Kabyle "Double" Consonants: Long or Strong?*

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SUMMARY

This paper describes the results of an acoustic experiment designed to test the properties of Kabyle Berber's "double" consonants. There is a debate in the literature as to whether these "double" consonants should be analyzed as geminate, long or fortis consonants. I outline the acoustic predictions which each of these labels entail, then measure the acoustic properties of a series of Kabyle words containing both singleton and "double" consonants. Based on the results of the experiment, I conclude that the label "fortis" is the most appropriate for Kabyle "double" consonants.

RESUME

Cet article décrit les résultats d'une expérience acoustique qui porte sur les les propriétés des consonnes "doubles" du Berbère Kabyle. Il existe un débat dans la littérature sur la status de ces consonnes "doubles": doivent-elles être analysées comme des consonnes géminées, longues ou tendues? J'énumère les prédictions acoustiques que chacun de ces termes impliquent, puis je mesure les propriétés acoustiques d'une série de mots kabyles contenant des consonnes simples et "doubles". Suivant les résultats de l'expérience, je conclus que le terme "tendu" est le plus appropriée pour les consonnes kabyle "doubles".

1 INTRODUCTION

A salient feature of the phonology of all Berber dialects, including Kabyle, is the presence of a series of “double” consonants. A majority of consonants can be “doubled”, and they can appear in any position in the word. Most analyses consider these “double” consonants to be fundamentally distinguished by the *length* of the consonant in question, and claim that there is a phonological opposition between long and short consonants in Kabyle. Another school of thought holds that it is

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actually the parameter of *articulatory strength* which sets them apart, and that the phonological opposition is between fortis and lenis consonants. The claim that they are fortis consonants makes certain predictions about their acoustic and articulatory properties beyond simply having increased length, such as increased amplitude of the release burst and a reduction in length of the preceding vowel. I recorded a series of nonce words produced by our native Kabyle consultant, Karima Ouazar, containing minimal pairs for plain and “double” consonants. Based on my acoustic measurements and arguments from the phonological behavior of these “double” consonants, I conclude that fortis/lenis is a more appropriate name for the opposition than long/short.

2 STRUCTURE OF PAPER

The organization of my paper will proceed as follows: in section 3 I will provide a review of other work done on the subject of Berber "double" consonants. Then, in section 4 I will review the previous uses and theoretical perspectives on several commonly used labels in phonology: geminate, long/short, fortis/lenis, tense/lax. Once I have provided context for those terms and defined how I intend to use them, I will lay out a set of acoustic predictions made by using ‘long/short’ labels as opposed to the ‘fortis/lenis’ in section 5. In section 6, I will specify the experimental method by which I collected my data. Then, in section 7, I will summarize my acoustic data and compare it to the predictions made by the use of each label, settling on the one whose predictions are better borne out. Finally, in section 8, I will discuss shortcomings of my analysis, and ways in which comparative analysis of Berber varieties could lead to a different conclusion.

3 REVIEW OF PREVIOUS WORK

Early descriptions of Berber "double" consonants describe them as "long", as in André Basset's 1946 description of Berber phonology. The question of whether length is in fact the primary phonological parameter was first raised in 1953 by Lionel Galand in his article "La phonétique en dialectologie berbère," and from then on Galand maintained in a series of articles (in 1960, 1988, 1997) that the consonants should be referred to as "tendu" (tense), based on phonological arguments. His use of the word "tense" corresponds to what I term "fortis" in this paper. His stance was supported by a number of experimental papers, including an electropalatographical study by Mitchell (1957) which supported the idea that "double" consonants are produced with greater articulatory force, translating into a greater area of contact between the tongue and palate.

However, most authors are of the opinion that it is fundamentally length which is distinctive, and not any other parameter. Chaker (1975) investigated the problem with acoustic measurements, and furthermore he dealt with Kabyle, the same variety under consideration in this paper. He concluded that length is the primary parameter, but that the acoustic distinction is enhanced by secondary correlates which are typical of "tension". Louali and Puech (1994) did an acoustic, articulatory and perceptual study of "double" consonants in two non-spirantizing dialects of Berber and found that length is the primary correlate. As for other acoustic correlates, they found that "double" stops have higher VOT (but not for all places of articulation), shorten the preceding vowel, and can be partially or completely devoiced. Ridouane (2007) investigated "double" consonants in Tashlhiyt, a non-spirantizing dialect. He found that length is the primary correlate, and the additional correlates he identified are a larger release burst, a shorter preceding vowel, and devoicing of voiced "double" consonants. Louali and Maddieson (1999) carried out a survey of the length of stops in eight Berber dialects, in which four were non-spirantizing, three were spirantizing, and one was assibilating (in which /t d/ become [s z], not [θ ð]). They found that the "double" stops are held for about twice the length of simple stops, even in dialects where simple stops became corresponding fricatives. From this, they conclude that length is the primary phonological parameter, even in spirantizing dialects, although they acknowledge that there are other acoustic differences between simple and "double" stops which they did not seek to measure, and which may contribute to their perception.

4 DEFINITIONS AND THEORETICAL BACKGROUND

Theoretical approaches to phonological length propose multiple processes by which a consonant can end up with increased length. The terminology used in this area is confusing and frequently contradictory, so I will review some concepts and terms which arise in the literature on Kabyle before specifying the meanings with which I intend to use each term.

4.1 GEMINATE VS. LONG

Using the terminology of Chomsky and Halle (1968), a distinction can be made between a sequence of two identical short segments, and a single segment with the feature [+long]. The first kind exists in English, for instance the long [n:] in the English word "penknife", while the second does not exist in English but can be found in Finnish or in Italian, for example. Both of these types of consonants have been referred to as "long" and "geminate" in the literature, and authors often switch between the terms as though they were completely interchangeable. For the sake of clarity and thoroughness, I will henceforth use the term **LONG** to entail a claim that it is a single segment carrying the feature [+long], while a **SHORT** consonant means a single segment carrying the feature [-long]. I will use the term **GEMINATE** only to mean a sequence of two identical short segments.

These differing representations carry with them an overlapping but different set of predictions regarding phonological behavior and phonetic production. Acoustically, the main correlates of both length and gemination are straightforward: there is always an increase in consonant duration, and almost always a reduction in the length of the preceding vowel. However, there are also differences between the two, which can be empirically verified to decide which is more appropriate.

Since a geminate is composed of two segments, it would be expected to pattern phonologically as a consonant cluster. The segments should also be separable, in that one of the segments could undergo a phonological process without its neighbor being affected. When two short segments come into contact, for instance across a word boundary, the result should be indistinguishable from other examples of the geminate. If one can detect two peaks, either in the articulatory or acoustic data, that is a sure sign of a geminate; true long consonants will never show the slight pause between articulations that is sometimes visible in geminates.

On the other hand, a long consonant (non-geminate) is expected to phonologically pattern as a single consonant, not a cluster of two identical consonants. The consonant should participate in phonological processes as a unit and never show signs of being separable. Acoustically and articulatorily, there should never be two peaks indicating a slight pause between productions.

4.2 FORTIS/LENIS VS. TENSE/LAX

In some languages, the words "fortis" and "lenis" have been used to describe a phonological opposition between two series of consonants. The precise nature of the opposition varies in the literature. Some authors have used the term **FORTIS** to mean a consonant produced with greater respiratory energy, such as Korean stiff consonants. Most of the time, it is used to mean a consonant produced with greater articulatory energy, and it is with that meaning that I will use it. Greater articulatory energy is a somewhat vague phrase; it is used to mean that the consonant is produced with more muscular tension, the articulators come into stronger contact and the pressure achieved in the oral cavity is higher. The opposite of fortis is **LENIS**, which implies a lower level of articulatory energy in production.

The term **TENSE** was originally applied to vowels, but some authors have used the term in reference to consonants. When used to refer to consonants, there is no substantial difference between "fortis" and "tense"; in most of Lionel Galand's work on Berber, he refers to the "double" consonants as "tendu", meaning essentially the same thing as "fortis". I will take them as perfectly synonymous and use the word "fortis" henceforth, with **LAX** being the equivalent of lenis.

The acoustic correlates of fortis consonants are less clearly defined than those of long consonants; but we may take as a starting point both the descriptions given in Ladefoged's "The Sounds of the World's Languages" and a 2008 thesis by DiCanio which thoroughly reviews the concept of fortis-lenis (before concluding that the Otomanguean language Trique de San Martín Itunyoso does not in fact have such an opposition). Ladefoged and DiCanio, in summarizing the literature on consonant strength, state that typical fortis consonants have some or all of the following properties: a tendency to be voiceless, they have longer VOT than lenis consonants, a longer duration of closure and a shorter preceding vowel, a higher F0 upon release, they have a more prominent burst of air upon release, and no variation in closure, as opposed to lenis consonants which can alternate between complete and incomplete closure. Lenis consonants tend to be voiced; have shorter VOTs; have shorter duration of closure and longer vowels, lower F0 upon release, are accompanied by a smaller puff of air upon release, and can be variable in their degree of closure, alternating between stops and fricatives.

5 SUMMARY OF PREDICTIONS MADE

I am now in a position to formulate three hypotheses about the nature of Kabyle "double" consonants and some predictions they make.

5.1 GEMINATE

a) longer duration of consonant
b) shorter preceding vowel
c) patterns as a cluster of two identical segments

5.2 LONG

a) longer duration of consonant
b) shorter preceding vowel
c) patterns as a single segment

5.3 FORTIS

a) longer duration of consonant
b) shorter preceding vowel
c) patterns as single segment
d) tendency towards voicelessness

e) tendency towards complete closure with no variation in closure
f) longer VOT

Note that all three hypotheses predict that the "double" consonants will have longer duration and a shorter preceding vowel. The first two hypotheses differ only in the behavior of the segments with respect to phonological rules; geminates are expected to act as clusters of two identical segments, while long consonants are expected to pattern as a single segment. The final hypothesis contains a number of additional predictions, and whether or not these are borne out will be the interesting part of the experiment.

6 EXPERIMENTAL METHOD

The recording was carried out in a sound-proofed booth with a head-worn microphone plugged into my MacBook Air, and all acoustic analysis was carried out manually using Praat.

I created a list of nonce words which placed the target segments word-initially, intervocalically, and word-finally, always in the context of the surrounding vowel /a/. Therefore, to investigate the properties of the opposition between single and "double" /m/, the following set of nonce words was used: /ma - ama - am - mma - amma - amm/. The nonce words were embedded in the carrier phrase /____ d tuntˤiqt iʃebħen/ meaning "____ is a beautiful syllable" to ensure that word-initial consonants were also utterance-initial and to avoid list intonation. Karima read each nonce word embedded in its carrier phrase four times. For each token I recorded the following information (where applicable):

1) VOT in ms
2) Amplitude of release burst in dB
3) Incomplete closure recorded as yes/no (presence of frication)
4) Duration of consonant in ms
5) Duration of previous vowel in ms
6) Amplitude of following vowel in dB
7) Amplitude of consonant in dB

The phonemes for which I carried out the complete acoustic analysis are the following: /t d k g f z zˤ ʃ ʒ x ɣ r rˤ l n/. I collected a subset of the acoustic data for the phonemes: /b tˤ q s m w/ consisting of items 1-5.

7 RESULTS

The results of my acoustic analysis indicate that the label "fortis" is most appropriate for Kabyle's "double" consonants, as most of the predictions listed in section 5.3 were borne out. I found that, of the acoustic properties I measured, the following served to distinguish "double" consonants from simple ones:

- longer duration of consonant
- shorter preceding vowel
- complete closure
- devoicing
- large puff of air upon release

The phonemes fall into two main classes: ones which alternate between stops and fricatives, and ones which do not. I will present my results for each class of sounds separately, then I will consider my results as they relate to each of the hypotheses in section 5.3.

In the summary tables of acoustic data, all "Duration" and "Previous Vow" measurements are in milliseconds (ms), and are shown with their standard deviation in parentheses afterwards. All "Fricative Amp" and "Rel Burst" values are in decibels (dB).

7.1 STOP-FRICATIVE ALTERNANTS

Of the phonemes I elicited, the stops /b t d k g/ participated in variation between a fricative singleton realization and a stop "double" realization. The length of the preceding vowel is also reliable indicator; vowels are shortened before "double" consonants. Length is not as reliable an indicator; although the "double" stops are usually longer in duration than the singleton fricatives, this is not the case for the pair /ab - abb/. Note that length is conditioned on position in the syllable, with syllable-final consonants lengthened with respect to other positions. The amplitude of the following vowel was not found to be a good indicator.

Table 1: Summary of acoustic data for initial /b t d k g/

Word	Manner	Duration (SD)
ba	Fricative	195.25 (42.9)
bba	Stop	240.5 (35.2)
ta	Fricative	153.25 (24.6)
tta	Stop	NA
da	Fricative	120.25 (13.2)
dda	Stop	266 (69.8)
ka	Fricative	151.25 (10.8)
kka	Stop	NA
ga	Fricative	150.25 (16.7)
gga	Stop	213 (46.4)

For syllable-initial consonants, the opposition is entirely implemented by the alternation in manner of articulation. The initial voiceless stops cannot be measured for duration, since there is nothing but silence before the release burst, and none of the fricatives can be measured for VOT or release burst. For the voiced stops, the "doubles" are somewhat longer than the singletons, but do not show as large an increase as their intervocalic peers.

Figure 1: Waveform and spectrogram for /da/

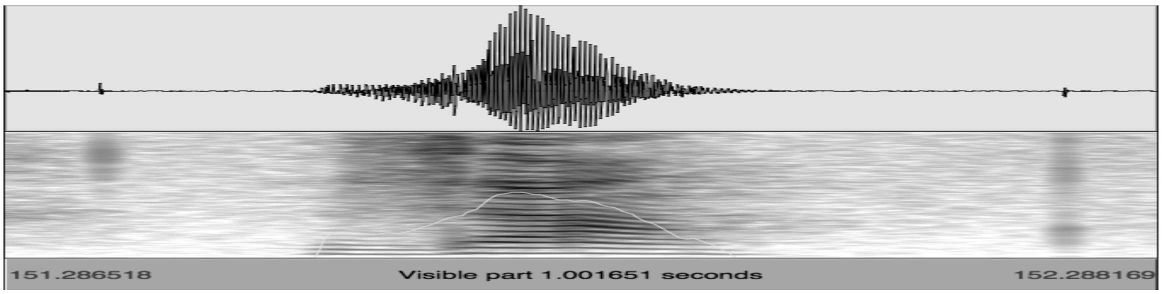


Figure 2: Waveform and spectrogram for /dda/

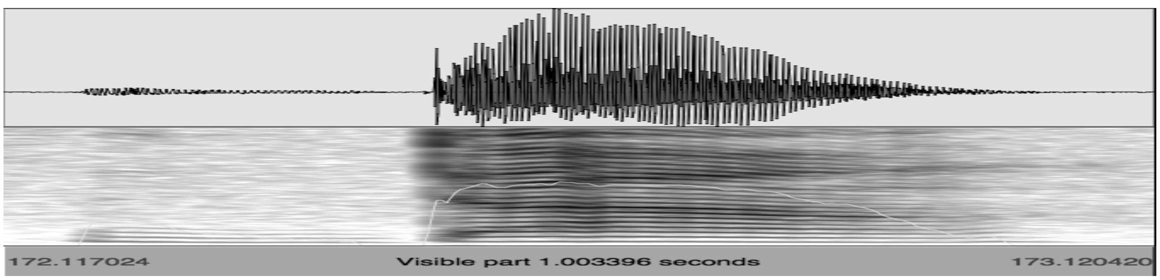


Table 2: Summary of acoustic data for intervocalic /b t d k g/

Word	Manner	Duration (SD)	Previous Vow (SD)
aba	Fricative	87 (7.7)	113.5 (14.1)
abba	Stop	162.5 (61.9)	91.75 (18.6)
ata	Fricative	125.5 (6.6)	103 (2.7)
atta	Stop	296.5 (55.5)	85.25 (11.9)
ada	Fricative	88.75 (7.3)	135.5 (14.3)
adda	Stop	268 (24.7)	100.5 (22.7)
aka	Fricative	143 (14.2)	110.25 (18.3)
akka	Stop	265 (30.8)	87.75 (24.3)
aga	Fricative	122.5 (13.0)	114.75 (14.5)
agga	Stop	249 (14.5)	96 (4.9)

Intervocalically, the best indicators are manner of articulation and duration of the previous vowel. Singleton consonants are fricatives, and vowels are reliably 20-35ms shorter before "double" consonants. In this position, length is a good indicator as well: "double" consonants are two to three times longer than their singleton counterparts.

Figure 3: Waveform and spectrogram for /aga/

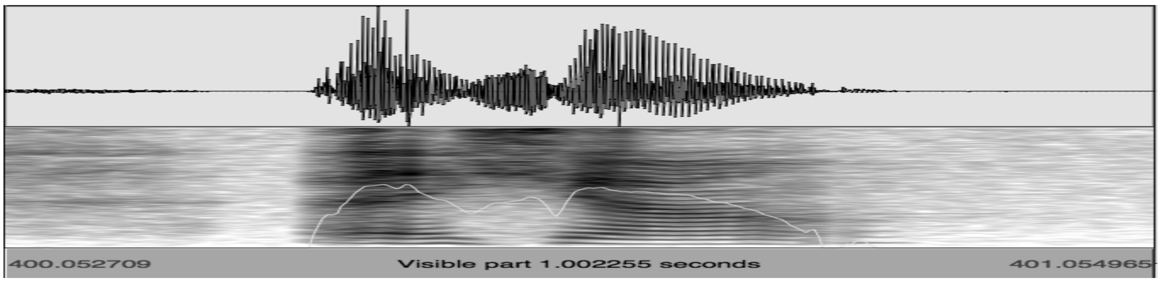


Figure 4: Waveform and spectrogram for /agga/

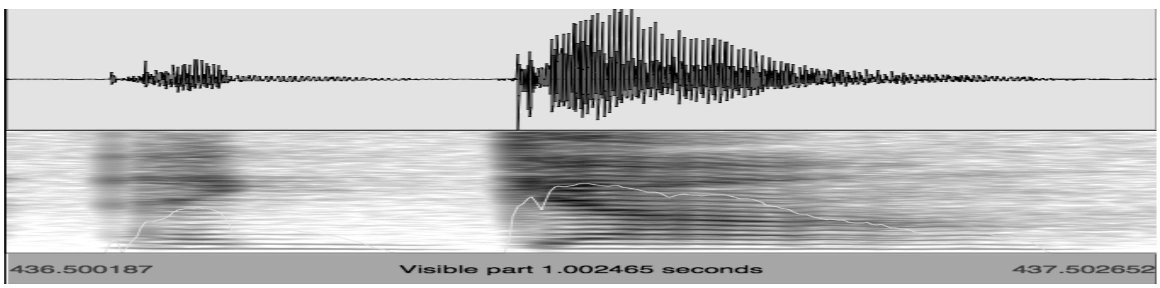


Table 3: Summary of acoustic data for final /b t d k g/

Word	Manner	Duration (SD)	Previous Vow (SD)
ab	Fricative	268 (29.0)	172.75 (21.1)
abb	Stop	264.75 (85.8)	127.75 (6.8)
at	Fricative	269.75 (26.9)	179.25 (21.2)
att	Stop	400.5 (19.1)	96.5 (4.9)
ad	Fricative	206 (23.8)	227 (37.0)
add	Stop	384.75 (74.1)	143.25 (20.6)
ak	Fricative	324.75 (23.9)	172.75 (13.5)
akk	Stop	379.75 (40.9)	90.75 (18.2)
ag	Fricative	242.25 (29.8)	209.75 (39.0)
agg	Stop	331.5 (62.6)	150 (16.9)

Syllable-finally, the manner of articulation and the duration of the preceding vowel are the most reliable indicators for "double" consonants. Notice that the average duration of the singleton fricative in /ab/ is longer than the average duration of the "double" stop in /abb/, so the duration of the consonant is not a cue to its phonological status. Across the board, syllable-final consonants are lengthened in comparison to initial and intervocalic ones. A notable feature of final "double" stops is that there is often a very prominent release of air afterwards, which can optionally be voiced.

Figure 5: Waveform and spectrogram for /ad/

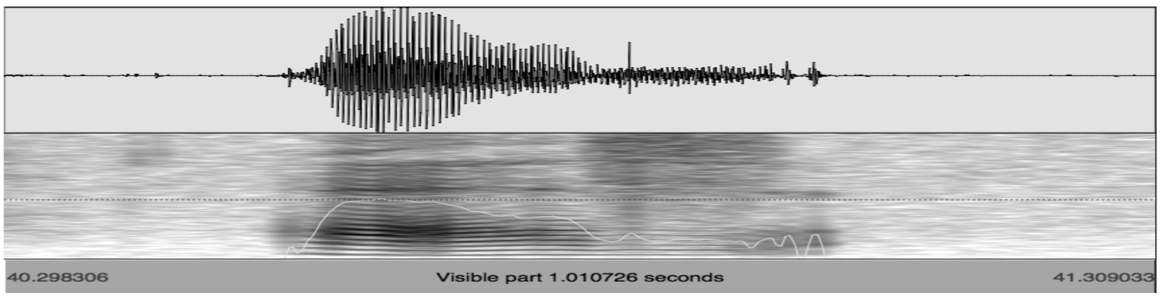
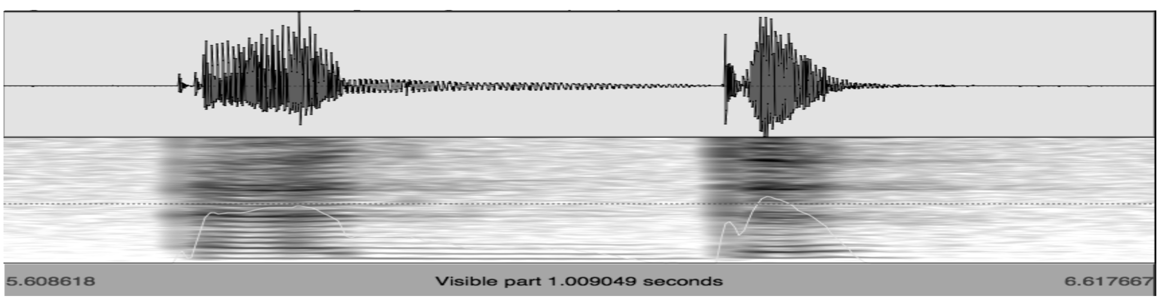


Figure 6: Waveform and spectrogram for /add/



7.2 FRICATIVES

The most reliable indicator for "double" fricatives is a longer duration. In syllable-initial and syllable-final positions, the preceding vowel is shortened, but that cue does not hold intervocalically. Most (but not all) of the fricatives show a higher maximum amplitude of the fricative when "double". The fricatives also show a tendency to have a large puff of air upon their release; syllable-finally, this manifests itself as a vocoid which may or may not be voiced, and in other positions, there is a boost to the vowel's amplitude directly after the release of the fricative.

Table 4: Summary of acoustic data for initial /f s ʃ ʒ z zˤ x/

Word	Duration (SD)	Fricative Amp (SD)
fa	156.5 (14.8)	74.1 (2.3)
ffa	373.25 (63.9)	79.9 (2.2)
sa	186 (39.7)	No data
ssa	362.75 (53.2)	No data
ʃa	150.5 (12.8)	80.6 (3.6)
ʃʃa	402.25 (51.5)	87.6 (1.0)
ʒa	154.5 (30.6)	81.1 (2.0)
ʒʒa	382.25 (37.5)	85.8 (2.2)
za	153.25 (28.9)	77.8 (3.3)
zza	334.5 (36.0)	81.9 (5.0)
zˤa	132.75 (36.2)	73.5 (4.6)
zˤzˤa	279 (27.1)	74.6 (2.7)
xa	213.75 (38.9)	70.0 (2.0)
xxa	294.5 (37.7)	71.2 (1.8)

In syllable-initial position, both duration and maximum amplitude of the fricative are robust indicators of the single-"double" opposition. "Double" fricatives are 1.5-2x times longer than singletons, and are louder on average by 2-7 dB.

Figure 7: Waveform and spectrogram for /fa/

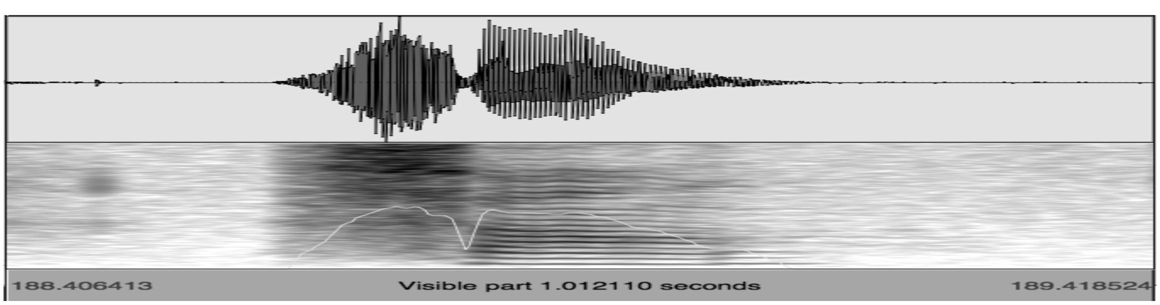


Figure 8: Waveform and spectrogram for /ffa/

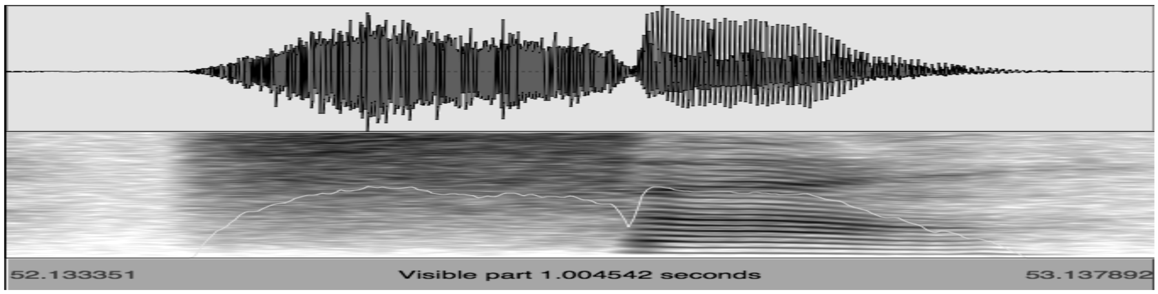


Table 5: Summary of acoustic data for intervocalic /f s ʃ ʒ z zˤ x/

Word	Duration (SD)	Previous Vow (SD)	Fric Amp (SD)
afa	129.25 (6.7)	103 (8.6)	76.2 (2.1)
affa	331 (20.5)	88.5 (9.0)	79.3 (1.9)
asa	117 (13.2)	87.5 (16.5)	No data
assa	303.75 (60.3)	102.25 (15.9)	No data
aʃa	137.5 (6.6)	91 (6.5)	83.6 (1.0)
aʃʃa	275.5 (78.9)	97 (13.2)	84.5 (2.0)
aʒa	116 (24.2)	127.75 (30.1)	81.6 (2.1)
aʒʒa	428 (65.9)	129.75 (7.5)	83.4 (4.0)
aza	97.75 (1.9)	127.75 (9.5)	78.0 (3.3)
azza	274 (59.0)	116.25 (23.5)	78.8 (4.6)
azˤa	91.5 (3.4)	152.5 (16.8)	78.8 (0.7)
azˤzˤa	248.25 (55.4)	137.25 (14.4)	76.1 (0.7)
axa	163 (25.9)	95 (21.9)	70.8 (2.0)
axxa	303.5 (33.4)	84 (30.2)	69.7 (1.2)

Intervocalically, the primary cue among the acoustic measurements I took is length, which is consistently two to three times longer in "double" fricatives. The other cues are weaker in this position; for the pairs /asa - assa/, /aʃa – aʃʃa/ and /aʒa –aʒʒa/, the preceding vowel is longer before a "double", not shorter. In addition, the increases in amplitude seen for "double" fricatives are often negligible and in the case of /azˤa – azˤzˤa/ and /axa - axxa/ are actually reversed. It is worth noting that the overall amplitude of emphatics is generally lower than nonemphatics, and that the velar/uvular fricatives /x ɣ/ also have low amplitude compared to other fricatives.

Figure 9: Waveform and spectrogram for /aʃa/

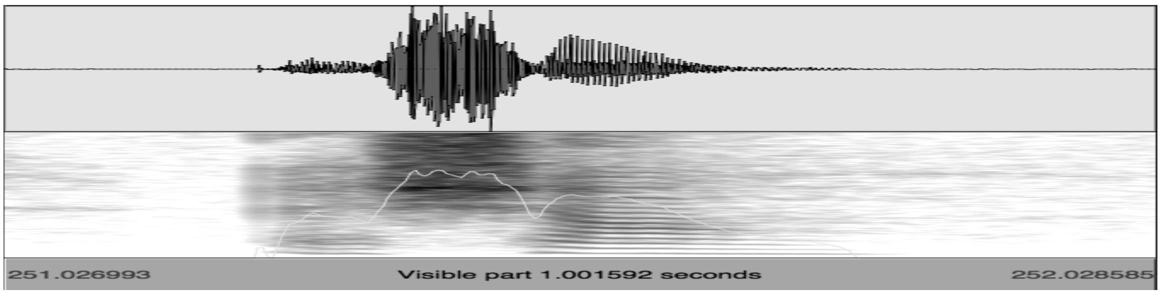


Figure 10: Waveform and spectrogram for /aʃʃa/

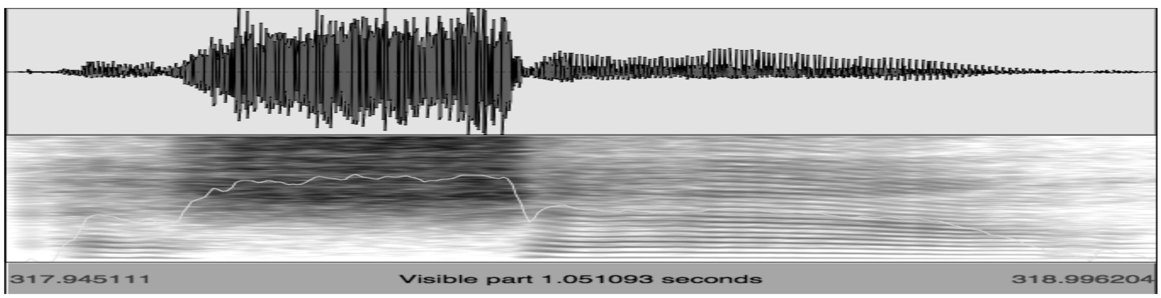


Table 6: Summary of acoustic data for final /f s ʃ ʒ z zˤ x/

Word	Duration (SD)	Previous Vow (SD)	Fric Amp (SD)
af	261.5 (50.7)	210 (28.6)	69.0 (1.4)
aff	521 (132.5)	117.75 (20.3)	79.0 (2.2)
as	235 (71.8)	185 (10.6)	No data
ass	454.75 (72.2)	140.75 (5.5)	No data
aʃ	338.75 (38.0)	177.5 (24.9)	80.3 (1.8)
aʃʃ	771 (30.9)	88 (17.7)	85.4 (0.8)
aʒ	301.5 (40.6)	204 (21.5)	77.2 (3.3)
aʒʒ	646.25 (31.2)	163 (20.4)	81.9 (3.5)
az	271 (26.0)	225.5 (29.3)	73.9 (0.7)

azz	518.5 (83.0)	135 (12.5)	79.8 (3.2)
azˤ	244 (51.8)	231 (52.6)	71.2 (3.1)
azˤzˤ	460.75 (33.7)	155.5 (3.1)	76.4 (2.6)
ax	271.75 (48.3)	163.5 (26.4)	64.5 (1.8)
axx	570.5 (44.7)	117.5 (13.7)	72.1 (3.5)

Syllable-finally, the duration, length of preceding vowel, and amplitude of the fricative are all robust cues. "Double" fricatives are about twice the length of singletons, and the preceding vowel is reliably shortened by 50+ ms. Additionally, note that fricatives in final position are significantly longer than in other positions. The amplitude of a "double" fricative in final position is 5-10 dB louder than its singleton counterpart. The "double" fricatives also commonly have a prominent puff of air upon their release with optional voicing.

Figure 11: Waveform and spectrogram for /aʒ/

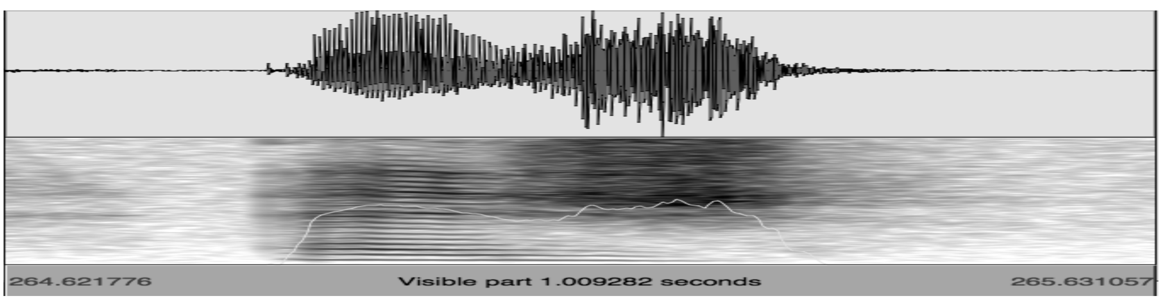
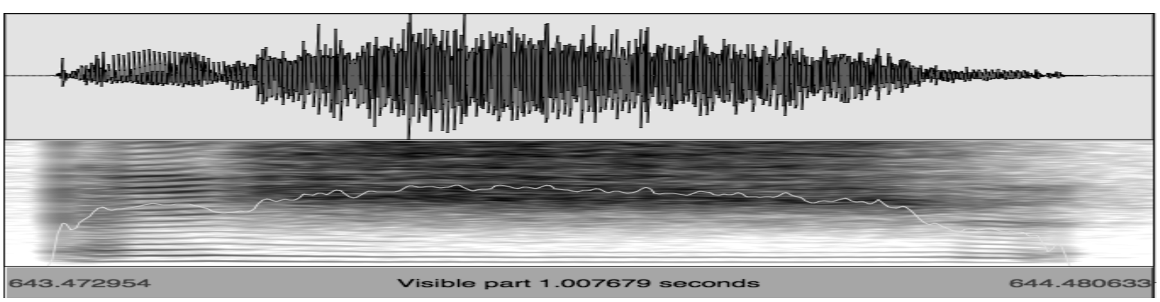


Figure 12: Waveform and spectrogram for /aʒʒ/



7.3 SONORANTS

The cues of duration and length of preceding vowel were the most robust cues for "double" sonorants among the measurements I took. The sonorants are characterized by a tendency towards a very large puff of air upon their release. This is visible as a vocoid which may or may not be voiced in syllable-final position, and as a momentary boost to the vowel's amplitude directly upon release of the sonorant in other positions.

Table 7: Summary of acoustic data for initial /w m n r rˤ l/

Word	Duration (SD)
wa	85 (27.6)
wwa	227 (35.6)
ma	128.75 (21.0)
mma	322 (33.4)
na	112 (49.9)
nna	263.5 (33.3)
ra	66.5 (11.6)
rra	155.75 (45.6)
rˤa	167.75 (30.8)
rˤrˤa	202.5 (3.0)
la	119.25 (22.2)
lla	302.25 (47.1)

For the most part, sonorants in initial position are distinguished by their additional length. It is also possible to note a boost to the vowel following a "double" sonorant, due to the escape of built-up air. The rhotic phonemes /r/ and /rˤ/ have variable realizations in initial position; /ra/ as a singleton is a tap, while "double" /rra/ is generally trilled but can be more akin to a fricative. They both can have a momentary schwa-like vocoid before the tapping or trilling begins. Singleton /rˤa/ was trilled in one token, and produced as a trill with significant frication in the other three tokens. "Double" /rˤrˤa/ was a true trill twice and a trill with frication the other two times, where the trill was held longer than for the singleton variant.

Figure 13: Waveform and spectrogram for /ra/

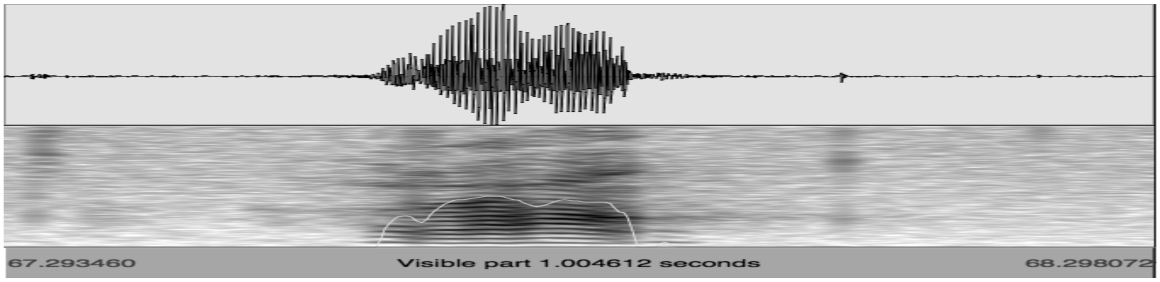


Figure 14: Waveform and spectrogram for /rra/

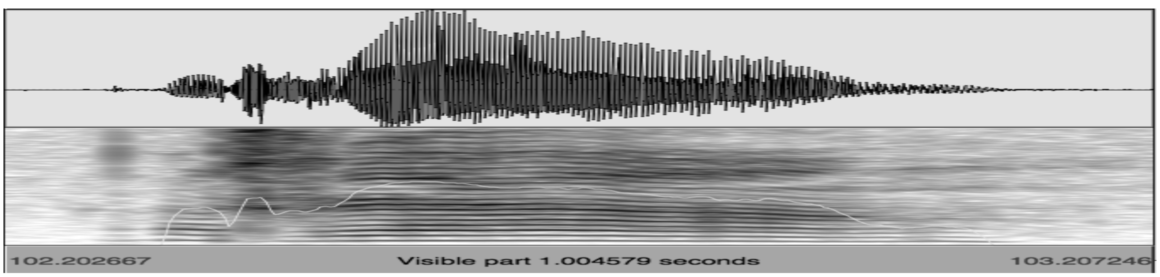


Table 8: Summary of acoustic data for intervocalic /w m n r rˤ l/

Word	Duration (SD)	Previous Vow (SD)
awa	53.25 (6.2)	120.25 (7.8)
awwa	202.25 (34.1)	143.25 (16.3)
ama	73.5 (3.9)	106.5 (4.8)
amma	243.75 (36.8)	89.5 (6.0)
ana	77 (7.6)	127.5 (18.9)
anna	262 (15.4)	114.5 (5.8)
ara	38.75 (8.2)	169 (11.2)
arra	156.25 (19.5)	129.5 (7.7)
arˤa	88 (35.3)	178.25 (26.6)
arˤrˤa	181 (24.8)	153.25 (15.8)
ala	64 (10.9)	111.75 (13.7)
alla	250 (32.1)	100.25 (7.0)

Like for the fricatives, length of the preceding vowel is not as robust an indicator intervocalically as in other positions. The main indicator which I measured was the length of the sonorant; "double" sonorants are 2-4x longer than their singleton counterparts. The singleton rhotic /ara/ is always a tap, and it is produced either as a trill or a trill with heavy frication when double /arra/. The singleton /arˤa/ was produced either as a trill or as an approximant, quite similar perceptually to an American rhotic. The "double" /arˤrˤa/ was produced either as a trill with heavy frication, or as an approximant, in either case being longer than its singleton counterpart.

Figure 15: Waveform and spectrogram for /ala/

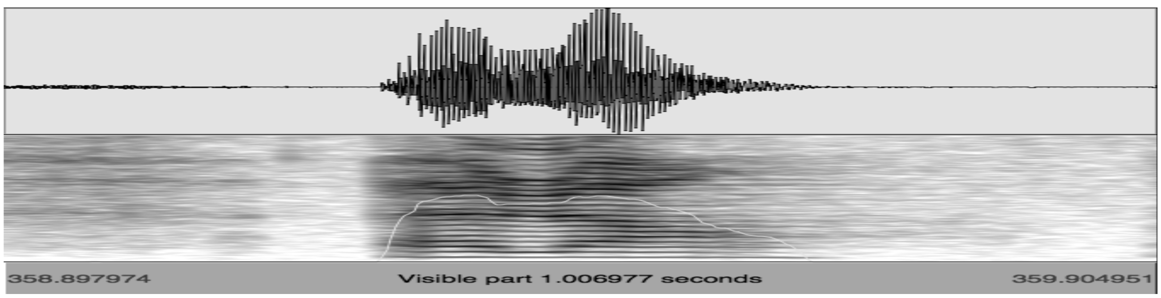


Figure 16: Waveform and spectrogram for /alla/

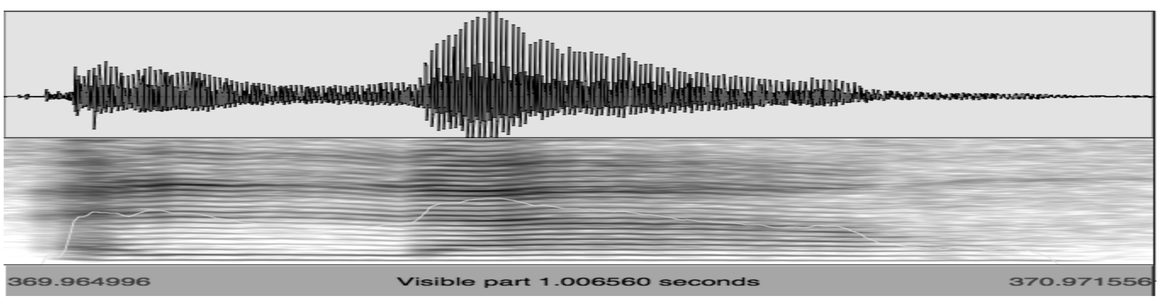


Table 9: Summary of acoustic data for final /w m n r rˤ l/

Word	Duration (SD)	Previous Vow (SD)
aw	188.25 (19.3)	169.5 (14.1)
aww	411.25 (144.8)	161 (30.7)
am	232.25 (26.4)	167 (29.3)
amm	519.5 (66.4)	107.5 (25.0)
an	256.75 (71.8)	194.25 (26.6)
ann	537.5 (58.5)	129.25 (13.3)

ar	No data	No data
arr	379 (21.6)	145.5 (17.9)
$ar^{ʕ}$	315.25 (27.1)	185.25 (41.8)
$ar^{ʕ}r^{ʕ}$	450.75 (88.7)	178.75 (66.0)
al	227.75 (42.8)	193.75 (18.4)
all	519.75 (67.5)	119.25 (42.0)

The most robust indicators are duration and length of the previous vowel. The vowel preceding a "double" consonant is consistently 10-70 ms shorter, and "double" sonorants are 1.5-2.5x longer than their singleton counterparts. In addition, all sonorants are lengthened in syllable-final position relative to other positions. I accidentally omitted /ar/ from my list of nonce words and so did not collect data for it.

Figure 17: Waveform and spectrogram for /an/

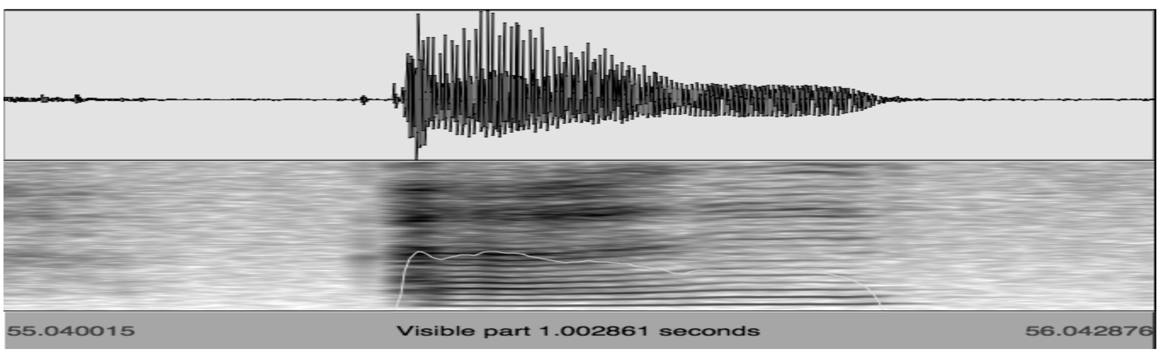
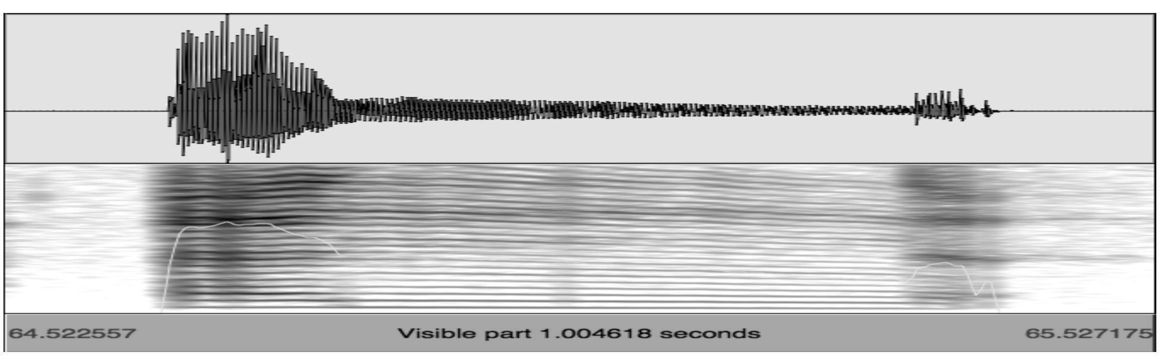


Figure 18: Waveform and spectrogram for /ann/



7.4 OTHERS

There are three remaining phonemes which I collected data for: the two stops which do not alternate between fricative and stop realizations /tˤ q/, and the fickle fricative /ɣ/, which sometimes becomes a stop when made "double", but sometimes does not.

Table 10: Summary of acoustic data for /tˤ q/ in all positions

Word	Rel Burst (SD)	Duration (SD)	Previous Vow (SD)
tˤa	72.75 (1.0)	NA	NA
tˤtˤa	74.75 (1.7)	NA	NA
atˤa	69.25 (2.2)	83.75 (4.6)	93 (15.8)
atˤtˤa	74.5 (3.4)	250.25 (44.8)	102.75 (24.3)
atˤ	70 (1.8)	246 (76.0)	150.5 (15.7)
atˤtˤ	77.25 (2.2)	386.25 (74.2)	114.25 (9.4)
qa	74.25 (3.7)	NA	NA
qqa	75.5 (1.7)	NA	NA
aqa	74.25 (2.5)	93.5 (3.8)	86.25 (14.6)
aqqa	73.5 (1.7)	298.5 (91.4)	110.75 (6.7)
aq	71.25 (2.2)	179.25 (33.6)	124 (24.2)
aqq	75 (2.9)	364.75 (30.8)	103.25 (11.4)

The best indicators are duration of the stop, amplitude of the release burst, and length of the preceding vowel. The amplitude of the released burst is slightly higher for "double" stops, and it that that is the only measure I took which is capable of distinguishing between singleton and "double" stops in initial position, and even then it is not very robust. There must be other acoustic features which allow Kabyle listeners to distinguish them, which I did not measure. As for other classes of sounds, vowels preceding "double" consonants are shorter, but not in intervocalic position, where the pattern is switched. The average release burst of a "double" stop is 2-7 dB louder than that of a singleton, but not in the case of /aqa - aqqa/, where the pattern is reversed. "Double" stops are 1.5-3x longer than singletons, and in final position, all the stops are lengthened.

The phoneme /ɣ/ is tricky because there are two "double" forms of it; historically, its "double" equivalent was /qq/, but in modern Kabyle in some morphological paradigms there exists a "double" fricative realization /ɣɣ/. Which realization is most natural appears to vary by position in the syllable, and Karima suggested that it can be either a stop or fricative in initial position, a stop intervocalically, and a fricative finally, and pronounced the tokens accordingly. An analogous situation holds with /w/ (which alternates with /bb(w)/ in many instances), but she did not produce anything except a long semi-vowel for that phoneme. In the alternation between /ɣ - qq/, the opposition is implemented mainly by manner of articulation, like for other stop-fricative alternants. When considering the case of /ɣ - ɣɣ/, it patterns like a fricative, and the opposition is mainly carried by duration of the fricative and length of the preceding vowel.

7.5 ARE THEY GEMINATE?

Although predictions 5.1.a and 5.1.b regarding the length of the consonant and the length of the preceding vowel are borne out, prediction 5.1.c regarding phonological behavior are definitively ruled out. We can confidently say that Kabyle "double" consonants are not simply sequences of two singleton segments; they are treated by the phonological system as a single unit. One particularly powerful argument for this is in the behavior of schwa insertion: although sequences of three or more consonants are broken up by insertion of a schwa, we see words such as tamtˤtˤut 'woman'. If "double" consonants were treated as two units by the phonological system, the word would have an underlying structure *CVCCCVC and we would expect to see a schwa inserted to break up the triple C cluster. Instead, it must have the structure CVCCVC, in which no schwa is required. Based on such phonological arguments, we can see that Kabyle "double" consonants are not geminate in the way that I defined the term earlier.

7.6 ARE THEY LONG?

Predictions 5.2.a and 5.2.b are borne out; the consonants are longer, and their preceding vowels are shorter. We also see that prediction 5.2.c regarding phonological behavior is borne out; "double" consonants pattern as a single unit. This is not a bad hypothesis, and accordingly, it has been put forth many times. However, there are certain acoustic properties which are not accounted for, and the predictions borne out by my third hypothesis (the fortis analysis), are even more numerous.

7.7 ARE THEY FORTIS?

Predictions 5.3.a and 5.3.b are borne out, as in the other cases. The phonological prediction 5.3.c is also validated, as before. Of the remaining predictions, only one, 5.3.f is not borne out by my results: I saw no increase in VOT for "double" consonants. The VOT's observed were all very short and did not vary significantly between singleton and "double" consonants. Prediction 5.3.d, a tendency towards voicelessness, is borne out by examples like "double" /ɣ/, which is produced as [qq]. This devoiced production is difficult to account for under a "long" analysis. Prediction 5.3.e, regarding variability in degree of closure, was spectacularly validated; the stop-fricative alternation which characterizes Kabyle phonology is a case of alternation between complete closure and incomplete closure. For the phonemes /b t d k g ɣ/, I saw that the singleton version was produced as a fricative and the "double" version as a stop. This pattern fits those described for other languages with proposed fortis-lenis contrasts, and is also difficult to account for under a long-short analysis. Finally, the last prediction 5.3.g was borne out: I noted the presence of large bursts of air after the release of "double" consonants in a variety of unusual places. For instance, at the end of syllables ending in "double" sonorants and fricatives such as /all/ or /aff/, I saw the presence of noisy releases of air, some of which had enough energy to make the vocal cords vibrate and produce schwa-like sound. I interpret that release of air as the result of increased oral pressure due to the increased strength of the articulation. In a typical long sound, there may be a build-up of pressure, especially if there is enough constriction in the sound to impede the flow of air, such as in a stop. However, in the case of sonorants like /l/, the flow of air is not significantly impeded; therefore one would not expect to see such a schwa-like release after a long /l/. Instead, it is explainable by reference to the concept of increased articulatory strength leading to an increase in pressure.

8 DISCUSSION

The main point that my paper is trying to make is the following: certain properties of Kabyle "double" consonants are not explicable under the assumption that they are simply "long", for instance: the alternation between stop and fricative manners of articulation seen throughout the stop system; the prominent puff of air which often accompanies the release of "double" consonants, even fricatives and sonorants; and the tendency to voicelessness seen in irregular pairs of alternants such as /ɣ - qq/. These are all considered typical of fortis-lenis contrasts, on the other hand, and it makes much more sense to interpret Kabyle's phonological system in terms of a fortis-lenis contrast. In a typical long-short opposition, a short stop would have a long stop as its partner, not a fricative; incomplete closure is a hallmark of lenis consonants. A sonorant or fricative which is long, not fortis, has no reason to show such a large puff of air upon release, since there is not enough constriction in the oral cavity to impede the airflow sufficiently; however a fortis sonorant or fricative would be expected to have greater oral pressure, and therefore the release of that oral pressure should be audible as a puff of air. A short voiced segment should be paired with a long voiced segment in a long-short opposition; instead, increased length and devoicing are simultaneous effects of increased articulatory strength, and are considered typical for a fortis-lenis alternation.

My analysis extended to almost all the phonemes but I excluded /dˤ j sˤ h ʕ/ because Karima rejected the double versions of these phonemes as non-existent. I think there was a certain degree of confusion because she perceives alternations as more than allophony; for instance, in much of the literature it is said that "double" /dˤ/ yields [tˤtˤ], which lead Karima to state that there is no "double" /dˤ/. Similarly, we have seen that "double" /j/ yields [gg~ggj] in morphological alternations, but she did not identify them as variants of one another. We have seen that "double" /w/ yields [bb~bbw~kk], but she produced a longer version of /w/, which she said now exists side-by-side with the regular outcome of the "doubling". These all reinforce my fortis-lenis analysis. The single /dˤ/ is a voiced fricative and becomes a voiceless stop when doubled, fulfilling predictions 5.3.d and 5.3.e. The phonemes /j/ and /w/ become stops, fulfilling prediction 5.3.e. There are certain problems with my analysis. First and foremost, in languages with proposed fortis-lenis oppositions, the difference in length between fortis and lenis consonants is rather small, being simply a by-product of the increased strength of the articulation. Instead, I saw increases in length on the order of 2-3x. It is hard to explain such a large increase in duration without explicit reference to length; at least some of the opposition, in the mind of the speaker, must consist of attempting to produce one version longer than the other. Secondly, very few languages are analyzed as having independent oppositions of voicing and strength. Part of the reason why fortis-lenis analyses are often controversial is that they can almost always be recast as either a long-short or a voiceless-voiced opposition. In the alternative cases, the consonant analyzed as "fortis" would be long/voiceless, and the one analyzed as lenis would be short/voiced. To my knowledge, the only languages for which independent voicing and strength contrasts have been proposed are three NE Caucasian languages, all analyzed by Kodzasov: Archi (Kodzasov 1977), Tabasaran (Kodzasov and Muravjeva 1982) and Agul (Kodzasov 1990). This typological rarity should be taken into account when evaluating the proposal, since there are compelling phonetic reasons why a fortis-lenis contrast and a voiceless voiced contrast would interfere with one another.

Finally, my analysis is valid in Karima's variety of Berber, which is heavily spirantizing (stops participate in stop-fricative allophony). In other branches of Berber, such as many Tuareg varieties, the short stops are never made into fricatives. In that case, one of my arguments, that the stops participate in the stop/fricative allophony typical of fortis-lenis contrasts, would be invalidated, and indeed the length of closure would become a much more significant factor. Therefore, in order to unify the analysis of the Berber languages, which have so much in common, it could make sense to appeal to varieties other than Kabyle, which would indicate a long-short analysis.

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