PHONEMIC QUANTITY CONTRASTS IN NORMAL AND NON-PATHOLOGICAL PERTURBED SPEECH

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ABSTRACT

This paper investigates the behaviour of vowel quantity contrasts when speaking rate is increased and durations tend to be compressed. Two speakers, with no speech or hearing impairment, produced oral vowels belonging to two phonological classes: short and long. Production was done at a self-selected conversational speaking rate and at a fast speaking rate. The overwhelming evidence from our acoustic data is that vowel duration is the determining factor in distinguishing the two categories. Acoustic results further show that short and long vowels are distinguished not only by vowel duration but also by post-vocalic consonant duration: phonologically short vowels are followed by phonetically long consonants in both normal and perturbed speech conditions. Increase in speech rate leads to a compression of absolute durations of short and long vowels as well as short and long post-vocalic consonants. Irrespective of the expansion or compression of the acoustic signal, phonemic contrasts emerge consistently in the VC domain.

Keywords: acoustic data, duration, normal speech rate, fast speech rate.

1. INTRODUCTION

The current study is part of a vast programmatic articulatory, acoustic and perceptual research carried out on vowel quantity, gemination and abutted consonants in our affiliate laboratory, *Institut de Phonétique de Strasbourg,* for different languages. This investigation, based on acoustic data, aims to report observations and results obtained in an experiment on short and long vowels in two speech conditions: normal and perturbed. The language under study is Twi a two tone language spoken in Ghana, West Africa. Quantity contrasts affect the entire vocalic system and seem to be a prominent phonological feature in the Twi language. Phonemic quantity contrast is used for lexical and grammatical distinctions. In this study, non-pathological perturbed speech, i.e. accelerated speaking rate, is examined in contradistinction to studies in pathologically perturbed speech [4] on cleft palate subjects, [8] on speech disorder involving stuttering, [9] on the visually impaired, [6] on distortions in the articulation of vowels in the speech of dysarthric speakers with Amyotrophic Lateral Sclerosis (ALS).

In normal self-selected speaking rate conditions, as shown in [1], vowel duration is the determining factor in distinguishing vowel quantity contrast. Data also indicate that consonant lengthening after short vowels may also contribute to enhancing the phonological contrasts. Short and long vowels are distinguished not only by vowel duration but also by post-vocalic consonant duration: phonologically short vowels are followed by phonetically long consonants. Will these conclusions apply to vowel quantity contrast under perturbed i.e. increased speaking rate conditions and the eventual compression that measured parameters might undergo?

2. METHOD

Two adult native Twi speakers, a female of 24 years and a male of 23, with no speech or hearing impairment were chosen for this experiment. They produced Twi minimal pairs, of the two phonological classes, embedded in the same meaningful carrier sentence. The corpus was made up of oral contrasts for the short and long categories in a C_1VC_2 context where C_1 is /p/, /t/ or /k/ and V is the short and long oral vowel /i/, /iː/, /ɪ/, /ɪː/, /ɛ/, /ɛː/, /ɑ/, /ɑː/, /ɔ/, /ɔː/, /o/, /oː/, /ʊ/, /ʊː/, /u/, /uː/, and C_2 is /k/ of the carrier phrase. The exception is /e/, /eː/ where no meaningful minimal pairs were found. Acoustic recordings were done with a Sennheisser E 845 S directional microphone connected to a Marantz Professional Solid State Recorder PMD660. The two subjects were seated comfortably at a distance of 20 cm from the microphone. The recordings were effected, first, at a normal self-selected speaking rate, and second, at an accelerated speaking rate. The randomised list of utterances was produced at least 10 times by each speaker in the two conditions.

By means of a PRAAT [5] sound editor, the acoustic analysis was performed. Measurements of duration were taken for the target vowel and the post-vocalic consonant /k/, thus obtaining 3 different durations: the target vowel, the post-vocalic

consonant and the syllable V+C durations. The data were then averaged over the ten repetitions of each short and long vowel. Statistical analyses (ANOVAs) were carried out on all measures obtained from the speakers ($p \leq 0.01$). Here are some examples of monosyllabic words from the three extreme vowels of the vowel triangle /i ɑ u/ from the corpus:

/pi/ thicken vs. /pii/ thickened, many

/pɑ/ good, fade vs./pɑɑ/ very much, faded

/pu/ vomit (animals) vs. /puu/ vomited.

3. RESULTS AND DISCUSSION

The basic trend in the data, vowel duration measures, short and long vowels, for the two speakers, in the two speech rate conditions: normal and fast, are illustrated in Figures 1 and 2.

The overall data indicate that the most important parameter for determining vowel quantity contrasts, i.e. vowel duration, is highly significant ($p<0.001$) in both speech conditions. In normal speech rate condition, absolute values for the female speaker, show that the duration of short vowels vary between 90 ms and 117 ms and long vowels between 300 ms and 430 ms, for /i/, /iː/, /ɑ/, /ɑː/ and /u/, /uː/. The corresponding measurements for the male Speaker are 125 ms and 165 ms for the short vowels and 300 ms and 364 ms for the long vowels, respectively (see Figures 1 & 2).

In fast/perturbed speech rate condition absolute values for the female speaker, show that the durational values of short vowels vary between 64 ms and 78 ms and long vowels between 160 ms and 202 ms. The corresponding durational values for the male speaker are 101 ms and 120 ms for the short vowels and 168 ms 206 ms for the long vowels, respectively, thus highlighting the robustness of the phonological distinction, regardless of compression induced by increased speaking rate.

The acoustic data further show that long vowels, in relative terms, take up a higher proportion of the CV domain compared to the short vowels in both the normal and fast speech conditions. Figures 1 & 2 are typical illustrations of such results: the long high back close vowel /uː/ has a value of 80% (std=3%) at a normal speaking rate for the female speaker. Proportions remain relatively stable in accelerated perturbed speech, as they are comparable in this speaking condition for the two speakers. For the female speaker data show 78% (std=4%) in fast speech for the same long vowel. The corresponding figures for the male speaker are 73% (std=5%) in normal speech rate condition and 75% (std=4%) in fast/non pathological perturbed speech condition for the same long vowel. The same observation can be made on the long vowel /ɑː/ where the durational value for the long vowel normal speech rate in the CV domain is 69% and the fast speech rate is 75% for the female speaker. The corresponding measurements for the male speaker are 64% and 72% for normal and perturbed speech rates respectively.

Figure 1: Short and long vowel /i ɑ u/ durations in normal and fast speech conditions: female speaker

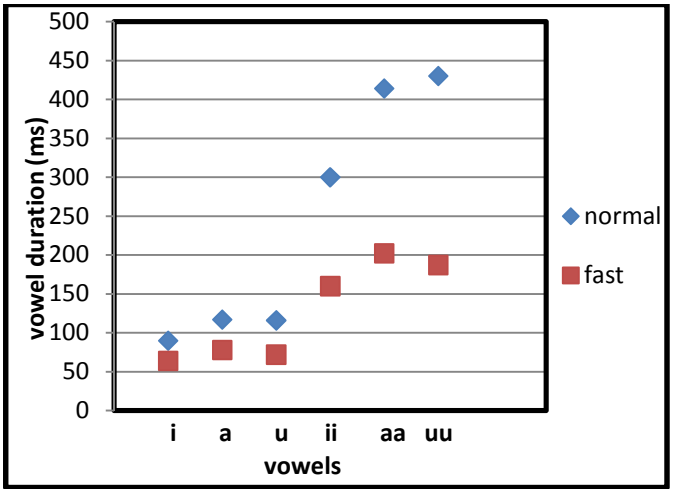
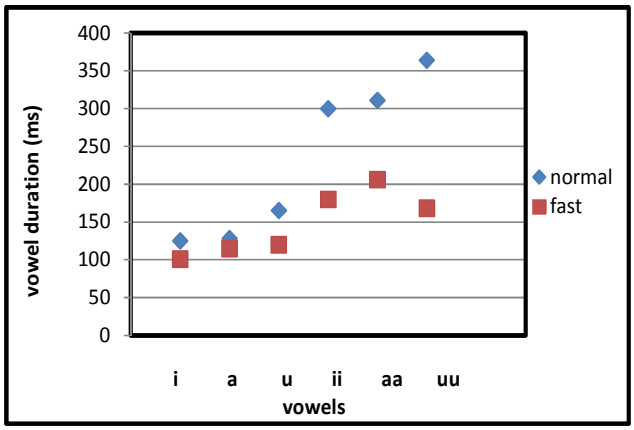


Figure 2: Short and long vowel /i ɑ u/durations in normal and fast speech conditions: male speaker



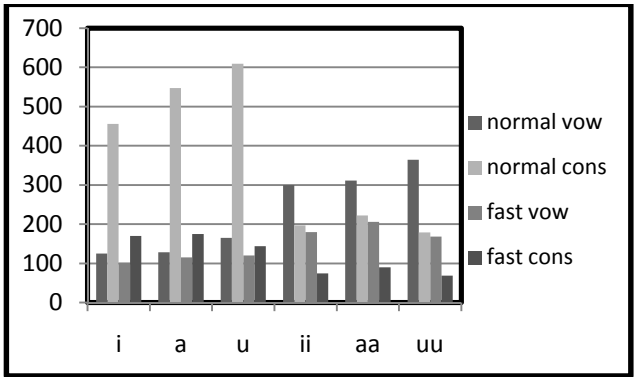
In normal speech rate conditions, absolute duration measures indicate the relevance of both vowel and consonant durations in distinguishing the two phonological classes. In the VC domain, when the vowel is phonologically short, the subsequent consonant is phonetically long [2]. In perturbed speech condition, acoustic data show that, for short vowel /i/ which measures 64 ms, the post-vocalic consonant is 102 ms, the measures for short /ɑ/ are 78 ms and 112 ms respectively all for the female speaker. The exception seems to be /u/ which

measures 72 ms whereas the post-vocalic consonant has 67 ms. The corresponding data for the male speaker for /i, ɑ, u/ are 101 ms for the vowel and 170 ms for the post-vocalic consonant; 115 ms for 175 ms and 120 ms for 144 ms in that order. Thus concomitant consonantal differences seem to reinforce vowel quantity contrasts in Twi where phonologically short vowels are consistently followed by phonetically long consonants in both normal and fast speech rate conditions (See Figures 3 and 4 again*).* To sum up, in the two speech conditions, differences in consonant duration between long and short vowels are significant ($p>0.001$).

Vowel quantity and relative values

The study of quantity in a language cannot be based solely on observations of absolute duration values, since these segmental values cannot wholly be representative of a phenomenon as elastic as speech. Relative values must be taken into consideration in order to be able to rationalise differences obtained in absolute segmental values. The VC domain, according to previous investigations [10] seems to be an efficient temporal span where quantity contrasts are clearly exemplified. A close look at the proportion of time taken by vowel duration in the VC syllable duration in the two speech conditions will therefore further clarify our observations.

Figure 3: Vowel and post-vocalic consonant durations in normal and fast speech conditions: male speaker

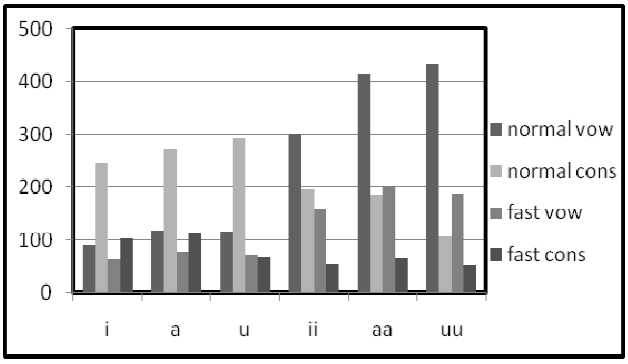


In normal speech condition it is observed for the female speaker that short oral vowels represent, on average, 27 % to 30 %. For the male speaker, short oral vowels represent 17 % to 22 % of the VC domain.

In non-pathological perturbed speech condition, similar observations are arrived at for the female speaker in that short oral vowels represent, on average, 40% to 51 % of the VC syllable durations of this syllable. For the male speaker, short oral vowels represent 33 % to 56 % of the VC domain. The acoustic data here suggest that the fast rate condition, in relative values, takes up higher proportion of the vowel in the VC domain, compared with their normal counterparts.

The present investigation clearly shows that vowel quantity contrasts emerge distinctly in this VC acoustic domain, regardless of expansion or compression of the speech signal.

Figure 4: Vowel and post-vocalic consonant durations in normal and fast speech conditions: female speaker



Relative values show that in the VC domain, phonologically short vowels are followed by phonetically long consonants. As shown in [1], differences in consonant duration between short and long oral vowels are statistically significant ($p>0.001$). With regards to phonologically long oral vowels, three cases can be observed for the normal speech condition: the post-vocalic consonant is either slightly longer than, equally long or slightly shorter than the vowel. Thus, there seems to be no compensatory relation between the long vowel and the consonant in the VC domain. Post-vocalic consonant duration differences seem to reinforce vowel quantity contrast in the language under study.

Differences in consonant duration between long and short vowels have also been attested for in the dialects of Modern Swedish, Schaeffling and Wretling [12] where it is demonstrated that there is a complementarity pattern whereby the long vowel+consonant (V:C) sequences have the tendency of possessing almost the same duration as the short vowel+consonant (VC:) sequences. According to their findings the VC: types are in general slightly shorter in total duration than the V:C sequences. It has been shown in normal speech condition that the complementarity pattern seems to apply partially, without reference to the vowel duration. Indeed, the tendency is verified in only 39% of the cases in both the oral and nasal contexts

[1, 3]. Thus, the observation on the complementarity pattern is in accordance with results obtained for Bolognese where it is shown that the phenomenon is only partially applicable [7].

In the present study, data in accelerated speech rate condition suggest that the pattern applies to the female speaker: /i/ VC: = 166 ms, V:C = 215 ms, /ɑ/ VC: = 190 ms, V:C = 268 ms and /u/ VC: = 139 ms, V:C = 240 ms. Contrary to the female speaker, the complementarity pattern seems to partially apply to the male speaker: /i/ VC: = 271 ms, V:C = 254 ms, /ɑ/ VC: = 290 ms, V:C = 296 ms and /u/ VC: = 264 ms, V:C = 277 ms. Durational differences between V:C and VC: syllables are maintained in non-pathological perturbed speech, in spite of the fact that V:C and VC: undergo compression. Results on durational contrasts and the contribution of the post-vocalic consonant to distinguish the two phonological classes, in normal speech conditions, are in agreement with information on Bolognese [7] and Thai [11].

Even though there are two distinct speech conditions, we observe, thanks to relative data analysis, that it is basically the same strategy that is adopted by the two speakers, in perturbed speech conditions, to preserve phonological contrasts and distinguish between the two phonological sets. A comparison of the normal and perturbed categories shows that the two speakers maintain the proportion of the vowel relatively stable within the VC syllable domain: a difference of around 10 % separates both phonologically normal and fast speech rate categories.

4. CONCLUSION

In the present study it has been shown, on the basis of the extensive corpus and the overwhelming evidence from our acoustic data that the most important parameter for determining vowel quantity contrasts, i.e. vowel duration, is highly significant in both normal and non-pathological perturbed speech conditions.

It has been demonstrated that concomitant consonantal differences seem to reinforce phonemic quantity contrasts in Twi where phonologically short vowels are followed by phonetically long consonants and long vowels are followed by short consonants in both normal and fast speech rate conditions.

It has also been revealed that vowel quantity contrasts emerge distinctly in this VC acoustic domain, regardless of expansion or compression of the speech signal.

In both normal and non-pathological perturbed speech conditions quantity contrasts affect the entire vocalic system and seems indeed to be a robust phonological feature in Twi. Nevertheless, it should be worthwhile looking at the behaviour of nasal vowel contrasts given that they have relatively longer durations than their oral counterparts in the short and long phonological categories.

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