Màdá Stop Consonants: An Instrumental Study

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Abstract

This paper is an acoustic phonetic study of the stop consonants in Màdá, a Central Nigerian language spoken in Nasarawa state of Nigeria. The analysis contained in this work is based on an annotated audio corpus of digital recordings from two adult male speakers. The digital recordings were made with an Edirol r-09 digital recorder at a sample rate of 44.1KHz, 24 bit wav files in either mono or stereo quality and saved as .wav files in Praat. The study aims to describe the phonetic facts of Màdá stop consonants and to illustrate the types of contrasts which distinguish them from one another. The paper investigated two major cues for stop consonants, the burst of the stop release and the formant transitions in the adjacent vowel.

The study investigated place and voicing contrasts of Màdá stop consonants. In order to examine the place contrast of the stop consonants, the release burst and the transition of F2 were checked. In an attempt to authenticate the place for velar stops, F3 was examined. To investigate the voicing contrast of Màdá stop consonants, the release burst and the transition of F1 were compared. Comparisons between voicing durations show that voiced stops have longer durations than their voiceless counterparts. Altogether, the study indicated that the voiceless stop release bursts were brief; voiced stops had F1 transition while voiceless stops did not have.

Introduction

The Màdá language is a tone language because it uses tone contrastively on lexical items. Màdá belongs to Plateau language group of Benue-Congo language family (Greenberg, 1963). Plateau language group is further classified as Platoid (Williamson, 1989; Ohiri-Aniche, 1999) and Central Nigerian (Williamson and Blench, 2000). Màdá is the language of the Màdá people. It is spoken specifically in Nigeria. According to one of my consultants, Dr. Emmanuel Dandaura, the Màdá people are mostly located in the north-central part of Nigeria. They are principally found in Nasarawa state.

This research work aims to describe the acoustic structure of Màdá stop consonants. Stops are a class of speech sounds whose characteristic feature is an interval during which the breath stream is completely blocked within the oral cavity (see Abramson and Lisker 1965; Ladefoged 2006; Crystal 2008). The articulation of the blockage necessarily entails three phases: the bringing together of the articulators to form the blockage ('closing phase'), the time during which the blockage is in place ('closure') and the release of the closure ('release phase').

Màdá, just like many other Nigerian languages, has a two-way voicing contrast in plosive stops. In this study, the acoustic properties of the place contrasts of stops in Màdá are considered. It has been observed from studies of the acoustics of stop place contrasts, and also of stop consonant perception that burst spectra and formant transitions are two major acoustic properties of stop place contrasts (See Liberman, Delattre and Cooper 1952; Delattre, Liberman and Cooper 1955; Stevens and Blumstein 1978; Blumstein and Stevens 1979; Pickett 1980; Kewley-Port 1983a, b; for example). The three phonological place categories of stop consonants in Màdá are bilabial, alveolar and velar.

Two adult male native Màdá speakers were asked to read frame sentences. The main wordlist consisted of 8 words - par 'spear', bar 'to touch', ta 'to throw', da 'cutlass', kon 'corpse', gon 'tree', kpa 'roof', gba 'cock'. This list was designed to illustrate Màdá stop consonant place and voicing contrasts. The data were recorded digitally with an Edirol r-09 and transferred onto a laptop computer. The digital recordings were made at a sample rate of 44.1KHz, 24 bit wav files in either mono or stereo quality. The data were converted to .wav files and saved in Praat. The sound recordings were analysed using a computer software package – Praat version 5.1.25 developed by Paul Boersma and David Weenink (www.praat.org). Praat software package allows imaging and editing of acoustic data.

Annotations were conducted using the Praat script. Formants and frequencies of the speech sounds were measured. Formants were checked on wideband spectrograms. The rest of the paper is organized as follows: Section two reviews previous works on the acoustics of stop consonants as well as works on Màdá phonology. Section three presents burst spectra analysis. Section four looks at inferences from formant transitions. Section five is on summary and conclusion.

Review of Related Literature

Blumstein (1986), comparing the burst spectra of velar and palatal stops in Hungarian, established that the spectra of palatal stops share the 'compact' property with velar stops, in the same way that the bilabial and alveolar stops share the property 'flat' or 'diffuse'. She established further that the peaks in palatal and velar stop bursts both vary "as a function of place of articulation and vowel context". Her results suggest that the peaks in velar burst spectra are generally lower in frequency than those for palatals in similar phonetic contexts, and that velars and palatals pattern differently with respect to front and back vowels (Blumstein 1986:183). Keating and Lahiri (1993) found that the spectra of palatal bursts had a high-frequency emphasis, in the region of F4 of the following vowel (Watkins 2000:76).

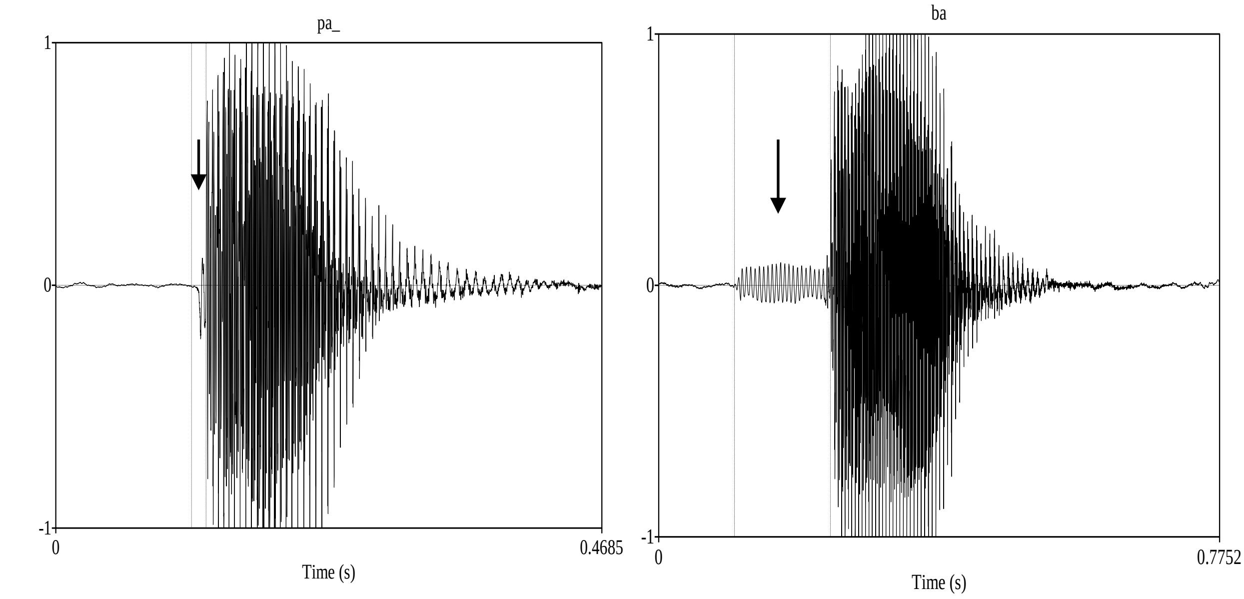
Dutta (2009) is an acoustic phonetic study of the four stops types in Hindi; namely the voiced stops (VS), voiced aspirated stops (VAS), voiceless and voiceless aspirated stops. It can be inferred from the study that the "Standard View" on the distinction between VS and VAS proposes that the VAS are VS with a breathy release and this feature is sufficient to make the contrast between the VS and VAS. Evidence from duration of voicing, effect of manner of articulation on the fundamental frequency (f0) of the following vowel, durational properties of stop closure and aspiration suggests the contrary. Both VAS and VS are known to lower f0 of the following vowel. VAS lower f0 even further. This study shows that f0 perturbations are reliable acoustic cues for stop identification and demonstrates the extent of this effect in the vowel. Spectral intensity analysis of the breathy release following VAS tests the assumptions of the standard view. Four measures of spectral intensity of the vowel following the stops indicate that the breathiness following the VAS persists for a long duration. Comparisons between durations of breathiness and aspiration show that aspiration is shorter in duration than breathiness.

Price (1989) is an outstanding work on Màdá phonology. Price identifies thirty seven phonemes in Màdá. These comprise twenty four consonants and thirteen vowels. The consonants are plosives /p b t d k ɡ kp ɡb/; nasals /m n ŋ /; fricatives /f v s z ʃ h/; affricates /ts tʃ dʒ/; trill /r/; lateral /l/ and approximants /j w/. Màdá vowels are divided into oral and nasalized. While the oral vowels are eight, the nasalized vowels are five. The oral vowels are as follows: /i e ɛ a ə u o ɔ/; the nasalized vowels are /ĩ ɛ̃ ã ũ ɔ̃/. Hannatu, Oluwatomi and Yayock's (2009) study of Màdá phonology is a confirmation of Price's (1989) work.

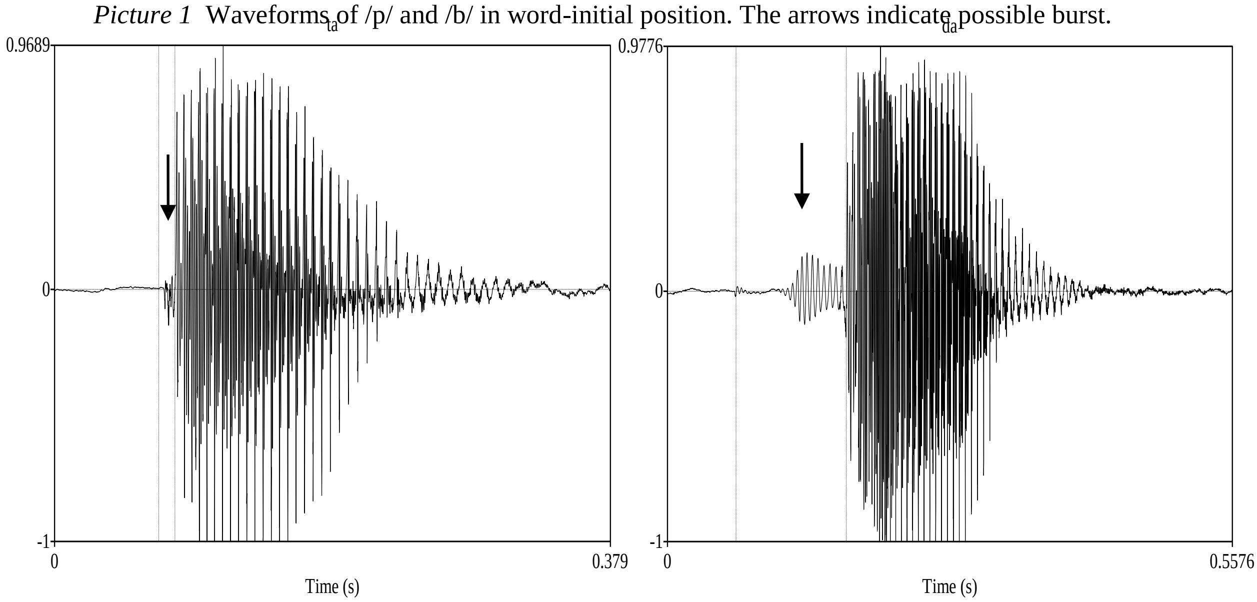
Saleh's (2007) work on Màdá phonology reveals the phonological interference of native Màdá learners of English. The study indicates that the English monophthongs /æ ɜ ɑ ʌ ə/, which do not exist in Màdá phonemic inventory pose some problems to Màdá learners of English. Almost all the English diphthongs do not occur in Màdá. This results in phoneme substitution. Few linguistic works have been done on the Màdá language but not nearly as much attention has been devoted to the instrumental phonetics of this language. In fact, to the best of my knowledge, nothing has been done on the phonetics of this language. This study, therefore, is an attempt to investigate the acoustic aspect of Màdá phonetics.

Burst Spectra

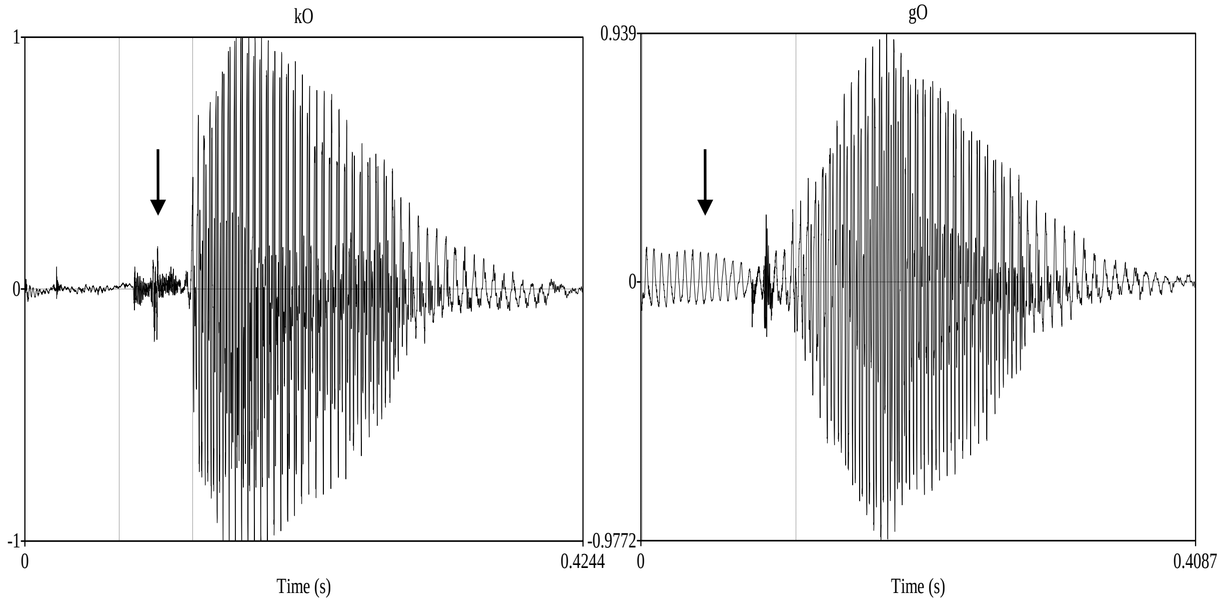
The burst spectrum, according to Watkins (2000:76), "is the acoustic footprint of the sound pressure pulse which accompanies the release of the oral articulators, and as such is a transient with a flat spectrum". This sound is shaped by the resonant qualities of the vocal tract in front of the closure, which are determined by place of articulation. Spectral 'templates' are described as 'flat and falling' for bilabials, 'flat and rising' for alveolars and 'compact with a mid-frequency peak' for velars. These templates have some basis in acoustic theory (Johnson 1997:134). Waveforms of Màdá stop consonants and possible bursts are presented below.



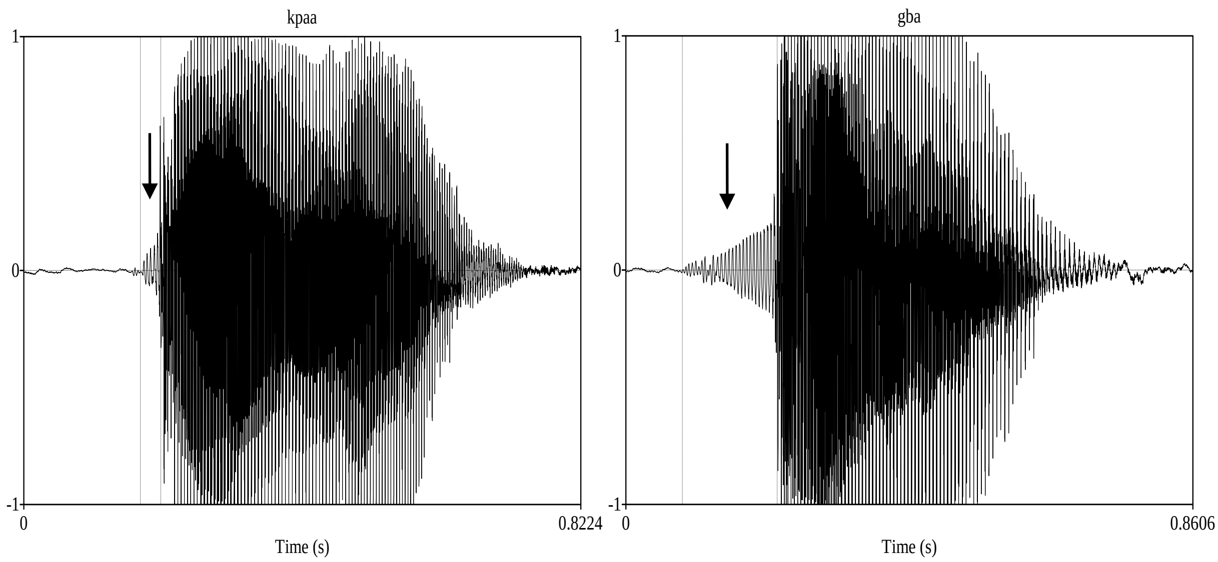
Picture 1 Waveforms of /p/ and /b/ in word-initial position. The arrows indicate possible burst.



Picture 2 Waveforms of /t/ and /d/ in word-initial position. The arrows indicate possible burst.



Picture 3 Waveforms of /k/ and /ɡ/ in word-initial position. The arrows indicate possible burst.



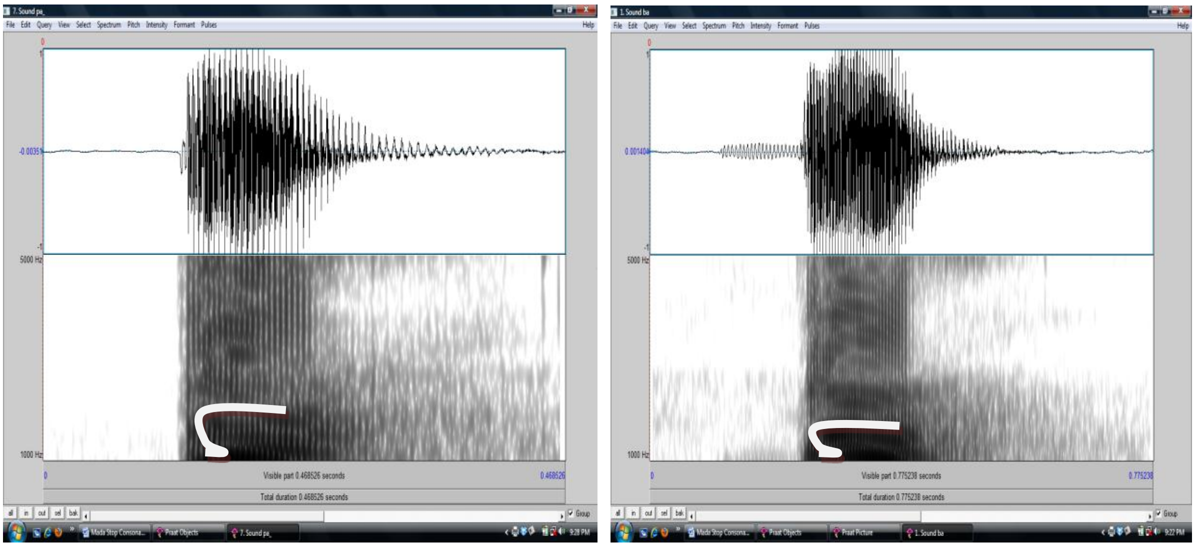
Picture 4 Waveforms of /kp/ and /ɡb/ in word-initial position. The arrows indicate possible burst.

Durations of the stop consonants in pictures 1-4 are as follows: /p/ 10ms, /b/ 36ms, /t/ 12ms, /d/ 41ms, /k/ 25ms, /ɡ/ 54ms, /kp/15 ms, /ɡb/ 38ms. It can be averred from pictures1-4 that the voiceless stop release bursts are brief, lasting only 10 to 25ms while voiced stops have very long durations. /ɡ/ has the longest burst. This is because stops that are made further back in the mouth usually have longer VOT (see Byrd 1993, Ladefoged 2003).

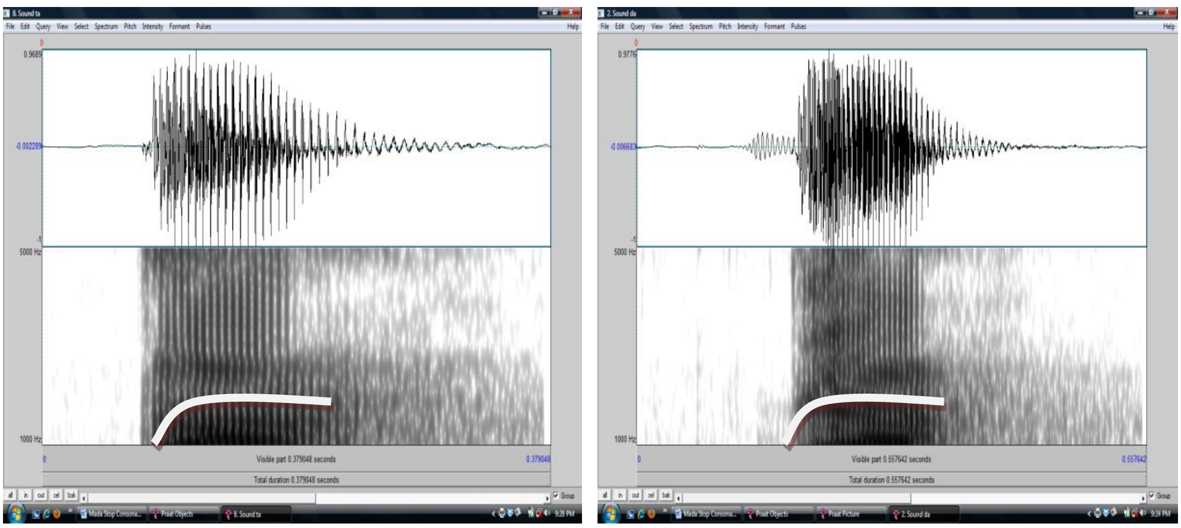
Formant Transitions

Formant transitions are a classic illustration of the overlapping of acoustic encoding of phonological information: although located in the syllable peak, they provide important information about adjacent consonants. The formant movements reflect the rapid shift of articulatory position from consonant to vowel, in which the tract changes its consonant constriction shape to become an unobstructed resonant system, often creating rapid resonance changes during the process (Clark, Yallop and Fletcher 2007:281).

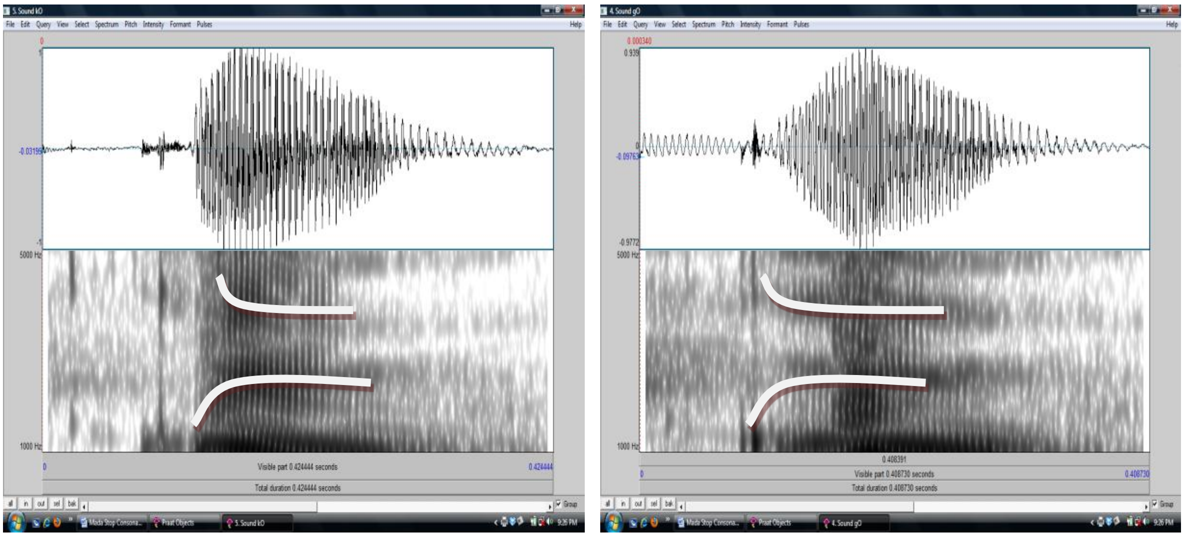
The shape of the vocal tract changes as the articulators move to form the stop obstruction, causing the formant resonances to shift towards a certain point, known as the locus frequency. Ladefoged (2006: 191) calls this apparent point of origin of the formant for each place of articulation "the locus of that place of articulation". This point is never actually reached, since actual formation of the closure cuts off the acoustic coupling between the front and back cavities, changing the resonant characteristics of the vocal tract completely (Johnson 1997:136). Waveforms and spectrograms of Màdá stop consonants are presented below.



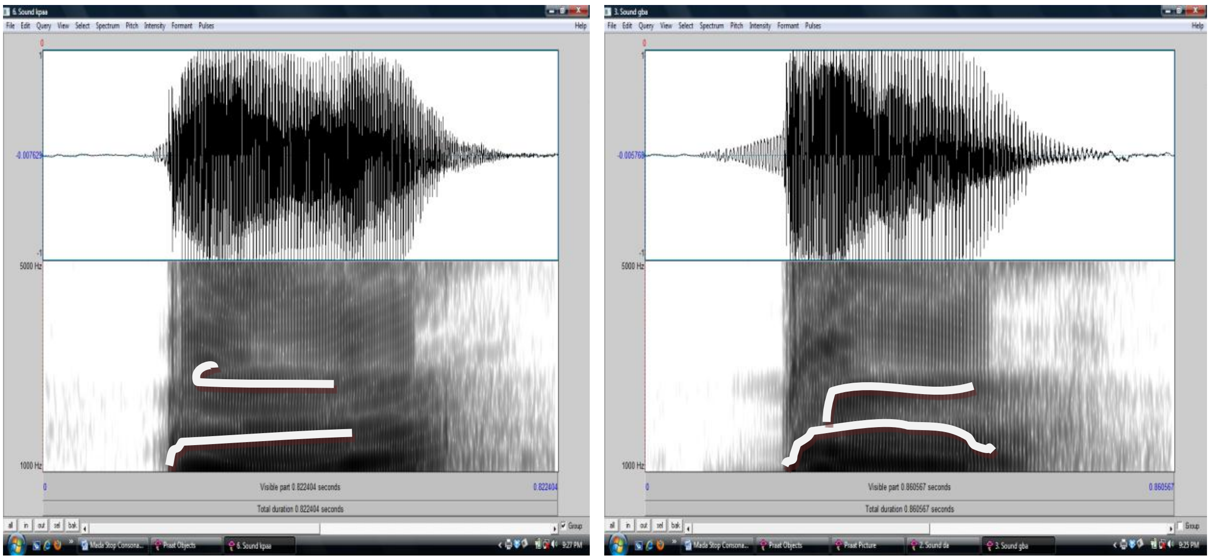
Picture 5 Waveforms and spectrograms (150Hz bandwidth) of par 'spear' and bar 'to touch' with second formant transitions highlighted.



Picture 6 Waveforms and spectrograms (150Hz bandwidth) of ta 'to throw' and da 'cutlass' with second formant transitions highlighted.



Picture 7 Waveforms and spectrograms (150Hz bandwidth) of kon 'corpse' and gon 'tree' with second and third formant transitions highlighted.



Picture 8 Waveforms and spectrograms (150Hz bandwidth) of kpa 'roof' and gba 'cock' with second and third formant transitions highlighted.

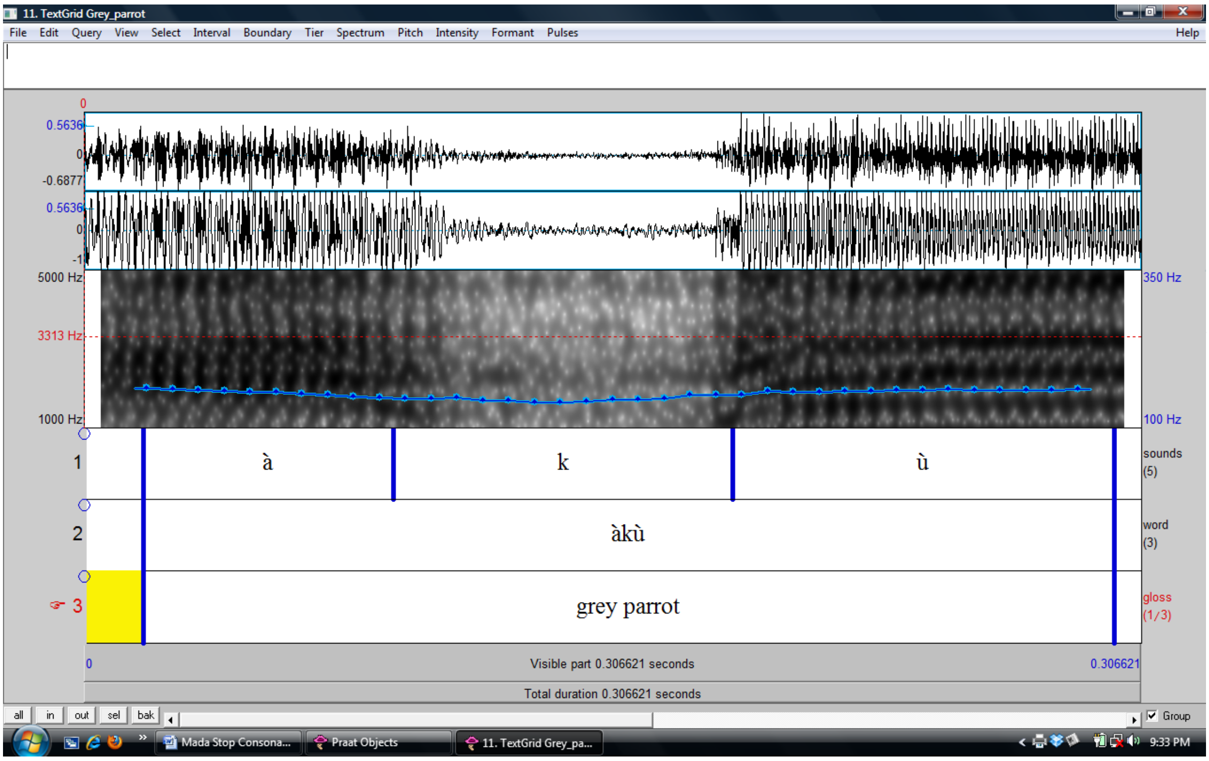
Picture 5 shows that the bilabial stops [p b] have the characteristically downward-pointing formant transitions expected with bilabials. It is also observed that the F2 transitions associated with [p] in picture 5 are very similar to those associated with [b]. This reflects the fact that the movement of the lips is similar for the two consonants. The alveolar stops [t d] in picture 6 also have downward-pointing formant transitions but not forming contours like those in bilabials.

Alveolar and velar stop consonants have similar F2 transitions; so an additional measurement was made of F3 transition in order to differentiate velar stop consonants from alveolars. The F2 and F3 transitions in picture 7 both form a wedge-shape, found to be characteristic of velars (Stevens & Blumstein 1978). Pictures 5-8 indicate that when there was an F1 transition, a voiced stop was heard and when there was no F1 transition, a voiceless stop tended to be heard (Cooper, Delattre, Liberman, Borst and Gerstman 1952). The production of labiovelar plosives [kp gb] involves a combination of three articulators, the lips and the velum. The impression of the author from looking at the labiovelars is that these stops may have formant transitions similar to labials and velars but further acoustic experimentation is necessary to determine how consistent this is.

F2 frequency values

/b/	1581Hz
/p/	1661Hz
/t/	1806Hz
/d/	1924Hz
/k/	2386Hz
/g/	2597Hz
/kp/	2030Hz
/gb/	3099Hz

The above measurements infer that with velar stop consonants F2 would rise in frequency while for labials and alveolars F2 frequency would fall. It will be seen that [k g kp gb] have strong energy which is located in a range above 2000Hz.



Picture 9: A segmented and labelled Màdá word, *àkù* 'grey parrot'.

Picture 9 is a textgrid of the annotated word, *àkù* 'grey parrot'. The word was recorded in stereo quality, which could be seen from the waveform. The pitch track of the word illustrates that the vowels are realized on low tones. Acoustically, stops are very easy to identify because they are characterized by silence. This is the case with [k] in the textgrid above; there is an empty patch of the spectrogram for [k] in picture 9 above.

Summary and Conclusion

This study observed in line with Pickett (1980), that voiceless stop consonants are accompanied by a release burst of noise during the transition between the opening of the closure and the point at which the voicing of the vowel begins. The duration of occlusion is usually slightly longer for voiced stops than voiceless stops. The distinction between places of stop articulation is simply indicated by the direction of F2 transition. It was observed that the F2 transition of alveolar and velar stop consonants were similar; so F3 was checked. The F3 transition, which is divergent from F2 transition, becomes a distinguishing factor between alveolar and velar places. Voiced stops have F1 transition which is missing in voiceless stops.

References

Abramson, Arthur S. and Leigh Lisker. (1965). Voice Onset Time in Stop Consonants: Acoustic Analysis and Synthesis. Retrieved October 5, 2011 from *www.haskins.yale.edu/Reprints/HL0134.pdf*

Blumstein, Sheila E. (1986). On Acoustic Invariance in Speech. In Joseph S. Perkell and Dennis H. Klatt (eds.). *Invariance and Variability in Speech Processes*. Pp. 178-193.

Blumstein, Sheila E. and Kenneth N. Stevens. (1979). Acoustic Invariance in Speech Production: Evidence from Measurements of the Acoustic Characteristics of Stop Consonants. *Journal of the Acoustical Society of America.* Vol. 66, pp. 1001-1017.

Boersma, Paul and David Weenink. (2010). Praat: Doing phonetics by computer (version 5.1.25) [computer program]. Retrieved March 31, 2010 from *http://www.praat.org/*

Byrd, Dani. (1993). 54,000 Stops. *UCLA Working Papers in Phonetics*. Vol. 83, pp. 97-115.

Clark, John, Colin Yallop and Janet Fletcher. (2007). *Introduction to Phonetics and Phonology (3rd edition).* London: Blackwell.

Cooper, W.E, P.C. Delattre, A.M. Liberman, J.M. Borst and L.J. Gerstman. (1952). Some Experiments on the Perception of Synthetic Speech Sounds. *Journal of Acoustical Society of America.* Vol. 24 pp. 597-606.

Crystal, David. (2008). *A Dictionary of Linguistics and Phonetics (6th edition).* Oxford: Blackwell Publishing.

Delattre, Pierre C., Alvin M. Liberman and Franklin S. Cooper. (1955). Acoustic Loci and Transitional Cues for Consonants. *Journal of the Acoustical Society of America.* Vol. 27, pp. 769-773.

Dutta, Indranil. 2009. *Acoustics of Stop Consonants in Hindi*. Leipzig: VDM Verlag.

Greenberg, J.H. (1963). *The Languages of Africa.* The Hague: Mouton.

Hannatu, Joseph, Alfred Oluwatomi and Justina Yayock. 2009. Aspects of Màdá grammar. A B.A. Project Submitted to the Department of Linguistics, Nasarawa State University, Keffi, Nigeria.

Johnson, Keith. (1997). *Acoustic and Auditory Phonetics*. Oxford: Blackwell.

Keating, Patricia A. and Aditi Lahiri. (1993). Fronted Velars, Palatalised Velars and Palatals. *Phonetica.* Vol. 50, pp. 73-101.

Kewley-Port, Diane. (1983a). Measurement of Formant Transitions in Naturally Produced Stop Consonant-Vowel Sequences. *Journal of the Acoustical Society of America*. Vol. 72, pp. 379-389.

Kewley-Port, Diane. (1983b). Time-Varying Features as Correlates of Place of Articulation in Stop Consonants. *Journal of the Acoustical Society of America*. Vol. 73, pp. 322-335.

Ladefoged, Peter. (2003). *Phonetic Data Analysis.* Oxford: Blackwell Publishing.

Ladefoged, Peter. (2006). *A Course in Phonetics (5th edition).* Boston: Wadsworth Cengage Learning.

Liberman, Alvin M., Delattre, Pierre C. and Franklin S. Cooper. (1952). The Role of Selected Stimulus Variables in the Perception of Unvoiced Stop Consonants. *American Journal of Psychology*. Vol. 65, pp. 497-516.

Ohiri-Aniche, Chinyere. (1999). Language Diversification in the Akoko Area of Western Nigeria. In Roger M. Blench and Matthew Spriggs (eds.) *Archaeology and Language IV. Language Change and Cultural Transformation.* One World Archaeology, vol. 4, pp. 79‑94. London: Routledge.

Pickett, J.M. (1980). *The Sounds of Speech Communication: A Primer of Acoustic Phonetics and Speech Perception.* Baltimore: University Park Press.

Price, N. 1989. *Notes on Màdá phonology*. Language Data, Africa Series, 23. Dallas: SIL.

Saleh, Aria J. (2007). Phonological Interference Experienced by Màdá Students Learning English as a Second Language. An M.Ed Thesis Submitted to the Department of Foundations, Arts and Social Science Education, University of Abuja, Nigeria.

Stevens, Kenneth N. and Sheila E. Blumstein. (1978). Invariant Cues for the Place of Articulation in Consonants. *Journal of the Acoustical Society of America.* Vol. 64, pp. 1358-1368.

Watkins, Justin. (2000). The Phonetics of Wa. A Doctoral Dissertation Submitted to the Department of South East Asia, School of Oriental and African Studies, University of London.

Williamson, Kay. (1989). Benue-Congo Overview. In John Bendor-Samuel and Rhonda L. Hartell (eds.). *The Niger-Congo Languages*. Lanham: University Press of America.

Williamson, Kay and Roger M. Blench. (2000). Niger-Congo. In Bernd Heine and Derek Nurse (eds.). *African Languages: An Introduction*. Cambridge: Cambridge University Press. Pp. 11‑42.