Aspects of Co-Articulation Phenomenon in External Sandhi in the Brazilian Portuguese: Elision, Diphthong, Contamination

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Abstract. *This work investigates, under the viewpoint of the physical properties of sounds, which co-articulation phenomenon in the external sandhi happens in the specific segmental context of the meeting of the sounds [ka] and [u] in the word-boundaries in unstressed syllables. Actually, it's intended to analyze if the phenomenon that happens is connected to the elision, to the diphthongal form or to the infection. It's studied, besides the word-boundaries positions, the sounds [ku] and [kaw] placed in the interior of the word, also verifying on the effects of speech rate in these segments. This work demonstrates, with the temporal and frequency measures, the influence which these positions, as well as the speech rate, have on the investigated segments. In this sense, the results of the statistical analyze not just allow to assert that the speech rate influence the acoustic aspects of the investigated segments, as well as corroborate the hypothesis of the existence of the consonant infection in the external sandhi. The contribution of this research is connected to the comprehension of the phenomena that occur in the speech under viewpoint of the phonetic, as well it contributes to the discussion of the Portuguese from Brazil phonetic representation*

1. Introduction

When two segments are juxtaposed, there may be articulatory influence on each other. This influence generates an acoustic alteration in the segments. Sandhi phenomena are related with the articulatory and acoustic alteration of the juxtaposed segments, either inside the word, when it's denominated internal sandhi, or in the word-boundaries, when it's denominated external sandhi.

According to Matthews (1974), the several sandhi phenomena occur in specific phonic contexts. Bisol (1996) verified in the Portuguese from Brazil that when two vowels meet in the word-boundaries sandhi phenomena of degemination, elision and diphthongal form may happen. Bisol also verified that the ideal context for these phenomena to happen is when the vowels are in unstressed syllables. When the pos-tonic vowel [a] and the pre-tonic vowel [u] meet in the word-boundaries, either the phenomenon of elision or the diphthongal form may be produced. In this specific context, Bisol verified that any of these two phenomena may occur, without priority of application.

To Câmara Jr. (1977), the phonetic phenomenon that occurs in the word-boundaries can also be explained through the syllabic intensity. According to this author, when the last syllable of the first word ends in [a], the favored one is the elision phenomenon, because according to Câmara Jr. (op.cit., pp.49), "it would be anomalous the formation of a falling diphthong with the weaker basis than the semi-vowel".

According to Martinet (1970), in the transition of the Archaic Irish to the Contemporary the synchronal colorful phenomenon of the consonants, called infection was supposed to happen. The infection of the consonant results from the characteristic articulatory anticipation of the following vowel, that is, the transference of the most important articulatory traits of this vowel, and, afterwards, the vowel extinguishment in function of the weak articulatory effort employed. To Martinet, only some vocalic sounds, for instance [i], [u] and [a], the ones that contrast more easily, would produce the infection of the consonant. The infection of the consonant is based in the checking of cases in which the vocalic timbre existing in the infected consonant is different from the vocalic timbre of the vowel that follows it. It was also checked that the most favorable context to occur the infection of the consonant and afterwards the falling of the vowel would be in unstressed syllable in the end of the word.

When the occlusives are in intervocalic position, we may say they present three phases (1) the beginning of the occlusion, (2) the occlusion and (3) the release of the occlusion (Abercrombie (1967)). In our work the third phase is analyzed, the release of the [k] occlusion. The labels position, which will allow to measure the [k] release, called in this research by "[k] nucleus", is supported by the sequence of the acoustic events in the release of the occlusion according to Fant (1973).

1.1. Proposal and objectives

The proposal of this work is to verify which co-articulation phenomenon (elision, diphthongal form or infection of the consonant by the subsequent vowel verified by Martinet (1970) in Archaic Irish) in external sandhi occurs in the specific segmental context of the meeting of the sounds [ka] and [u] in the word-boundaries in unstressed syllables. So, the tested hypothesis is that in the word-boundaries, when there isn't a falling [a] which belongs to the unstressed syllable placed in the end of the first word in favor of the pretonic vowel [u] placed in the beginning of the following word, there is the happening of a sound that has acoustic characteristics different from vowel [a] that belongs to the diphthong [aw].

Two positions of the word-boundaries will be investigated: boundary between the nominal and verbal syntagmas and, interior nomimal syntagma, boundary between the noun group and the adjective group. The work is also interested in verifying if the different speech rates (slow, normal, fast) generate variance in the phonic segments studied.

In order to answer all these questions it will be analyzed, in the external sandhi, the existent relation between the last syllable of the first word, combination consonant/vowel [ka], and the first syllable of the following word, vowel [u]. It will also be analyzed the [ku] and [kaw] sounds placed in the interior of the word. From this point on, it will be possible to verify the [ka] + [ku] sounds found in the word-boundaries in acoustic similarities to the [ku] or [kaw] sounds found in the interior of the words. Two acoustic aspects will be analyzed: duration (ms) and frequency (Hz) - F1.

1.2. Work organization

This work is organized the following way. In this section, theoretical concepts necessary to the comprehension of this work were presented as well as its proposals and objectives. In section 2 the Methodology, Treatment and Corpus Establishment are described. The Analysis and Results will be presented in section 3. The section 4 is dedicated to the Conclusions and Future Work.

2. Methodology, Treatment and Corpus Establishment

2.1. Corpus organization

In the corpus organization, five talkers took part, three male and two female. Four different sentences spoken in three different rates (slow, normal and fast) were elaborated. Each talker performed ten repetitions for each sentence and for each rate. Thus, the corpus contains 600 utterances. The sentences used in the corpus were carefully elaborated with the objective of keeping the rhythmical uniformity. The chosen sentences and the phonetic transcription of the phonic contexts investigated are: {1} "*A menina acusou com muita comoção*" [ku] (The girl accused with a lot of commotion); {2} "*O Guarani causava muita emoção*" [kaw] (The "Guarani" caused a lot of emotion); {3} "*A Chica usou muito o meu blusão*" [ka]+[u] (Chica used my sports jaket a lot) and {4} "*A arnica usada deu muita reação*" [ka]+[u] (The arnica used gave a lot of reaction).

2.2. Procedure

The work was divided in two parts: composition of rate and sentences recording used in the corpus. In the composition of the rate, one of the talkers recorded the sentence "*O sushi causou muita indigestão*" (The sushi caused a lot of indigestion) in ten different speech rates, repeating the sentence three times for each rate. Three utterances were chosen, according to the utterance naturalness and obeying the distinction of the speech rate (slow, normal and fast) among them. These utterances were used as examples of the different speech rate that the talkers should perform during the corpus recording.

In the sentences recording used in the corpus, after listening to the exemplification of the speech rate, each talker performed a single recording section divided in three stages, using a speech rate for stage. En each stage, the talker repeated each sentence ten times, recording, in the total, forty utterances. The five talkers that took place in the corpus sentences recording had independent recording sections, that is, one didn't see the other's recording. The signal was registered in PC using the softwares SounForge and Vegas Audio from Madison Media Software, Inc. a subsidiary of Sony Corporation of America [1].

2.3. Acoustic sound treatment

The recorded signals were edited in the software PRAAT [2]. The position of the labels could be done using either the wave information or the spectral information.

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[1]http://www.sonymediasoftware.com/products/
[2]http://www.fon.hum.uva.nl/praat/

Five acoustic labels (T1, T2, T3, T4 e T5) were positioned to accomplish the temporal and frequencies measures. The labels T2-T1 represent the interval related with the total duration of the utterances, that is, with the speech rate. The labels T4-T3 are related with the [k] nucleus duration, while the labels T5-T3 are related with the [k] nucleus duration + subsequent vowel attack. The label T5 is related with the first F1 maximum point of the formant structure of the subsequent vowel to the [k].

3. Analysis and Results

The analyses of the temporal and frequency measures of the involved segments were done using the ANOVA test and the HSD test - Honestly Significant Difference (Tukey Test). These analyses were done using the STATISTICA software [3].

3.1. Total sentences duration

This analysis was done to verify if the talkers produced three different speech rates. The results of the total duration measures utterances allowed to conclude there is reduction in the total duration of the utterances while the talkers increase the speech rate.

3.2. [k] nucleus duration, [k] nucleus duration + attack and F1 frequency of the subsequent vowel to the [k] - rates

This analysis was done to verify if there is variation of the measures in function of the different speech rate. The results of the statisticals tests applied (ANOVA and Tukey) allowed to conclude that for more than the half of the talkers, only the difference between the slow {1} and fast {3} rate generates variation in the [k] nucleus duration and in the F1 value. It was verified variation in the [k] duration + attack between the slow {1} and fast {3}, and normal {2} and fast {3} speech rates.

3.3. [k] nucleus duration, [k] nucleus duration + attack and F1 frequency of the subsequent vowel to the [k] - sentences

This analysis was done to verify if there is variation of the measures in function of the sentences {1}, {2}, {3} and {4}. The results of the statistical tests applied (ANOVA and Tukey) allowed to conclude that for more than the half of the talkers, the [k] nucleus duration has its duration influenced only in the comparison of the positions in the word-boundaries, sentences {3} and {4}. It was also allowed to conclude the [k] duration + attack is not sensitive only in the comparison of the sentences {2} and {4}, interior and boundary of words, and in the sentences {3} and {4}, in two positions of the word-boundaries, and that the F1 value is different for all the vocalic sounds subsequent to the [k], as it can be observed in Figure 1, that presents graphics in the distribution of F1 vocalic segments frequencies subsequent to the [k] of the four sentences for each talker.
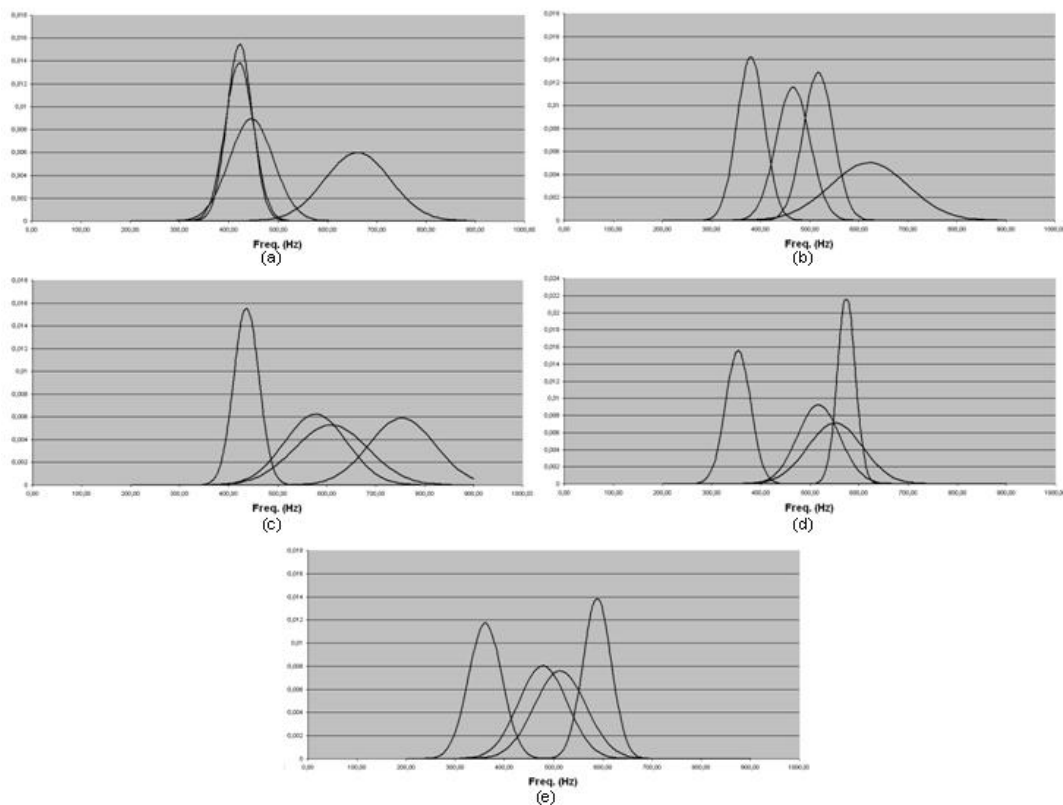
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[3]http://www.statsoft.com/products/products.htm

Figure 1. F1, Frequency distribution for the four used sentences in corpus and for each talker.

In Figure 1.a, the two first superposed Gaussian distribution, represent the sentences {1} and {4}, "*A menina acusou com muita comoção*" and "*A arnica usada deu muita reação*" (higher Gaussian distribution), while the third Gaussian distribution represents the sentence {3} "*A Chica usou muito o meu blusão*" and the fourth, the sentence {2} "*O Guarani causava muita emoção*". In figure 1.b, 1.c, 1.d and 1.e, the Gaussian distribution follow the same arrangement: the first Gaussian distribution represents the sentence {1} "*A menina acusou com muita comoção*", the second, the sentence {3} "*A Chica usou muito o meu blusão*", the third, the sentence {4} "*A arnica usada deu muita reação*" and the fourth Gaussian distribution, the sentence {2} "*O guarani causava muita emoção.*"

Comparing the two results of [k] nucleus and [k] nucleus + attack analyzes, related with the sentences {3} and {4}, it was observed that for more than the half of the talkers there is variation of duration when it's analyzed only the [k] nucleus, not occurring variation of [k] nucleus + attack duration. This implicates that the interval between the labels T3-T5 (related with the duration of [k] nucleus + subsequent vowel attack, that is, [k] nucleus duration related to the labels T4-T3, and the attack, related to the label T5) for the two sentences is the same, while the label T4 moves (T4 positioned in the end of the possible aspiration noise existing in the [k] nucleus). The movement of the T4 label makes possible to conclude that the consonantic segment duration ([k] nucleus) and vocalic (attack of the vowel), are both sensitive to the positions difference of word-boundaries. So, it believed that some vowel trait may have been transported to the consonant, explaining

this way the [k] nucleus duration expansion and the attack reduction.

4. Conclusions and Future Work

The results present subsidies that lead to the acceptance of the tested hypothesis: when there isn't elision, that is, the falling of [a] belonging to the final unstressed syllable of the word in favor of the initial vowel of the following word, [u], there is the happening of a sound with different acoustic characteristics from the vowel [a] produced in the diphthong [aw].

The acceptance of this hypothesis allows to discuss a more suitable phonetic representation in the external sandhi process. In this sense, the words "arnica usada" and "Chica usou", could be represented phonetically as [aRnikuzada] and [ʃikuzow] when there will be elision and [aRnik^{a}uzada] and [ʃik^{a}uzow] when there won't be elision, instead of [aRnikawzada] and [ʃikawzow] that represents the diphthong.

To give continuity to this work, first it's intended to increase the sample, in order to put into evidence the obtained results. It's also intended to do a more detailed [k] nucleus analysis, spreading the wave in time, what will allow to verify the beginning of the co-articulation with the subsequent vowel. This way, it will be possible to analyze, in a more detailed way, the sequence of acoustic events in the occlusion release.

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