Bodomo (1997) describes intervocalic velar [g] in Dàgáärè as fricative [ɣ]. With 42 tokens of intervocalic [g] from a native speaker of Dàgáärè, we investigated the acoustic and articulatory features of Dàgáärè intervocalic velar [g] using ultrasound images, waveforms, spectrograms, and palatogram. The results of the study suggest that Dàgáärè intervocalic [g] is not a fricative but a velar with strong tap-like features, a previously unattested sound in natural language (Ladefoged 1990). Following from this, we conclude that Dàgáärè intervocalic velar [g] is not a fricative but a tap.

1 Introduction

Dàgáärè is a Gur language of the Niger-Congo family, part of a group of languages known as the Mabia languages. It is spoken by about 1.5 million people
Samuel Akinbo, Alexander Angsongna, Avery Ozburn, Murray Schellenberg & Douglas Pulleyblank

in northwestern Ghana and some parts of Burkina Faso (Kennedy 1966; Bodomo 1997).

Dàgáárè is described as having twenty-five consonants and two underlying glides (Bodomo 1997). The vowel inventory contains nine vowels, with tongue root contrasts for high and mid vowels, but a single low vowel [a]. In Bodomo’s (1997) description of the consonant inventory, voiced velar stop [g] is said to alternate with [ɣ] intervocalically. The data included with this description is the single word (/pɔ́ɡɔ́/ ‘woman’) where [g] occurs between RTR vowels. According to our auditory impression, including that of the second author who is a native speaker, intervocalic <g> is not a velar fricative.

This paper describes an acoustic and articulatory study of Dàgáárè <g> in Central Dàgáárè, spoken in Nadowli-Kaleo district. Waveforms, spectrograms, duration, ultrasound images, and static palatograms of intervocalic <g> are studied. The acoustic and articulatory results show that intervocalic <g> has the complex waveform, amplitude variation, formant structure, tongue movement, and closure typical of a tap, rather than a velar fricative.

2 Methodology

Data comes from a native speaker of Dàgáárè and was collected at ISRL Lab, University of British Columbia in a room using Sennheiser MKH 8060 shotgun microphone at the sampling rate of 44kHz: 16bit.

An Aloka Pro-Sound SSD 5000 ultrasound machine with an Aloka UST-9119-3.5 convex transducer (pulse frequency 3.5MHz, field of view 120°) collected a moving image of tongue movement. The ultrasound probe was positioned manually against the mylohyoid muscle; it was kept stable with a mechanical arm. The stimuli for ultrasound and acoustic studies contain 42 tokens with intervocalic [g]. Each token was repeated twice.

To determine the place of articulation of the closure, a palatogram was recorded. The tongue was painted with charcoal mixed in olive oil before the participant produced four tokens of intervocalic <g>. After articulating each of the tokens, an image of the soft-palate was captured.

3 Results

All intervocalic <g> were segmented manually in Praat (Boersma 2002) and a script was used to extract duration values. The waveform and spectogram were manually extracted.
The waveform of Dagaare <g> has an amplitude decrease compared to surrounding vowels, but it is complex as can be seen in Figure 1. This is similar to the expected properties of a tap, but distinct from both voiced velar stops and resonants; from a voiced stop, we would expect a simple waveform for voicing, while with a resonant, we would not expect an amplitude decrease.

In the spectrogram of Dàgáárè <g>, we regularly see formant structure throughout the consonant. This is typical of resonants and possible for taps but is not consistent with a stop. For a [g], we would expect a gap in the spectrogram with a voicing bar at the bottom; this is not what we see for Dàgáárè <g>.

In terms of duration, the average duration of the collected <g> tokens was 0.055 seconds. This is substantially shorter than English [g], as a comparison, which has a duration of around 0.081 seconds. It is also longer than an alveolar tap, which tends to have a duration between 0.028 and 0.041 seconds. The durations for the Dagaare velar can be seen compared to English [g] and [ɾ] in Figure 2.
On the ultrasound, the tongue movement between the vowel position and the consonant was substantial; the tongue back raised towards the palate/velum. This degree of movement is consistent with either a stop or a tap, because the tongue moves far from the vowel position to make closure. A resonant would have less movement, due to the lack of closure. The ultrasound images can be seen in Figure 3.

Figure 2: Dàgáárè <g> relative to English [g] and [ɾ]

Figure 3: Intervocalic <g> in Dàgáárè
In the palatography shown in Figure 4, the pattern of charcoal left on the palate after production of <g> showed evidence of closure in the palatal/velar region. Closure is typically seen for stops and taps, but not for resonants.

Figure 4: Palatogram showing closure

In summary, although the Dagaare <g> has a longer duration than an alveolar tap, its production is most consistent with the behaviour of a tap, in terms of waveform, spectrogram, ultrasound, and palatography. In particular, it is not consistent in a number of ways with a stop or a resonant. These results are summarized in Table 1.
Table 1: Result summary

<table>
<thead>
<tr>
<th>Properties</th>
<th>Dàgáárè results</th>
<th>Expected of [g] (Byrd 1993)</th>
<th>Expected of tap (Ting 2007)</th>
<th>Expected of resonant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waveform</td>
<td>complex waveform, amplitude decrease</td>
<td>simple waveform (voicing)</td>
<td>more complex waveform, amplitude decrease</td>
<td>no amplitude decrease</td>
</tr>
<tr>
<td>Spectrogram</td>
<td>formant structure, gap with voicing bar</td>
<td>formant structure possible</td>
<td>formant structure</td>
<td></td>
</tr>
<tr>
<td>Duration</td>
<td>0.055 sec</td>
<td>~0.081 sec</td>
<td>~0.028-0.041 sec</td>
<td>&lt;not available&gt;</td>
</tr>
<tr>
<td>Ultrasound</td>
<td>lots of tongue movement</td>
<td>lots of movement</td>
<td>lots of movement</td>
<td>less movement</td>
</tr>
<tr>
<td>Palatography</td>
<td>closure</td>
<td>closure</td>
<td>closure</td>
<td>no closure</td>
</tr>
</tbody>
</table>

4 Discussion and Conclusion

The results show that intervocalic [g] in Dàgáárè has a complex waveform, amplitude decrease, formant structure, a short duration, significant tongue movement, and closure. These features are strong tap-like features and suggest that Dàgáárè intervocalic velar [g] is not a velar fricative but a tap. Such a segment type has previously been unattested and predicted, moreover, to be impossible (Ladefoged 1990). Given cross-linguistic evidence that velar softening mostly results in palatalization (Halle 2005) and the charcoal stain on the participant’s velum and hard palate in the palatograms, we note however that the intervocalic velar in Dàgáárè could be a palatal tap, a sound which is also unattested but predicted to be possible.

Given that this study was based on data from a single native speaker of Dàgáárè,
future work should focus on a larger population sample of Dàgáárè speakers. Dàgáárè intervocalic velar [g] should also be compared with velar [g] in clusters and related segments in related languages, e.g. lenited velars in Dagbani (Hudu 2010).

Generally, this study has shown that Dàgáárè intervocalic [g] is not a fricative, but a velar tap or a palatal tap which are both previously unattested sounds. Based on these findings, Dàgáárè velar [g] requires further investigation.

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References