THE ARTICULATION OF MUTATED CONSONANTS: PALATALIZATION IN SCOTTISH GAELIC

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ABSTRACT

Scottish Gaelic (henceforth SG) exhibits a rich system of consonant mutation, which is mostly governed by its morphology. Using ultrasound imaging, this study explores the articulation of palatalization in SG, considered a type of consonant mutation, asking the question of how various palatalized consonants are produced. The results from 6 SG speakers show that there is a clear gestural difference between plain and palatalized consonants, but yield highly idiosyncratic variations in how speakers distinguish them. The findings from this study provide empirical evidence that the phonemic contrast plain vs. palatalized in SG manifests gesturally, and potentially support speaker-specific variability in speech production.

Keywords: Scottish Gaelic, consonant mutation, palatalization, articulation, ultrasound imaging

1. INTRODUCTION

It is widely acknowledged that Scottish Gaelic (Gàidlig, henceforth SG) exhibits a rich, highly morphologized consonant mutation system, in which consonants undergo various phonological changes depending on the morphological context [7, 6, 4, 8]. For instance, the initial consonant /p/ of a SG word *bàta* 'boat' changes to [v] when the word undergoes morphological inflection, as in *a bhàta* 'his boat', in which the sound spelled *bh* is pronounced as [v]. Palatalization in SG is considered a type of this lexicalized consonant mutation and is marked with an adjacent orthographic <i> that procedes a target segment, as shown in Table 1.

Table 1: Palatalization in SG

example	effect	gloss
go**b** - gui**b**	/p/ → [p^j]	'beak' - 'beak's'
ar**d** - air**d**e	/t/ → [t^j]	'high' - 'higher'
dù**n** - dùi**n**	/n/ → [n^j]	'fort' - 'forts'

This study investigates the articulatory patterns of palatalized consonants in SG using ultrasound imaging. Despite its short tradition in linguistics, ultrasound imaging technology has been used for numerous studies in speech production addressing various phonological questions, and also proven to be an excellent method for phonetic fieldwork [3, 1].

The goal of this project is to add to our understanding of consonant mutation in SG by exploring the articulatory properties of mutated (i.e., palatalized) consonants. Two questions that our work poses are: 1) Do speakers maintain an articulatory distinction between plain and palatalized consonants? 2) Do different types of consonants lead to the same articulatory distinction between plain and palatalized?

2. METHODS

2.1. Participants

A total of 26 SG speakers have participated in a production experiment conducted on the Isle of Skye, Scotland. The results from 6 speakers are reported here. All speakers are SG-English bilinguals, but used SG exclusively from birth until elementary school, and have continued to use SG on a daily basis. The detailed demographic information of speakers reported on here is shown in Table 2.

Table 2: Demographic information of speakers

speaker #	gender	age	SG dialect
S5	male	19	Uist
S7	female	34	Lewis
S10	female	50	Uist
S12	male	26	Lewis
S23	female	51	Skye
S26	female	59	Skye

2.2. Stimuli

A total of 10 items relevant to palatalization were extracted from the stimuli pool, shown in Table 3. Minimal or near-minimal pairs were selected if possible. All the test words were presented in standard SG orthography.

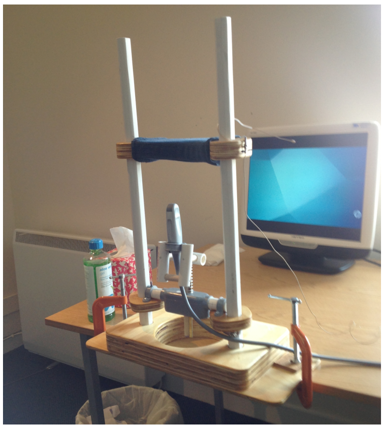
Table 3: Test items

segment	word	gloss
/t/	cat	'cat'
	cait	'cat's'
	bad	'place'
	phògamaid	'we would kiss'
/s/	cas	'foot'
	achlais	'armpit'
/n/	ceann	'head'
	cinn	'grow'
/l/	Gall	'lowlander'
	Goill	'lowlander's'

2.3. Procedure

During the course of the experiment, head movement was limited with a custom-made head stabilization device (See Figure 1). Participants were instructed to sit comfortably in front of the device, and place his or her chin on the ultrasound probe, which was immobilized by the device, then read out the words on a computer screen. They were also asked to place their forehead onto the blue cotton pad during the experiment, which helped them minimize their head movements.

Figure 1: The head stabilization device, with the adjustable-height head-rest/probe-holder



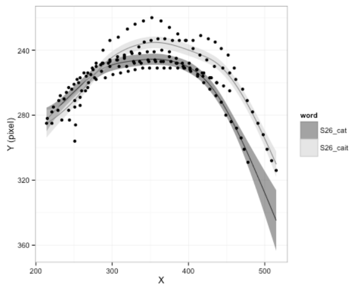
To further correct any head movement during data collection, raw tongue contours extracted from the recordings were adjusted using a MATLAB® script. First, tongue-at-rest positions between tokens of interest were identified and extracted for each speaker. Second, the angles of the tongue-at-rest positions were identified so that the positions correspond with each other. Then the angles of raw tongue contours for target consonants were adjusted to match the angle of adjacent tongue-at-rest contour.

As is typical with fieldwork, there were unavoidable disruptions that affected the quality of the audio recordings during the experiment sessions, such as car pulling up, birds chirping, and bagpipes. Given the fact that our primary focus is the articulatory gestures for target segments, these disruptions were considered to have minimal impact on the quality of the tongue movement recordings.

2.4. Analysis

For image frames to analyze, we identified the gestural peak of each target consonant based on the corresponding acoustic signals, selecting the last full image frame before stop release for stops, and the image frame at the midpoint of the sound otherwise. The data points from the tongue contours were statistically analyzed using Smoothing Spline ANOVA (henceforth SSANOVA) [5, 2] to test whether two sets of tongue contours from one speaker are significantly different. The sets of tongue contours are considered to be different when the confidence intervals (95%) for the two sets do not overlap, equivalent to $p < .05$, as shown in Figure 2. The x-axis in Figure 2 represents position along the tongue, where the leftmost endpoint is the tongue root and the rightmost endpoint is the tongue tip. The y-axis represents tongue height in pixels. As shown in Figure 2, confidence intervals for two tongue curves do not overlap, which indicates significant difference between curves.

Figure 2: An SSANOVA plot of tongue contours for word-final /t/s in the SG words *cat* and *cait* from Speaker 26. Thick lines are averaged tongue curves, and shades around them are confidence intervals of the averaged curves. Fewer data points (shown as black dots) create wider confidence intervals.



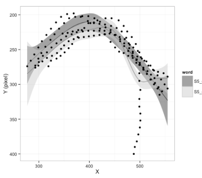
3. RESULTS

3.1. Plain vs. palatalized obstruents

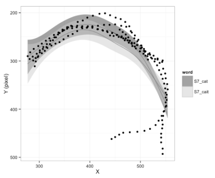
3.1.1. /t/

Figure 3 and 4 present comparisons of plain vs. palatalized /t/ from the SG words *cat* and *cait*, and *bad* and *phògamaid*, respectively. As illustrated in Figure 3, while 3 out of 6 speakers show significantly different tongue contours for /t/ in plain (ca**t**) and palatalizing (cai**t**) contexts, the way speakers make such distinction is not uniform across speakers. For instance, speaker 12 makes the backer tongue curve in the palatalizing context, whereas speaker 26 makes the fronter tongue gesture. Figure 4 also shows that the articulations of /t/ in plain (ba**d**) and palatalizing (phògamai**d**) contexts are clearly distinct, and exhibit speaker-specific variability.

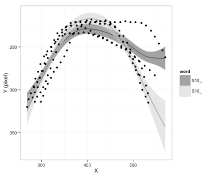
Figure 3: SSANOVA plots of tongue contours: plain (dark grey) vs. palatalized (light grey) /t/ from *cat* and *cait*



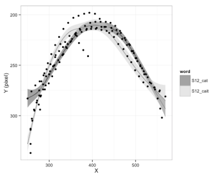
(a) S5



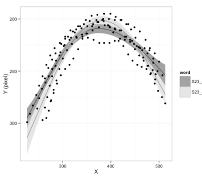
(b) S7



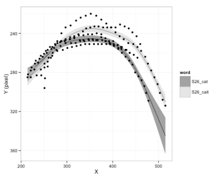
(c) S10



(d) S12

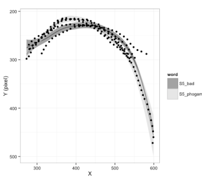


(e) S23

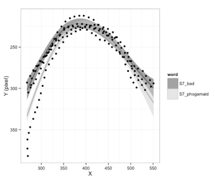


(f) S26

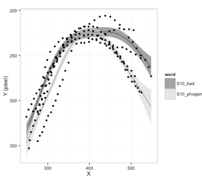
Figure 4: SSANOVA plots of tongue contours: plain vs. palatalized /t/ from *bad* and *phògamaid*



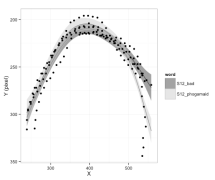
(a) S5



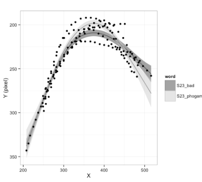
(b) S7



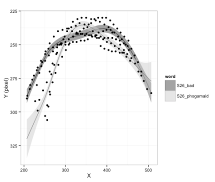
(c) S10



(d) S12



(e) S23

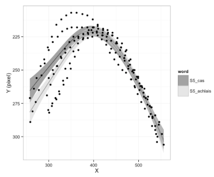


(f) S26

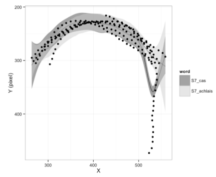
3.1.2. /s/

Figure 5 shows comparisons of plain vs. palatalized /s/ from the SG words *cas* and *achlais*. Here, the articulatory distinction between plain and palatalized /s/ is not as robust as that between plain and palatalized /t/, but it still yields individualized patterns. While speakers 5 and 23 make the fronter tongue shape in the palatalizing context, speaker 12 makes the backer tongue gesture.

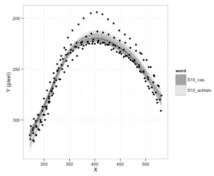
Figure 5: SSANOVA plots of tongue contours: plain vs. palatalized /s/ from *cas* and *achlais*



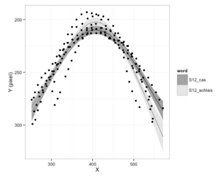
(a) S5



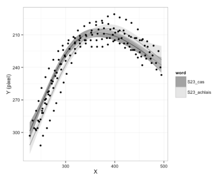
(b) S7



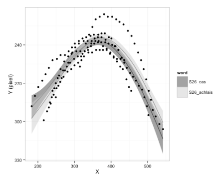
(c) S10



(d) S12



(e) S23



(f) S26

3.2. Plain vs. palatalized sonorants

3.2.1. /n/

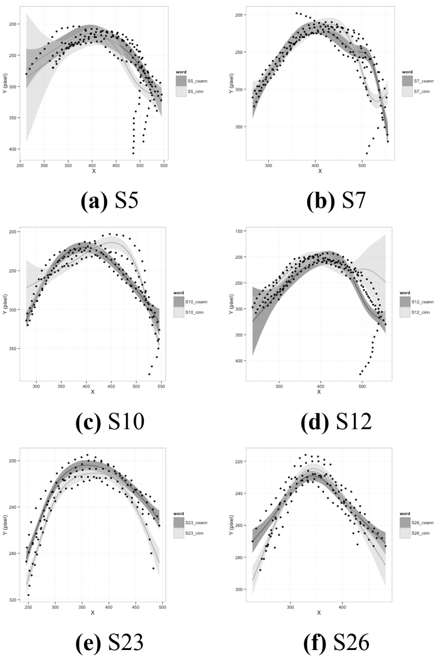
Figure 6 shows comparisons of plain vs. palatalized /n/ from *ceann* and *cinn*. While the majority of the speakers make distinct articulatory gestures for /n/ in two contexts, some speakers show the similar articulatory shapes. For instance, when in the palatalizing context, speakers 7 and 23 both show a lower tongue height in the front region of the tongue.

3.2.2. /l/

Figure 7 present comparisons of plain vs. palatalized /l/ from the SG words *Gall* and *Goill*. Following speaker-specific variability shown in the previous comparisons, the results yield highly individualized patterns, in which none of the speakers share the similar articulatory patterns.

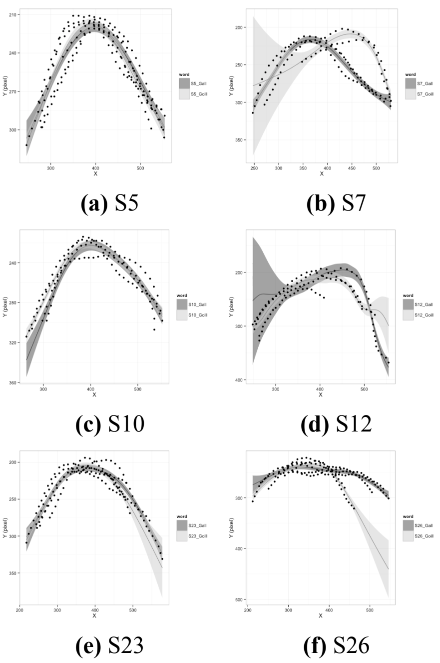
Overall, it is clear that the phonemic distinction

Figure 6: SSANOVA plots of tongue contours: plain (dark grey) vs. palatalized (light grey) /n/ from *ceann* and *cinn*



(a) S5 **(b)** S7 **(c)** S10 **(d)** S12 **(e)** S23 **(f)** S26

Figure 7: SSANOVA plots of tongue contours: plain vs. palatalized /l/ from *Gall* and *Goill*



(a) S5 **(b)** S7 **(c)** S10 **(d)** S12 **(e)** S23 **(f)** S26

between plain and palatalized consonants is manifested as distinct tongue gestures by speakers. The findings from this study are summarized in Table 4.

4. DISCUSSION

While the work here is preliminary, based on the data collected from 6 speakers, the results show a clear sign of contrast between two contexts. While the majority of speakers maintain some degree of articulatory distinction in most of the comparisons, it is not clear whether speakers actually produce "palatalized" versions of the phonemes in palatalizing contexts. It is possible that native SG speakers preserve the phonemic contrast between plain and palatalized consonants in their production, but not in a systematic way that corresponds a "palatal gesture". Based on the results from our study, we did not find any systematic means of creating palatalized consonants within speakers.

Table 4: A summary of the results: Check (✓) indicates difference, and cross (×) shows no difference.

	S5	S7	S10	S12	S23	S26
/t/ (<t>)	×	×	✓	✓	×	✓
/t/ (<d>)	✓	✓	✓	✓	✓	✓
/s/	✓	×	×	✓	✓	×
/n/	✓	✓	✓	✓	✓	✓
/l/	×	✓	✓	✓	×	✓

Despite the small sample of the population, the articulatory patterns observed in this study leave open the possibility of dialectal differences and speaker-specific variability that have been previously reported. Whether the above-discussed gestural properties are dialectal or purely individual needs to be further examined with a larger population and greater dialectal variation.

5. CONCLUSION

Although it is a well-known phenomenon, consonant mutation in SG is poorly studied in an experimental perspective. Our work adds to the small literature on the articulatory properties of Gaelic languages. The gestural characteristics observed in this study provides empirical evidence for articulatory realizations of consonant mutation, and also supports an increasing body of literature on variability in speech production.

6. ACKNOWLEDGEMENT

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7. REFERENCES

[1] Davidson, L. 2005. Addressing phonological questions with ultrasound. *Clinical Linguistics & Phonetics* 19, 619–633.

[2] Davidson, L. 2006. Comparing tongue shapes from ultrasound imaging using smoothing spline analysis of variance. *Journal of Acoustical Society of America* 120, 407–415.

[3] Gick, B. 2002. The use of ultrasound for linguistic phonetic fieldwork. *Journal of the International Phonetic Association* 32, 113–121.

[4] Gillies, W. 2002. Scottish Gaelic. In: Ball, M., Fife, J., (eds), *The Celtic Languages*. Routledge 145–227.

[5] Gu, C. 2002. *Smoothing Spline ANOVA Models*. Springer.

[6] Ladefoged, P., Ladefoged, J., Turk, A., Hind, K., Skilton, S. J. 1998. Phonetic structures of Scottish Gaelic. *Journal of the International Phonetic Association* 28, 1–41.

[7] Macaulay, D. 1992. The Scottish Gaelic language. In: Macaulay, D., (ed), *The Celtic Languages*. Cambridge University Press 137–248.

[8] Stewart, T. W. 2004. *Mutation as morphology: bases, stems, and shapes in Scottish Gaelic*. PhD thesis The Ohio State University.