Consonant Cluster Duration in Modern Standard Arabic

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ABSTRACT

This paper investigates the duration of single consonants and two-consonant clusters in Modern Standard Arabic as produced by Tunisian male subjects. The data consisted of 105 words of the type *CVCVCV* and *CVCCVCV* with stress on the first syllable. The results show that in Arabic, a language which contrasts geminate and simple consonants, the durations of single stops are considerably shorter than those reported for English or Dutch.

The results also show that the observed duration of a two-consonant cluster exceeds the sum of the durations of each consonant when it occurs as singleton. The lengthening of consonants in clusters, as opposed the compression reported in other languages, is observed in both obstruents and sonorants, and is inversely proportional to the duration of single consonants. The paper also discusses the effects of variables such as position within the cluster, voicing and major class features on the duration of simple consonants and clusters.

1 INTRODUCTION

There seems to be some agreement in the literature on the temporal organization of speech segments that consonants tend to have shorter duration when they occur in clusters. The compression ratios affecting the duration of individual consonants vary according to different factors such as number of consonants in a cluster, position in the cluster, position with respect to syllable boundary, degree of sonority of a particular consonant etc. [1, 2, , 3, 4,] . Most of these findings are based on descriptions of Indo-European languages such as English, Dutch or French, with no phonemic contrast between geminate and simple consonants. Arabic , where short and long segments whether vowels or consonants contrast, clusters consisting of more than two consonants are not allowed. In addition, the cluster can only occur in intervocalic position where the first consonant is the coda of the preceding syllable and the second is the onset of the following . In other words the consonant cluster may not be tauto-syllabic. While data on the duration of Arabic consonants when produced as singletons exist [5], no information on the temporal organization of consonants in clusters are, to our knowledge, available. The present investigation is an attempt to provide such data. It must be kept in mind, however, that our conclusions will be based on measurements obtained from Tunisian subjects only. Although Modern Standard Arabic is essentially the same for all speakers of Arabic regardless of their dialect, one cannot totally discard the possibility that dialectal variations will influence the duration of consonants in Modern Standard Arabic. It is a well known fact that North African Arabic dialects differs in vowel duration and syllable structures from the Arabic dialects of the Middle East [6]

2 Method

2.1. Data

The experimental data consist of 105 words divided into two unequal parts. The first part is intended to measure the duration of single consonants while the second part, which includes a larger number of words, deals with clusters.

For the duration of single consonants, the recorded material consists of 3 sets of words of the form taCaba (*CVCVCV)* where the second (underlined) consonant is the test segment. For all the word in this set , the vowel is always [a], the first consonant is [t], the last consonant is [b] in most cases, and stress falls on the first syllable in the word. In the position of the test consonant, we find the voiceless stops [k], [q], [?] and both plain and pharyngealized [t], the voiced stops [b] and [d] , the nasal stops [m] and [n], and the liquids [l] and [r].

The data intended to measure the duration of clusters comprise 15 sets of words of the form taCCaCu (CVCCVCV) with stress on the first syllable. The CC cluster represents all the different occurring combinations of voiced and voiceless stops, nasal and liquids as will be discussed in the results.

All the words were included in the carrier sentence: “qaal zaydun…….marratyani” “ Zayd said ……twice.” The sentences containing the test words are randomly sequenced and mixed with other sentences such “good morning”, “how are you?” “thank you” and other expressions. These distracter sentences aim at reducing the effect of chanting that may result from repeating similar sentences. All the sets of data were recorded three times in a sound-proof room by each of the subjects described in the following section.

2.2. Subjects

The subjects are 3 Tunisian adult males. They all hold a post graduate degree in Arabic language and literature and teach Arabic in secondary schools.

2.3. Data analysis.

The speech data was sampled at 16KH and segmented

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using the speech processing software Speech Analyzer from S.I.L. During segmentation, we used both the speech waveform and the corresponding spectrogram for increased accuracy. The burst of friction following stop closure was considered as part of the duration of stop consonants.

3 Results

3.1 Single consonants

3.1.1 Voiced and voiceless stops. The average duration of voiceless stops was 76 ms while that of voiced stops was 61msec. The t-test procedures show that the results are significant at the 0.05 level. The obtained durations confirm the findings of an earlier investigation [5] of the same sounds using a similar population where the duration of voiceless stops was reported to be between 70 and 80 ms and that voiced stops between 60 and 70 ms. However, if only the closure phase is considered, the difference in the duration between voiced and voiceless stops becomes negligible (61 and 62 ms respectively). This difference is not statistically significant and again confirms earlier findings on Arabic [5]. Note that he differences in the duration of stop closure between voiced and voiceless stops was reported to be important in English [2].

3.1.2. Anterior vs. back place of articulation.

The average duration of the stop consonants according to their place of articulation was as follows: 69 ms for alveolar, 73 ms for velar, 85ms for uvular and 83msec for the glottal stop, with considerable agreement between subjects. A t-test comparing the mean duration of the anterior (alveolar) consonants with the remaining back consonants and the glottal stop shows that the difference is significant at the 0.05 level.

3.1.3. Obstruents vs. sonorants. In this section we compare the durations of oral stops with those of nasals and liquids. The results show that stops (71 ms) are longer than nasals (50 ms) which in turn are longer than liquids (32 ms). As has been reported for other languages, consonantal duration in Arabic is inversely proportional to sonority. The differences between Arabic and some languages such as Dutch or English [4] concern mainly the total duration of single consonants which, in comparable environments, seem to be much shorter in Arabic .

3.2. Consonant clusters.

3.2.1. major classes. Looking at the two major classes of sounds we note that the average durations of clusters consisting of obsturents are longer than those of clusters made up of sonorants. Here again, duration is inversely proportional to sonority. Table 1 gives a breakdown of the average durations of various combinations involving osbtruents on the one hand, and sonorants on the other.

The first important observation that can be made on the basis of these results is that , while the duration of a consonant has been reported to be compressed within clusters in various languages [4], in Arabic, consonantal duration in clusters increases.

Type of cluster	Duration in ms
Voiceless +voiceless	270
Voiced + voiceless	259
Voiceless + voiced	253
Voiced + voiced	237
Nasal + nasal	207
Nasal + liquid	204
Liquid + nasal	194
Liquid + liquid	181

Table 1.. Duration of different clusters according to major- class features

In fact, Arabic consonants seem to lengthen in clusters behaving the same way as when they are geminated. The reported lengthening ratio for Arabic geminates (i.e., when their duration is divided by that of their simple counterparts) is 2.7 to 2.9 for sonorants, 2.4 for voiced stops and 2.2 for voiceless stops [5]. It may be the case that, in Arabic, clusters pattern with geminates with respect to duration because they cannot consist of more than two consonants. In other words, there may be no need for a mechanism to adjust the duration of consonants in order to accommodate larger clusters of three of four segments and preserve the general moraic structure of the language.

We will now examine the behaviour of these classes of consonants within clusters with respect to other features.

3.2.2. Voicing effects. As shown in table 1, a cluster made up of two voiceless stops is longer than a cluster of a voiced + voiceless stop, which in turn is longer than a cluster of two voiced stops. The observed differences in duration are not, however, statistically significant, which may be explained by the important inter-subject durational variations in the production of oral stops in the two positions within the cluster.

3.2.3. Position within the cluster. Stops have an average duration of 138 ms in cluster-initial position and only 112 ms when they are the second element of the cluster. Note that while both voiced and voiceless cluster-initial stops have the same duration , in cluster final position voiced stops are shorter (92 ms) than the voiceless ones (120 ms). A t-test was carried out to compare the mean duration of stop consonants by position in the cluster . The results show that the difference is highly significant for this data . The same conclusions can be drawn for liquids and nasals. Cluster-initial liquids and

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nasals are 111 and 125 ms respectively . In cluster-final position, liquids have an average duration of 70 ms and nasals 93 ms . These differences are again statistically significant.

The longer duration of cluster-initial consonants in Arabic may be explained, in part, by the fact that the first consonant in the cluster is in fact the last consonant in the syllable and thus subject to the effects of final lengthening. Since Arabic does not permit complex onsets or codas , words of the form CVCCVCV, such as those used in this experiment, can only be syllabified as follows: CVC-CV-CV. Stress, which falls on the first syllable in these words, may be thought to be responsible for the extra length in the first consonant of the cluster. Preliminary research on the acoustic correlates of stress in Modern Standard Arabic shows, however, that stressed vowels do not lengthen to accommodate stress , but no data are available on the duration of the syllable as a whole [7].

3.2.4. Co-intrinsic effects. On the average, sonorants keep the same duration (119 ms) when they are the first element of a cluster regardless of whether the following consonant is a nasal, a liquid or an oral stop.

Similarly, they have a constant duration (85 ms) in the second position independently of the nature of the preceding consonant. The duration of stops in the first position of a cluster is not affected by the nature of the second consonant. In second position, however, they are longer when preceded by another stop (121 ms) than when the preceding consonant is a sonorant (108 ms). Finally, the average voice onset time for voiceless consonants is 15 ms when they are cluster-initial and 13 ms in final position. Although small, this difference was proven to be significant at the 0.005 level.

3.3. consonantal lengthening in cluster.

As stated above, an Arabic consonant shows a longer duration when it is within a cluster than when it is produced as singleton. .

Types of consonants	Lengthening ratios
Voiceless stops	1.6
Voiced stops	1.8
Nasals	2.1
Liquids	2.8

Table 2. Average lengthening ratios of classes of consonants in clusters.

As shown in table 2, which represents the mean lengthening ratios of consonants in four classes of clusters, the increase in duration is highest for sonorants and lowest for stops. It is inversely proportional to the durations of these consonants when they are produced as singletons. In other words, the shorter the duration of a single consonant, the longer it becomes when that consonant is produced within a cluster. Similarly, as the sonority of a consonant increases, its lengthening ratio within a cluster increases. Lengthening within clusters also affects both the duration of stop closure and voice onset time in both cluster-initial and cluster-final positions.

Tables 3, 4, 5 and 6 illustrate the lengthening ratios of voiceless and voiced stops when they are in cluster initial position. Tables 7 and 8 show these ratios in the same position for nasal and liquids respectively . Note that there are no occurrences of liquid + liquid clusters in Arabic. Also, a clusters comprised of an alveolar nasal [n] and a lateral [l] is not permitted. No tables are provided here to show the lengthening ration for these different consonants in cluster-final position for lack of space. We just reiterate the general remarks stated above , namely that consonants are shorter in cluster final position.

Type of consonant	Duration as singleton	Duration in cluster	ratio
t	71	119	1.6
k	73	132	1.8
q	85	131	1.5
?	83	143	1.7

Table 3. duration in ms. of voiceless stops as singleton and as first consonant in a voiceless + voiceless cluster.

Type of consonant	Duration as singleton	Duration in a cluster	ratio
t	71	129	1.8
k	73	132	1.8
q	85	145	1.7
?	83	150	1.8

Table 4. duration in ms of voiceless stops as singleton and as first consonant in a voiceless + voiced cluster.

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Type of consonant	Duration as singleton	Duration in a cluster	ratio
b	63	122	1.9
d	58	165	2.8

Table 5. Duration in ms of voiced stops as singleton and as first consonant in voiced + voiced cluster

Type of consonant	Duration as singleton	Duration in a cluster	ratio
b	63	138	2.2
d	58	123	2.1

Table 6. Duration in ms of voiced stops as singleton and as first consonant in voiced + voiceless cluster

Type of consonant	Duration as singleton	Duration in a cluster	ratio
n	41	98	2.3
m	60	124	2

Table 7. Duration in ms of nasal stops as singleton and as first consonant in nasal + nasal cluster

Type of consonant	Duration as singleton	Duration in a cluster	ratio
r	24	106	4.4
l	39	102	2.6

Table 8. Duration in ms .of liquids as singleton and as first consonant in liquid + nasal cluster

4 CONCLUSION

With respect to temporal organization, the salient characteristics of Arabic stops nasals and liquids observed in this investigation can be summarized as follows: a) Arabic consonants exhibit a relatively shorter duration than those reported for consonants in some other languages , mainly English and Dutch. This may be explained by the fact that Arabic opposes simple to geminate consonants. b) The duration of a consonant increases when it is within a cluster. The lengthening ratio of a consonant in a cluster is inversely proportional to its duration as a singleton. Most studies report that consonants either shorten within clusters or keep the duration they have as single consonants. Arabic clusters seem to pattern with geminate consonants with respect to duration. c) as the duration of a consonant increases, it sonority decreases, thus stops are longer than nasals and liquids. d) Any consonant is longer when it occurs in cluster-initial position than when it is the second element of the cluster. e) The test words also included one pharyngealized consonant , the voiceless dental alveolar . The results show that, although it has the same duration as its plain counterpart [t] as a singleton, its lengthening ratio in all types of clusters is much higher than plain [t] (1.6 and 2.2 respectively).

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