Timing Differences in St'át'imcets Glottalised Resonants: Linguistic or Bio-mechanical?

Sonya Bird

Department of Linguistics
University of Victoria, Canada
sbird@uvic.ca

Marion Caldecott

Department of Linguistics
University of British Columbia, Canada
mariongc@interchange.ubc.ca

Abstract

In this paper we explore articulatory timing in the glottalised resonant series of St'át'imcets, an Interior Salish language spoken in British Columbia, Canada. We show that while these sounds form a natural class phonologically (van Eijk, 1997), they behave as two distinct classes phonetically: [-sonorant] segments /ż ʕ̓/ are systematically pre-glottalised. In contrast, [+sonorant] segments /m̓ n̓ l̓ ḷ' j' ẇ ʕ̓ʷ/ are post-glottalised word-finally, and intervocalically glottalisation overlaps with the oral articulation. We propose that articulatory timing in complex segments in subject not only to positional effects (Gick, 2003; Krakow, 1993; Silverman, 1995; Steriade, 1997), but also consonantal effects. We further propose that these effects are due to articulatory and biomechanical restrictions on speech, and need not be linguistically encoded.

1. Introduction

Glottalised resonants are extremely rare cross-linguistically. Of the 317 languages sampled by Maddieson (1984), only 20 have glottalised resonants. These complex consonants involve both oral and sub-oral articulations. For example, a glottalised /m̓/ consists of two oral articulations: closure at the lips and lowering of the velum (as in English /m/). It also involves a sub-oral articulation: either a laryngeal constriction resulting in creaky voicing or a glottal constriction resulting in complete glottal closure[1]. The manner of sub-oral articulation and its timing with respect to the oral articulation(s), vary not only across languages but also within languages depending on factors such as syllable and word position (Bird, 2003; Bird and Caldecott, 2004; Caldecott, 1999, 2004; Carlson et al. 2004, Esling et al. in press; Silverman, 1995; Steriade, 1997 and others).

One of the languages which has glottalised resonants is St'át'imcets (also known as Lillooet), an Interior Salish language spoken in Southwestern Interior British Columbia, Canada (Davis, in prep; van Eijk, 1997). It is estimated that there are between 50-100 speakers remaining of St'át'imcets, which has two main dialects know simply as "Upper" and "Lower". The phoneme inventory can be seen in Figure 1.

Lab	Alv	Lat	Pal	Vel	Lab-velar	Uvular	Lab-uvular	Glottal
p	t			k	kw	q	qw	ʔ
p'				k'	k̓ʷ	q	q̓ʷ	
	ts		tš					
	ts'	tl'						
	s	ɬ	š	x	xʷ	χ	χʷ	h
	z			ɣ		ʕ	ʕʷ	
	z'			ɣ̓		ʕ̓	ʕ̓ʷ	
m	n							
m'	n'							
			j'		w			
			j'		ẇ			
		l ḷ						
		l̓ ḷ'						

Figure 1: St'át'imcets phoneme inventory (adapted from van Eijk 1997)

[1] In this paper, 'glottalisation' will refer to both laryngeal and glottal constriction.

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Like other Salish languages, St'át'imcets has an extremely rich consonant inventory, including the following glottalised consonants: /ṁ ṅ l̇ ḷ’ j’ ẇ ż ɣ̇ ʕ̇ ʕ̇^{w}/, all of which have non-glottalised counterparts[1]. These consonants are interesting both phonologically and phonetically. First, they all pattern together phonologically, and are therefore considered to form a natural class: ‘resonants’. This classification is unexpected phonetically, given that /ż ɣ̇ / are traditionally considered [-sonorant]. The status of /ʕ̇ ʕ̇^{w}/ is unclear, though their non-glottalised counterparts are described as approximants (van Eijk 1997; Davis p.c.)

Second, recent acoustic analyses show that the production of glottalised resonants is extremely varied. Glottalisation is being lost in St’át’imcets such that orthographically glottalised resonants are often pronounced without any glottalisation at all (Bird, 2003; Bird and Caldecott, 2004). Findings so far indicate that loss of glottalisation is primarily a function of syllable position and age of speaker, with the role of stress unclear (Bird, 2003; Bird and Caldecott, 2004). Even when glottalisation is retained, its phonetic implementation seems to vary considerably in terms of (a) whether it involves creaky voicing or complete glottal closure and (b) the timing of the sub-oral constriction in relation to the oral articulation (pre- vs. post-glottalisation).

Very little is known about the variability exhibited in the implementation of glottalisation when it is present. The goal of this study is therefore to explore this variability, focusing on two potential contributing factors: (1) sonority of the resonant involved and (2) syllable position.

Bird and Caldecott (2004) found a systematic difference in articulatory timing between /ṁ/ and /ż/ word-finally. The sound /ṁ/ was systematically post-glottalised (glottalisation and release *following* [m]). In contrast, /ż/ was systematically pre-glottalised (glottalisation *preceding* [z]). This experiment will examine all St'át'imcets glottalised resonants in two positions (word-final and intervocalic) to determine whether: a) the previously observed difference between /ṁ/ and / ż/ word-finally can be extended to all glottalised resonants and b) the observed timing difference occurs in other environments as well - namely intervocalically. The first prediction tested is that the observed difference between /ṁ/ (post-glottalised) and /ż/ (pre-glottalised) reflects a more general difference between [+sonorant] consonants /ṁ ṅ l̇ ḷ’ j’ ẇ/ and [-sonorant] consonants /ż ɣ̇/. Since the sonority status of uvular glottalised resonants /ʕ̇ ʕ̇^{w}/ is unclear, a secondary goal of this study is to provide evidence for classifying them either as [+sonorant] or as [-sonorant] based on their articulatory timing.

[1] Note: the place of articulation of /ʕ̇ ʕ̇^{w}/ is somewhat unclear. They are listed here with the uvulars based on van Eijk (1997), but may be better characterized as uvulo-pharyngeals or pharyngeals, as in other neighbouring Salish languages (Carlson et al. 2004; Kinkade, 1967). See also Shank and Wilson (2000) and Shahin (2004) for related research.

The second prediction tested is that timing differences should hold across positions in the word. If sonority **is** the factor determining articulatory timing, we would predict the sonority split to be expressed in intervocalic position as well as word-finally.

2. Methods

2.1. Subjects

Three fluent speakers of Upper St’át’imcets participated in this study:

- CA: mid 60s, brother of AP, Upper St’át’imcets
- AP: early 60s, sister of CA, Upper St’át’imcets
- LR: mid 50s, Upper St’át’imcets with some Lower St’át’imcets influence (from mother)

2.2. Tokens

Intervocalic (onset) and word-final glottalised resonants were chosen for analysis. Intervocalic position was selected as a comparison to word-final position because it is an environment that will maximize glottalisation cues in cases of either pre- or post-glottalisation (see Steriade 1997).

Words containing glottalised resonants /ṁ ṅ l̇ ḷ’ j’ ẇ ż ɣ̇ ʕ̇ ʕ̇^{w}/[2] in intervocalic and word-final position were selected from van Ejik’s (1987) *A Dictionary of the Lillooet Language*. Because of the rarity of these segments, it was not possible to control for environment in selecting words. Each speaker’s familiarity with these words was checked before the words were framed in the sentence: *Tsut sDaryn* X *inatcwas* (‘Daryn said X yesterday’), and presented to subjects on a computer screen.

In total, 254 words were recorded (across all three speakers), containing 258 glottalised resonants[3]. Of these, 42 were discarded: 37 due to mispronunciations, poor recording quality, etc. and 5 due to glottalisation being realized in an unclear manner (see Section 4). In total, 216 glottalised resonants were analysed. Table 1 summarizes the number of tokens of each consonant analysed per speaker (‘iv’ stands for ‘intervocalic’ and ‘wf’ stands for ‘word-final’). Table 2 provides some examples of words used.

[2] /ɣ̇/ was found in only two words in the dictionary, neither in the environments considered in this study, so are not analysed.
[3] Four words contained two glottalised resonants each.

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Table 1: Number of tokens per speaker

	CA		AP		LR		**Total**
	iv	wf	iv	wf	iv	wf	
m̓	3	5	5	6	5	4	**28**
n̓	4	5	5	5	7	5	**31**
l̓	4	3	6	5	7	4	**29**
l̥'	0	4	0	5	0	5	**14**
j'	4	3	3	3	4	3	**20**
w̓	4	3	4	5	4	5	**25**
ż	3	5	5	5	4	5	**27**
ʕ̓	3	6	3	4	3	5	**24**
ʕ̓ʷ	1	3	3	5	2	4	**18**
Total	**26**	**37**	**34**	**43**	**36**	**40**	**216**

Table 2: Example words used

	IPA	St'át'imcets	English gloss
m̓	pɛ́x̌əm̓	píxem'	to hunt
n̓	p̓æn̓ǽnɬkæn	p'an'ánlhkan	I bent it
l̓	kúl̓un	k'úl'un	to soak something
l̥'	xʷa̱l̥'	cwa̱ḻ'	light (weight)
w̓	šqlə́ləw̓	sqlélew'	little beaver
j'	xʷaj'	cway'	disappeared, gone
ż	cqáżam	tsqáz'am	to store away barbequed salmon
ʕ̓	mɛ́ʔəʕ̓	mé7eg'	breaking daylight
ʕ̓ʷ	katɛ́ʕ̓ʷa	ka-tíg'wa	it came loose; it was set free

2.3. Experimental setup

Recording sessions were held in the kitchen of a private home in Lillooet, British Columbia. Subjects were asked to read sentences from a computer screen and were recorded using a Sony MZ-B10 portable mini-disc recorder and a Sony ECM-T115 lapel microphone. Data were then uploaded to an iMac OSX using Sound Studio 2.07. Data were analysed on two Toshiba Satellite PCs using Praat 4.1.13 (P. Boersma).

2.4. Analysis

Glottalised resonants were analysed by speaker and position according to:

- Whether there was any phonetic evidence of glottalisation: **yes** or **no**
- What the timing of glottalisation was relative to the resonant: **pre-glottalised** (cues to glottalisation preceded or were simultaneous to the resonant onset and preceded resonant offset), **post-glottalised** (cues to glottalisation followed the resonant onset and extended beyond, or coincided with the resonant offset), **middle** (cues to glottalisation occurred in the middle of the resonant with modal voicing both before and after glottalisation), **throughout** (cues to glottalisation occurred throughout the resonant), or **other** (discussed below)
- What cues were used to produce glottalisation (stop only, creaky voicing[1] only, stop + creaky voicing)

For this study, only the first two factors were considered. The categories **middle** and **throughout** were grouped together, and contrasted with **pre-glottalised**, **post-glottalised**, and **other**. This last category was used strictly for phonetic implementation of /ʕ̓/, which was sometimes realized simply as an (epi)glottal stop. In these cases where there was no oral articulation, the timing between oral and sub-oral articulations was irrelevant, and the implementation was termed **other**[2].

3. Results

Of the 216 consonants written orthographically as glottalised resonants, 176 were actually produced with glottalisation. Table 3 provides the distribution of glottalised vs. not glottalised resonants in word-final and intervocalic positions.

Table 3: Overall results: glottalisation by position

	Glottalised (%)		**Not Glottalised (%)**		**Total**
Word Final	99	(82.5)	21	(17.5)	120
Intervocalic	77	(80.2)	19	(19.8)	96
Total	176	(81.5)	40	(18.5)	216

3.1. Word-final position

The first goal of this study was to determine whether the differences in articulatory timing found between /m̓/ and /ż/ (Bird and Caldecott, 2004) were representative of all glottalised resonants in word-final position. Table 4 illustrates the percentage of tokens of each resonant by timing: **pre**-glottalised, **post**-glottalised, glottalised in the middle of the consonant or throughout the consonant (**mid/thru**), and **other**. Percentages were used to make the figures comparable, since not all consonants were associated with the same number of tokens; bolded figures indicate the most frequent timing type for each consonant.

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[1] At this point, the term 'creaky voicing' is used for any sub-oral constriction other than complete closure. However, Esling et al. (in press) distinguishes between levels and locations of constriction, illustrating that finer distinctions are needed to characterize phonological glottalisation in Salish languages.

[2] The exact locus of constriction is unclear. In Nlaka'pamux, a neighbouring Salish language, Carlson, Esling and Harris (2004:64) found glottalised pharyngeals to be articulated with both epiglottal and glottal stricture. Following Carlson et al. (2004), we use the term "(epi)glottal stop" to refer to the implementation of /ʕ̓/ when it involves complete stop closure.

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Table 4: Percentage of word-final resonants by timing

	Pre (%)	**Post** (%)	**Mid/thru** (%)	**Other** (%)
ṁ	0	**81.8**	18.2	0
ṅ	7.1	**85.7**	7.1	0
l̀	0	**90.0**	10.0	0
ḷ’	0	**100**	0	0
j’	0	**88.9**	11.1	0
ẇ	8.3	**83.3**	8.3	0
ż	**100**	0	0	0
ʕ̇	45.5	0	0	**54.5**
ʕ̇ʷ	0	**100**	0	0

Table 4 shows a clear distinction between two categories of glottalised resonants: /ṁ ṅ l̀ ḷ’ j’ ẇ ʕ̇ʷ/ pattern together in being primarily post-glottalised. In contrast, /ż, ʕ̇/ are primarily pre-glottalised, at least where there is an oral articulation. The sound /ʕ̇/ is actually most often replaced by a glottal stop, but in cases where there is an oral articulation (so that timing is relevant), /ʕ̇/ is pre-glottalised.

In terms of features, these two categories differ in sonority: sounds in the first category have a [+sonorant] component whereas sounds in the second category are [-sonorant]. Figure 1 summarizes the timing of glottalisation as a function of sonority, clarifying the findings provided in Table 4: [-sonorant] consonants are pre-glottalised and [+sonorant] consonants are post-glottalised.

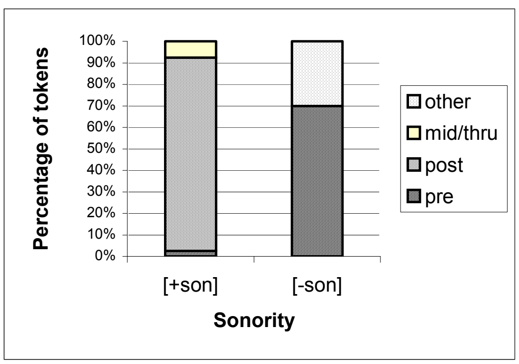

Figure 1: Glottal timing in word-final position as a function of sonority

The observed asymmetry in the timing of [+sonorant] vs. [-sonorant] consonants is significant ($\chi^2 = 88.14$, $p \leq 0.001$).

3.2. Intervocalic position

The second goal of this study was to see whether the word-final sonority-related timing differences held in other positions in the word. Table 5 presents the timing percentages across resonants in intervocalic position.

Table 5: Percentage of intervocalic resonants by timing

	Pre (%)	**Post** (%)	**Mid/thru** (%)	**Other** (%)
ṁ	36.4	0	**63.6**	0
ṅ	25	8.3	**66.7**	0
l̀	**68.8**	0	31.3	0
ḷ’	0	0	0	0
j’	10	20	**70**	0
ẇ	28.6	14.3	**57.1**	0
ż	**77.8**	11.1	11.1	0
ʕ̇	28.6	0	14.3	**57.1**
ʕ̇ʷ	40	0	**60**	0

Table 5 shows that [-sonorant] consonants patterns similarly in word-final and intervocalic position: as long as there is an oral articulation in addition to the sub-oral one, [-sonorant] consonants are primarily pre-glottalised intervocalically, just as they are word-finally. For [+sonorant] consonants, the picture is less clear. While [+sonorant] resonants still pattern together as a class intervocalically (with the interesting exception of /l/), the sub-oral articulation overlaps with the resonant instead of following it as is the case word-finally.

Figure 2 below shows timing as function of sonority in intervocalic position. The difference in timing between [+sonorant] and [-sonorant] consonants is still present, but it is not as robust as word-finally. Two factors contribute to this: (1) /l̀/ patterns with /ż/ rather than with other [+sonorant] consonants and (2) the proportion of /ʕ̇/ tokens produced as (epi)glottal stops is greater intervocalically than word-finally. These factors are discussed in Section 4 below.

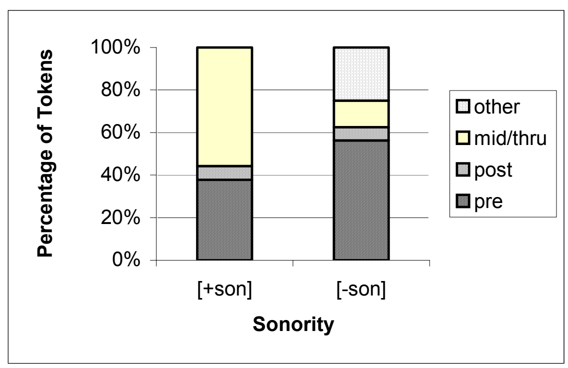

Figure 2: Glottal timing by sonority in intervocalic position

As in word-final position, the timing asymmetry between [+sonorant] and [-sonorant] segments in intervocalic position is significant ($\chi^2 = 21.37$, $p \leq 0.001$).

Summarizing, Figures 1 and 2 show that [+sonoroant] vs. [-sonorant] consonants pattern differently from each other

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both word-finally and intervocalically. Segments that are [-sonorant] show no significant differences in word-final vs. intervocalic position (p > 1): in both cases they are pre-glottalised as long as an oral articulation is present. In contrast, [+sonorant] consonants exhibit significantly different timing properties in word-final vs. intervocalic position (χ^2 = 96.37, $p \leq 0.001$): word-finally they are post-glottalised, whereas intervocalically glottalisation overlaps with the oral articulation. In other words, there is an interaction between consonant type ([±sonorant]) and word-position: only [+sonorant] consonants are affected by word position.

4. Discussion

The glottalised resonant series in St'át'imcets is considered a natural class based on its phonological properties. However, this class is comprised both of traditionally [+sonorant] and [-sonorant] segments. This experiment set out to answer two main questions: a) can previously observed timing differences in word-final position be accounted for along this sonority split? and b) do these timing differences apply in other positions in the word, or only word-finally?

The answer to the first question is a resounding yes. These data illustrate a discrepancy between phonetically vs. phonologically motivated featural descriptions: the sounds considered are all phonological 'resonants'. However, their phonetic implementation - i.e. the timing between the oral and glottal articulations - depends on what their specification of the feature [sonorant] is: word-finally, segments traditionally considered [+sonorant] and /ʕ̓ʷ/, realized with the [+sonorant] component [w], were consistently post-glottalised. In contrast, the [-sonorant] segments /ż ʕ̓/ were predominantly pre-glottalised. It is interesting that /ʕ̓ʷ/ and /ʕ̓/ pattern differently from each other in terms of glottalisation even though the only difference between them is the secondary articulation in /ʕ̓ʷ/.

The answer to the second question is less clear. The timing of [-sonorant] consonants was systematic across positions: both word-finally and intervocalically, these consonants were pre-glottalised. However, the timing of [+sonorant] consonants across positions was *not* systematic: within the [+sonorant] consonants only, a positional effect was observed, such that [+sonorant] segments were post-glottalised word-finally but intervocalically exhibited glottalisation during the oral articulation (i.e. an overlap in timing between the oral and glottal articulations). This asymmetry between [+sonorant] and [-sonorant] glottalised 'resonants' provides further evidence that they behave as two different phonetic classes of sounds. Why are only [+sonorant] segments subject to positional effects? The answer to this question remains a mystery for the time being, but may have to do with articulatory and biomechanical restrictions specific to [+sonorant] consonants which are especially prone to positional effects.

Although the effect of sonority was significant across positions, two factors contributed to decreasing this effect intervocalically. First, /l̓/ patterned with [-sonorant] consonants in that it was most often pre-glottalised. It is unclear whether this pattern is significant or coincidental at this point. Future research will hopefully clarify the articulatory timing properties of /l̓/ and why they differ from those of other resonants. One point worth mentioning is that St'át'imcets /z/ is said to have a lateral component, at least in the Lower dialect. It is possible that the common [lateral] feature of /l̓/ and /ż/ has something to do with their common articulatory timing intervocalically.

Second, /ʕ̓/ was replaced by an (epi)-glottal stop more often intervocalically than word-finally. In general, the phonetic implementation of /ʕ̓/ varied considerably both across and within speakers[1]. CA pronounced /ʕ̓/ as pre-glottalised both word-finally and intervocalically, patterning with /ż/. For LR, /ʕ̓/ was realized as a (epi)glottal stop both word-finally and intervocalically. AP's timing and manner of articulating /ʕ̓/ was inconsistent, and unclear. In word-final position, /ʕ̓/ was not glottalised. Intervocalically, if /ʕ̓/ was glottalised, it was glottalised in the middle. However, it is worth pointing out that three tokens of word-final /ʕ̓/ were discarded from AP's speech because we were unable to determine how to analyse the properties of glottalisation[2]. This indicates that although she is glottalising, she is not doing so in a systematic manner.

The difference in the three speaker's implementation of /ʕ̓/ parallels the difference in their use of glottalisation as a whole. In exploring the loss of glottalisation in St'át'imcets, Bird and Caldecott (2004) found that CA (the oldest of the three speakers) retained glottalisation most (76%), LR (the youngest of the three) retained it the least (51%) and AP fell in the middle (68%). The results presented here indicate that the loss of glottalisation may be associated with a change in the way glottalisation is implemented: CA, who glottalises the most, consistently pre-glottalises /ʕ̓/, treating it as a fricative similar to /ż/. LR, who glottalises the least, consistently replaces /ʕ̓/ with a simple glottal stop, i.e. she may be losing /ʕ̓/ entirely as a phoneme. AP, who is between CA and LR in her use of glottalisation, produces /ʕ̓/ with the most variability, as if she exhibits a change in progress.

The results presented here raise an interesting question regarding language-specific vs. universal phonetics. Results show systematic differences in the phonetic implementation of /m̓ n̓ l̓ ḷ' j' w̓ ʕ̓ʷ/ vs. /ż ʕ̓/. The question is: do these differences matter? In other words, are the details of phonetic implementation linguistically important (and consequently encoded as part of a speaker's language knowledge) or are they simply an effect of universal restrictions on speech production? If the observed timing differences are linguistically important, then they argue against grouping all glottalised resonants together into one natural class. Indeed, at least phonetically they should be split into two classes, based on sonority. On the other hand, if the observed differences in timing in [+sonorant] vs. [-sonorant] segments simply result from articulatory restrictions, for example, they need not be accounted for within formal linguistic theory (Bird and Gick 2004), and glottalised resonants can happily form a natural

[1] In contrast, the phonetic implementation of /ʕ̓ʷ/ was consistent across speakers and patterned with other sonorants both word-finally (post-glottalised) and intervocalically (pre-glottalised or glottalised in the middle),

[2] These were in fact the only three tokens across all speakers discarded because the cues to glottalisation and their timing relative to the oral articulation were unclear. The other two discarded tokens were from CA, and were cases in which the glottalised resonant was produced as an ejective.

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class. Indeed, phonetically unnatural, but phonologically relevant classes are not uncommon cross-linguistically (c.f. Mielke, 2004). Given that timing differences do not occur systematically across all positions (at least for [+sonorant] segments), it seems likely that they are due to articulatory or biomechanical limitations rather than to linguistically-encoded differences between consonants. However, it may be the case that timing differences between consonants *are* linguistically encoded, but interact in certain environments (e.g. intervocalically) with other factors. Further work will, hopefully, shed light on this issue.

Finally, however they are interpreted (linguistically important vs. not), the data here show that timing in doubly-articulated consonants can be an effect of the consonant involved. Previous work on articulatory timing has considered word and syllable position as influencing timing (Gick et al. 2003; Krakow, 1993; Silverman, 1995; Steriade, 1997). Results obtained here show that another factor that influences articulatory timing is the consonant type (sonority). Given that different consonants are associated with different articulatory and biomechanical restrictions, it is not surprising that articulatory timing is affected by these restrictions. The extent to which consonantal and syllable-based timing effects interact remains unclear, but is certainly an area for future research.

5. Conclusions

Loss of glottalisation in St'át'imcets, as well as the advanced age of many of the fluent speakers means that research on glottalised resonants must be conducted sooner rather than later. The challenges of working with endangered languages involve a restricted number of speakers and speaker variation not included in primary reference materials. These data come from only one speaker of each 'generation', and it is thus difficult to establish whether trends observed will apply across a range of speakers. Future research will involve examining resonants in all word positions, as well exploring the precise articulatory (and acoustic) cues used to realise glottalisation.

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