An Acoustic Study of Bininj Gun-Wok Medial Stop Consonants

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ABSTRACT

It has previously shown that there is a clear duration difference between the long and short stop series in Bininj Gun-Wok, a language spoken in Northern Australia. Previously these have been phonologically labeled *lenis* and *fortis*. This investigation looks at some non-durational phonetic correlates of the contrast between *lenis* and *fortis* consonants. H1-H2, H1-A2 and H1-A3 measurements were made using acoustic recordings and the closed quotient (CQ) was measured using an electroglottograph. Voice quality was not found to be a consistent cue to a contrast.

Keywords: Australian, acoustic geminate, consonant.

1. BACKGROUND

Bininj Gun-Wok (henceforth BGW) is a Non-Pama-Nyungan Language spoken in the western part of Arnhem Land in the Northern Territory of Australia. The contrastive stop series it displays makes it distinct from the majority of Australian languages. It has been argued this is in fact a gemination effect [1].

The phonemic inventory of BGW is shown in Table 1. [2]. There are paired oral and nasal stops at five places of articulation. The *fortis* oral stops and the glottal stop have a restricted distribution with the former only appearing in a word medial intervocalic position and the glottal stop in a syllable final position.

Table 1: BGW consonant phoneme inventory.

	bilab.	vel.	alv.	retroflex	lamio-palatal	glottal
lenis	p	k	t	ʈ	c	ʔ
fortis	pː	kː	tː	ʈː	cː	
nasal	m	ŋ	n	ɳ	ɲ	
lateral			l	ɭ		
rhotic			r	ɹ (ɻ)		
glide	w				j	

1.1. Previous phonetic work

In BGW the medial durationally long stops are the subject of an unanswered question as to whether they are geminates or a class of *fortis* stop. The phonological labels *lenis* and *fortis* are not well defined with respect to their phonetic correlates. Ladefoged and Maddieson, [3] suggest that *fortis* is either an indicator of increased respiratory energy, or that *fortis* is an indicator of greater articulatory energy, relative to its *lenis* counterpart. They maintain that the use of increased respiratory energy is relatively rare, occurring, for example in Korean stiff voice – where a heightened sub-glottal pressure accompanies the more constricted glottis and tenser walls of the vocal tract. Cho, Jun and Ladefoged [4] have investigated some of the phonetic correlates (both acoustic and aerodynamic) of Korean. On the basis of this and other studies, Korean tense stops are described as a true *fortis* stops. Arvaniti and Tserdanelis [5] have detailed non-durational phonetic correlates of Cypriot Greek geminates. Both of these studies make use of spectral analysis of acoustic signals to infer voice quality.

Butcher [6] [7], has conducted instrumental studies with speakers of various Australian Languages including Kunwinjku (a dialect of BGW), which shows the most consistent cue to the contrast as the duration of the articulatory stricture, rather than voice onset time (VOT). Butcher observes that in some languages related to BGW (such as Burarra), the *fortis* (long) stop requires the glottis to be abducted simultaneously with closure of the supraglottal articulators, and then adduction of the glottis has to be co-incident with the release of the articulators at the end of the closure phase [6]. Intra-oral pressure in Burrara is higher in *fortis* stops and lower for the related *lenis* stops. There are various ways that an intra-oral pressure opposition may be realised. Either a particular target pressure for each contrasting stop is aimed for, maintained by either varying pulmonic pressure or glottal area. It is also possible, however, that glottal area and pulmonic pressure are equivalent in each of the contrasting phonemes, and the differences in intra-oral pressure are due to differences in the closure duration (articulatory stricture).

On the basis of this experimental work, Butcher has applied the labels *fortis* vs. *lenis* to describe the phonological contrast in some other Gunwinyguan and Burarran languages. We have provisionally used these terms to describe the phonological status of the stop series contrast in BGW although a revision of this terminology based on further experimental results is possible.

2. METHODS

2.1. Data acquisition and speakers

2.1.1. Speakers

In the current study five speakers, four female and one male of a dialect of BGW (Kunwinjku) were recorded under field conditions at Mamardawerre, an outstation of Kunbarllanjnja (formerly Oenpelli) in the Northern Territory of Australia.

2.1.2. Word lists

The experiment consisted of 5 pairs of words (*fortis* and *lenis*) at the bilabial and velar place of articulation (POA). Bilabial: *balabbala, ngabbard, kubbunj, kabbal, kebberelh* and *aba, bibom, bobo, kabo, yabok,*. Velar: *makka, bekkan, bukkan, kakkak, yekke, kakan, kokok, rakalk.*

The test-words were embedded in the carrier phrase: [yun yime _____ yimen _____] 'don't say _____ say _____'. The first token of the pair was measured to control for higher prosodic interference.

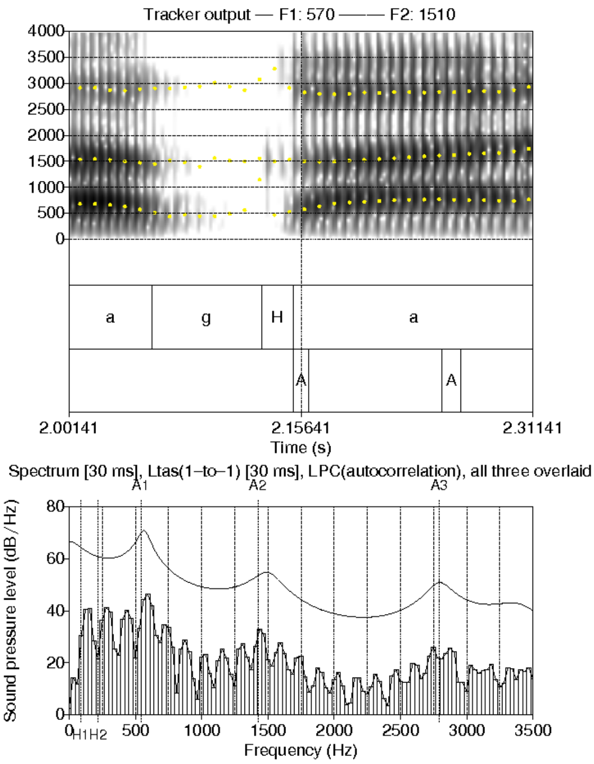
2.1.3. Acoustic recordings

All acoustic recordings were recorded, using a Sony ECM-MS957 Electret Condenser microphone and recorded onto a Marantz PMD690 Portable Flash recorder, as stereo, uncompressed Broadcast WAV files at 48 kHz 16 bit (The highest setting the hardware would allow). These were then labeled in Praat [8] and imported into the Emu Speech Database [9]. And analysed using a modified script [10] in Praat and EMU/R.

2.2. Measurements

H1-H2, H1-A2 and H1-A3 (sometimes referred to as H1-F3) were measured at the onset and midpoint of the vowel following the target consonant, as shown in figure 1 below.

Figure 1: Measurement at the onset of the vowel following the target consonant.



By analysis of the spectral qualities of a vowel it is possible to infer the voice quality of the preceding consonant. H1-H2 is said to be a measure of the open quotient (OQ), the ratio of the open phase of the glottal cycle to the total period [11]. It has previously been used as an acoustic measure to distinguish between breathy and modal voice. In modal voice there is a similar value for both the first and second harmonic whereas in creaky (or pressed) voice the second harmonic has a higher value than the first. Creaky voice is distinguished from breathy and modal voice by high adductive tension and little longitudinal tension in the vocal folds [12] [13]. During creaky voice, the vocal folds are only opened very slightly, resulting in irregularly spaced glottal pulses. H1-A2 (close to F2) measures spectral slope and H1-A3 measures spectral tilt.

3. RESULTS

3.1.1. Durational results

Previous work by has shown that there is a duration difference between *lenis* and *fortis* stops. There is also no measurable correlation between length of the vowel either preceding or following the target consonant. No further discussion of duration will be undertaken in the current study.

3.1.2. Analysis

The following figures (2-7) chart the average values of all the target consonants. The plot shows the values plotted at the onset and the midpoint of the vowel. Only H1-H2 at the bilabial place of articulation shows a significant difference between the *lenis* and *fortis* consonants when averaged for all speakers (see figure 2). The low values for H1-H2 indicate significant levels of creak in the vowel following the target consonant. The bilabial data show no differences in voice quality when measured in this way. In the following figures the *fortis* consonants are shown with diamonds and the *lenis* series with triangles.

Figure 2: H1-H2 Bilabial place of articulation**.**

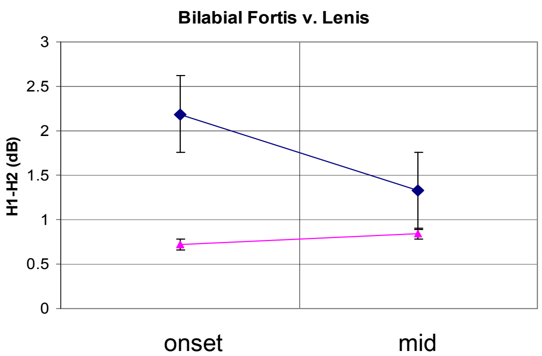


Figure 3: H1-A2 Bilabial POA**.**

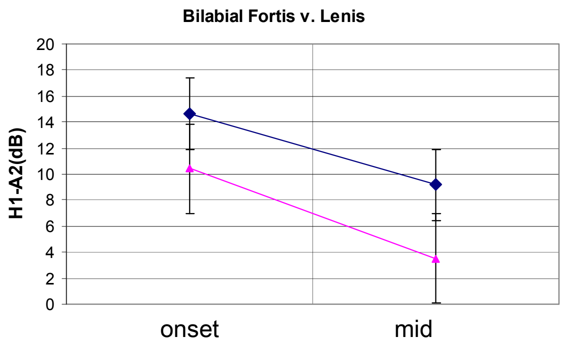
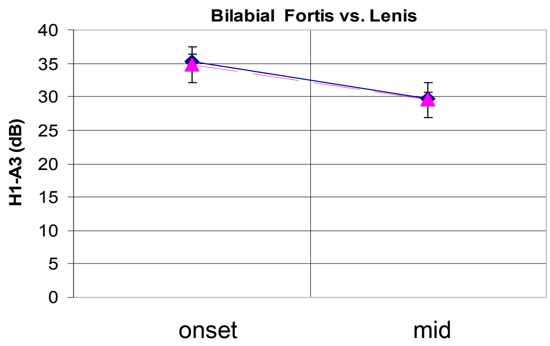


Figure 4: H1-A3 Bilabial POA



The velar place of articulation shows that the H1-H2 values are similar in scale to those at the bilabial place of articulation.

Figure 5: H1-H2 Velar POA.

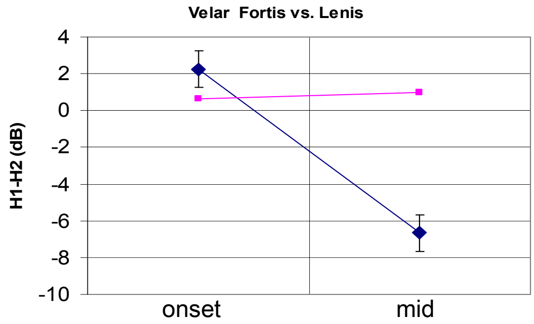


Figure 6: H1-A2 Bilabial POA.

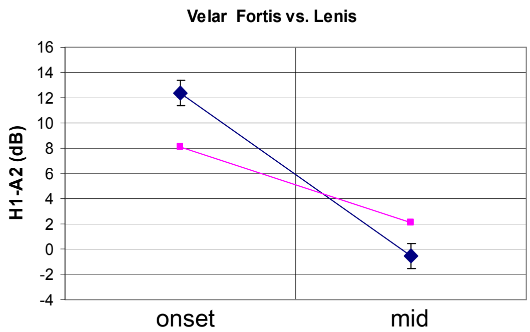
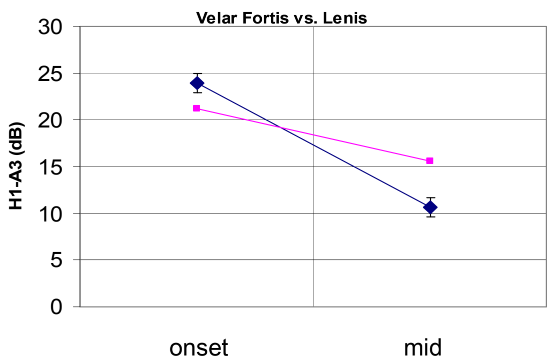


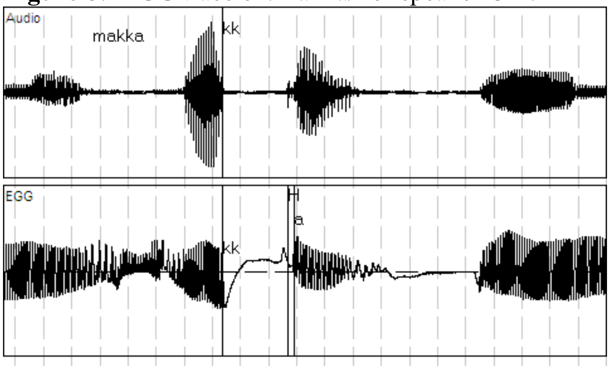
Figure 7: H1-A3 Velar POA.



3.1.3. Electroglottograph Results.

Using an electroglottograph (EGG) it was possible to measure the closed quotient (CQ) of the preceding and following vowel. When the CQ approaches 1 (> 0.5) the glottis is in hyperadduction when the CQ approaches (< 0.5) the glottis is hypoadducted. In the word illustrated in figure 2, the preceding vowel is hypoadducted (CQ = 0.28) and the following vowel is hyperadducted (CQ = 0.68).

Figure 8: EGG trace of /makka/ for speaker CM.



Future work will correlate this aerodynamic data with the acoustic measurements already taken.

4. DISCUSSION

Based on this study the voice quality of the vowel is affected marginally by the preceding medial consonant. However this is only shown in the H1-H2 values and is not echoed in the other measurements. Esposito [12] has shown that there is a difference in strategy for attaining voice quality in vowels between males and females in Zapotec. It is possible that this may also be the case in BGW. If so, the data must be able to be reanalysed separating by sex of speaker which due to the paucity of appropriate data, was not possible in the current study. Further investigation is required however, as more data needs to be gathered. The logical next step for investigations into BGW consonants is to carry out similar measurements for heterorganic clusters to investigate if these clusters pattern in the same manner as homorganic clusters.

5. REFERENCES

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