarding the status and origin of secondary cues that are non-durational (e.g., release burst amplitude in stops, see Hamzah, Fletcher, & Hajek, 2012). The purpose of the current paper is to show that secondary cues may be stronger or weaker depending on which segment is geminated. As a consequence, geminates may sometimes be viewed as segments in their own right that have articulatory and acoustic properties that are not always easily derived as some form of strengthening of the singleton.

In previous research on geminates, there is some disagreement on the importance of secondary cues. Some argue that segment duration really is the main cue and that other cues may be perceptually close to irrelevant (Kotzor, Wetterlin, Roberts, & Lahiri, 2016), but others argue that secondary cues may be part and parcel of the distinction (Yoshida, de Jong, Kruschke, & Päiviö, 2015). Yoshida et al. (2015) varied the duration of the closure of a singleton /p/ or geminate /p:/ and tested the relative contribution of closure duration and the base (i.e., whether the stimulus was originally a singleton or a geminate). To do so, they asked Finnish and Japanese participants–both familiar with singleton-geminate contrasts in their native language–whether they perceived a singleton or a geminate. Both Finnish and Japanese stimuli were presented to Finnish and Japanese listeners. The results showed strong effects of the base, sometimes with differences of about 40% in quantity categorization. That is, a closure duration of 105 ms would be perceived as geminate in only 10% of the cases when the base stimulus originally contained a singleton, but as a geminate in 50% of the cases when the base stimulus originally contained a geminate. Interestingly, they found that such effects were, to some extent, language independent. That is, similar effects were found when Finnish listeners categorized Finnish and Japanese stimuli (and vice versa), indicating that some secondary cues are similar across languages.

Yoshida et al. (2015) explain this result by arguing that the quantity contrasts change the word prosody. This fits nicely with other proposals that the main difference between

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Table 1
Outcome of the linear mixed-effect model predicting the amount of voicing leak depending on the underlying segment and its quantity.

Term	Estimate (ms)	*t*	*p*
(Intercept)	35.75	22.89	<0.001
Quantity	−9.94	−5.66	<0.001
Glottal vs Oral	20.21	5.43	<0.001
/s/ vs oral stop	−5.15	−1.42	0.16
/h/ vs glottal stop	−43.33	−5.65	<0.001
Quantity x Glottal vs Oral	−15.18	−3.64	<0.001
Quantity x /s/ vs oral stop	0.05	0.01	0.99
Quantity x /h/ vs glottal stop	5.31	0.75	0.46

singletons and geminates is rhythmic/prosodic. Ridouane (2010) argued that geminates are associated with two timing slots and are additionally supplied with the feature *tense*, leading to a more forceful articulation. Evidence for this claim stems from acoustic and articulatory measures that show that geminates are produced more forcefully, for instance, with larger alveolar tongue contact for geminate /t:/ than singleton /t/. Kotzor et al. (2016) proposed that the primary distinction between singleton and geminates is that words with the geminate contain an extra mora (following Hayes, 1989) and that such a difference in rhythmic properties is necessary and sufficient for speakers to implement the distinction and for listeners to hear the distinction. That is, a geminate segment can be decomposed into the properties of the respective singleton segment plus some gemination property even in its phonetic implementation. Even though such accounts may seem rather different, it is more difficult to distinguish between them than it appears. The assumption that a geminate is connected to an additional mora means that the geminate would have more prosodic weight. This, in turn, would mean that geminates are a strengthened articulation in comparison to the singleton, also realized as increased duration (Cho & McQueen, 2005; Cho, McQueen, & Cox, 2007). Both assumptions—an extra timing slot or an extra mora for a geminate—hence predict that geminates are longer and have a strengthened articulation in comparison to the singleton.

This would mean that there are differences between singleton and geminates other than the duration of the segment itself and that those differences may be language-independent. While Yoshida et al. (2015) found evidence for such language-independent secondary cues for gemination, there is also evidence that there are language-specific ways to enhance the singleton-geminate distinction. One focus of previous research was the duration of the neighbouring vowels. Most languages show a contrastive pattern, so that vowels are phonetically shorter next to long consonants. Japanese provides a counterexample to this pattern by lengthening vowels before geminates (Kingston, Kawahara, Chambless, Mash, & Brenner-Alsop, 2009). These effects lead to language-specific learning, so that listeners will use vowel length to categorize consonants as singletons or geminates according to the production pattern in their native language. Japanese listeners give more geminate responses when the preceding vowel is long, while Norwegian and Italian listeners—from languages with a contrastive pattern—give fewer geminate responses when the preceding vowel is long (see Kingston et al., 2009). This suggests that there also is language-specific phonetic knowledge (Kingston & Diehl, 1994) on how to implement the singleton-geminate contrast.

Despite such differences in views regarding secondary cues to gemination, there is one common assumption to these approaches (Kotzor et al., 2016; Yoshida et al., 2015): That gemination works similarly for all consonants that are geminated. While there may be secondary cues which are specific to some segments (e.g., burst amplitude which only occurs in stops, but not in nasals, since they do not have a burst), it is nevertheless assumed that, underlyingly, the planning and execution of singletons and geminates is governed by the same principles, be it a stronger articulation due to a feature [TENSE] or more prosodic weight due to an additional mora (Kotzor et al., 2016; Ridouane, 2010). This is in line with the prevalence of feature theories in linguistics (Embick & Poeppel, 2015), which assume that segments are not primary in speech processing, but that the features (and timing properties) that define these segments are the primary objects of speech perception. The objective of this paper is to question such one-size-fits all approaches to gemination.

There is, for instance, an informal observation about the singleton-geminate distinction that challenges this general approach. Ladefoged and Maddieson (1996, p. 75) noted that the glottal stop is by default not really a stop but tends to surface as glottalization with no stop closure. A stop-like pronunciation is only reliably observed when the glottal stop occurs as a geminate. This would suggest that the acoustic cues for the singleton-geminate distinction would vary over place of articulation of a stop. For oral stops, the main cue would be constriction duration, while there is an additional difference for glottal stops, so that the singleton glottal stop surfaces as a glottalization while the geminate glottal stop surfaces as a stop.

Even if this is borne out by more thorough empirical investigation—which is one goal of the present paper—this may still be explained, though not very well, as an example of strengthening. After all, oral stops may also undergo lenition in connected speech and surface as flaps (Warner & Tucker, 2011). Ridouane (2010) argued that gemination leads to protection from lenition, so that singleton but not geminate stops can be produced without a release burst. The pattern observed by Ladefoged and Maddieson (1996) may hence be viewed in terms of (prosodic) strengthening of the glottal stop by assuming that the effects of the strengthening affect the acoustic outcome in a non-linear fashion. Even with such an explanation, such a finding would still raise the question whether features can be primary in speech processing. After all, the listener only has access to the auditory speech signal and when the acoustic consequences of gemination—whatever feature or timing unit it is associated with—differ radically between segments, it is questionable whether it would be functional to assume that the listener makes use of such features in speech perception. The critical question here then is whether the implementation of gemination differs strongly between oral and glottal stops and, if that is the case, whether the secondary cues that are specific to the glottal stop are important in perception. Answering this question is the first aim of this paper.

As will be reviewed below, Maltese is a language in which minimal pairs differing only in consonant quantity can be elicited for both oral and glottal stops, thanks to the derivational