VOWEL VARIABILITY IN SPEAKERS WITH PARKINSON'S DISEASE

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ABSTRACT

This study investigates the production of Brazilian Portuguese (BP) vowels by subjects with hypokinetic dysarthria. Twelve subjects participated in the study, including six who had hypokinetic dysarthria, and six without any neurological disorders or speech disturbance. The data consist of the first two formant frequency values for the samples of the seven vowels in BP. Analyses were performed on the following parameters: (a) F1 and F2 range; (b) variability and (c) vowel dispersion. The results showed that subjects with PD tended to have restrictions on the F1 and F2 axis, a finding which is in accordance with the literature. There was a marked difference in the patterns of variability for vowel production between the two groups, as demonstrated in the analysis of vowel ellipses, as well as in the dispersion index, which tended to be higher in the dysarthric group. It is possible infer that this increase in vocalic variability may play a greater role in the reduction of intelligibility than does a restriction of vowel articulatory space.

Keywords: acoustic, dysarthria, Parkinson's disease, phonetics

1. INTRODUCTION

Research exploring speech production by subjects with hypokinetic dysarthria caused by Parkinson's Disease (PD) has been pursued for many reason, such as exemple: production of pathological speech, neuromotor control, treatment efficacy and mechanisms for motor adaptation. Investigations of vowel production are based from the hypothesis that the motor difficulties inherent to the pathophysiology of PD — bradykinesia, rigidness and tremor — can restrict the extent and amplitude of articulatory movements, which has a negative impact on the intelligibility.

The geometric calculation of the vowel space area has been widely used in examinations of dysarthric speech as a reference index of articulatory working space. In fact, all of the studies have confirmed the hypothesis about the reduction of vowel space in subjects with PD [3, 5, 10, 11, 12, 13]. Despite the evidence for the compression of the vowel space, the majority of studies have not statistically proven the phenomenon through a comparison with a control group of subjects without any neurological disorders [5, 10, 11, 13].

However a strait look of the vowel space in subjects with PD has shown that the compression of vowel space is not symmetrical for all vowels. The variability in the impact of the reduction of the F1 and F2 axes depends on the speaker. The great degree of intra-subject variability, as well as inter-subject variability, is also important [13]. This variability underscores the need for caution in using mean values to characterize the production of dysarthric subjects' speech. Nevertheless, among all the studies which talk about vowel production in dysarthric subjects, using averages as an analytic procedure, there has been no one exploring vowel variability for this group thus far [3, 5, 8, 9, 10, 11, 12, 13].

There is recognition in the literature that intelligibility is directly tied to variability of vowel production; individuals with a higher index of intelligibility generally have an expanded zone of vowel articulation [2, 7]. However, it can be inferred that excessive variability can cause the opposite effect, making it difficult for the listener to perceive the speech. Hence, there is a need to include methodologies that evaluate the acoustic variability of production in investigations of vowel production by dysarthric subjects.

The present study investigated the production of Brazilian Portuguese (BP) vowels in subjects with hypokinetic dysarthria. To this end, were inspected the acoustics measures of the first two formant frequency – F1 and F2 – based on methods of analysis for the variability of vowel production: (a) the length of F1 and F2; (b) variability; and (c) vowel dispersion.

2. METHODOLOGY

2.1. Subjects

There were two experimental groups in this study: subjects with hypokinetic dysarthria caused by PD (target group – A) and subjects with no neurological disorders (control group – C). Both groups consisted of six subjects, three men and three women, with an average age of 66.08 years old. All of the subjects with PD were being tracked neurologically and, at the time of data collection, were under the effects of medication (ON phase). The subjects were classified according to their disease progression stage (Hoen and Yard scale) [4] by a neurologist and the degree of dysarthria severity was establish by a speech pathologist. The control subjects had no dysarthria and no complaints of communication disturbances.

2.2. Procedures

A repetition of sentences paradigm was selected as the experimental task. The corpus consisted of examples of seven BP vowels /i, e, ɛ, a, ɔ, o, u/. For this purpose, 19 trisyllabic, paroxytone words containing the target vowel in the accentual position were selected. The words were presented within sentences. Eight samples of each sentence were collected, with a total of 152 target vowels.

The data were collected in a quiet environment and recorded on a MacBook notebook, using the pre-amplification mobile M-AUDIO and AKG C420 head microphone. The Audacity software, version 1.2.6, was used for interface of recording and the data were analyzed acoustically using Praat version 5.0 [1] and analyzed statistically using the Statistica 6.0 statistics program.

The vowels were segmented manually. The first two formants were extracted from a 30-ms local window, in a steady-state portion of the formatic trajectory, and were considered the average of the window's values. The formant values in Hz were transformed into Bark, and the data were analyzed with respect to the following parameters: (a) range of F1 and F2 – minimum and maximum values; (b) variability – plot of ellipsis; and (c) dispersion – total and by vowel.

3. RESULTS

3.1. F1 and F2 range

The differences between the extreme values for each formant, across all of the vowels, were calculated. The maximum values for F1 and F2 were verified as being well defined within the vowels of /i/ for F2 and /a/ for F1, in the two experimental groups. The minimum values for both F1 and F2 showed little fluctuation. The minimum values for F1 were divided between the vowels /i/ and /u/. The control group subjects tended to make the vowel /i/ by opening the jaw less than for the vowel /u/, while the target group did not show such distinction, alternating in 50% of the cases between /i/ and /u/.

The minimum F2 values showed a great fluctuation between the three back vowels /o, ɔ, u/. The /u/ vowel tended to be further back, with lower F2 values, for the control group, while the target group, in most cases, made the /o/ vowel with the more posterior vowel. This finding can indicate that the elevation of the tongue's dorsal region for the articulation of the /u/ restricts movement in the posterior direction.

The F1 axis was often shorter for male subjects than female. The values for the range of the F1 axes had more variability in the target group than in the control group. Statistical analyses by T-test did not reveal a difference between the groups for F1 range ($t = .0712$, $p = .9446$), while the values for F2 range did differ significantly between the two groups ($t = .-4.571$, $p = .00102$).

3.2. Variability

For the observation of vowel variability, ellipse graphs were plotted for all of the samples for the production of each vowel. Each ellipse defines the zone of variability for the production of a particular vowel, within the vowel space. It was expected that each vowel would have a zone of production that was distinct from the zones of the other vowels, and that the superimposition between the ellipses would be small.

There was a marked difference in the patterns of variability for vowel production between the subjects with PD and the control subjects, as shown in Figures 1 and 2. The target group subjects showed a substantial intersection between the ellipses that defined the zones of production for the vowels. The vowels that were most compromised were /ɔ, o, u/, and these four vowels frequently appeared to be included in the production zones of other vowels. In some cases, there were not only intersections between the ellipses, but total inclusion of one ellipse within another.

The zones of vowel production were generally better defined for the control group than for the target group. The tendency to share zones of vowel production was similar in quality to that presented by the target group; the high and middle vowels, both front and back, showed more confluence in their ellipses, and there was a greater confluence for posterior articulation vowels.

Figure 1: Least confluent vowel ellipses in control subjects (C1).

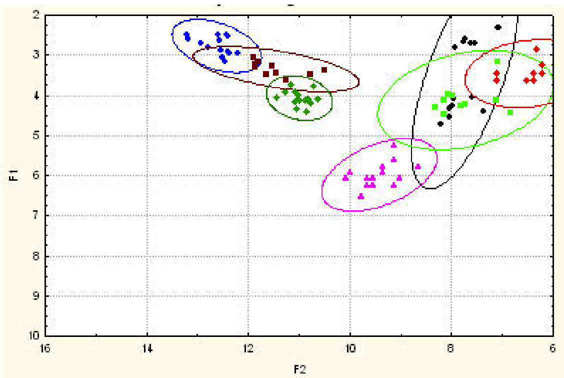
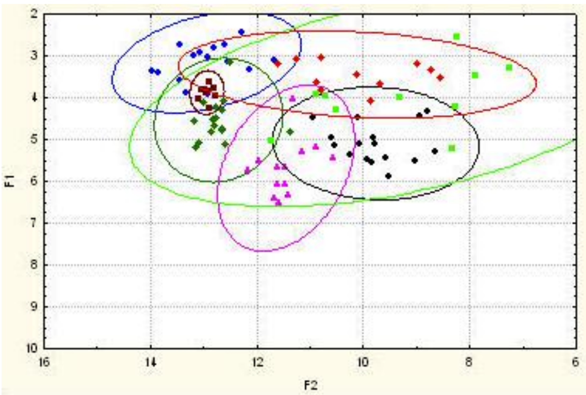


Figure 2: Most confluent vowel ellipses in target subjects (A7).



3.3. Dispersion

Two analytical procedures were used for analyze the dispersion of vowels. First, the dispersion index of all the vowels, calculated as the mean of the Euclidian distance for all vowels to centroid. This measure provides an indication of the overall expansion or compactness of the set of individual vowel tokens. Second, a dispersion analysis of each vowel by subject.

The vowel dispersion index had a higher absolute value for the target group than for the control group. However, the T-test comparison (t = 5.001, p=.101) indicated that there was not statistically significant difference between the groups' index values.

In general, the dispersion data between vowels tended to be more similar for the control group than for the target group. The posterior articulation vowels — /o, ɔ, u/ — had higher dispersion indices than other vowels in both groups. Contrary to the pattern presented by the other vowels, the /u/ vowel showed more dispersion in the control group than in the target group. When the vowel dispersion index was calculated and statistically analyzed by group, T-tests showed that only the /i/ vowel differed significantly between the groups (t = 6.687, p = .057).

4. DISCUSSION

The analyses presented in this study make it possible to infer that subjects with PD tended to present a greater reduction in the range of F1 and F2 than did control group subjects. This finding confirms prior findings in the literature about vowel compression and a reduction in the area of vowel space [3, 5, 8, 9, 10, 11, 12, 13].

A gender-difference in the F1 range was suggested, with men tending to have shorter range F1 than women. A hypothesis of such a difference between sexes has been discussed previously in literature [2].

Variability in vowel production, is an important difference between the groups. The analytical procedure used here is relatively new to the literature [2, 7] and has not yet been applied in studies of dysarthric speech. The back vowels and high vowels were those with the greatest variability and dispersion, which can indicates that movement of the tongue's dorsal region, both in the vertical and horizontal direction is more compromised than movement of the tongue's body. The relationship between acoustic variability and kinetic variability is not direct and need more studies to better understand it [6].

The subjects with PD show more variability than did the control subjects, especially with respect to dispersion. The greatest difference between the groups is that control subjects had dispersions in the same direction; on the other hand, subjects with PD exhibited dispersions in all directions, expanding the zone of vowel production in such a way that all the vowels shared common zones.

The reduction in intelligibility in dysarthric subjects is unquestionable [3, 5, 12, 13]. One of the causes of a reduction of intelligibility in dysarthric subjects noted in the literature is a restriction of the space for vowel production. However, while studies have showed some evidence of articulatory restriction, they have failed to demonstrate a statistically significant difference between the vowel articulatory spaces of dysarthric subjects versus those of subjects without neurological disorders. The findings of the present study suggest that through a lack of motor control and through the attempt to reach the acoustic-articulatory target, an increase in variability may play a greater role in the reduction of intelligibility than does a restriction of vowel articulatory space. Further studies relating intelligibility and vowel articulation variability, with a greater number of subjects, need to be conducted to test that hypothesis.

5. CONCLUSIONS

This study examined the variability of vowel production in subjects with PD. The results of the present analyses confirmed prior findings with respect to vowel space while offering new perspectives for the interpretation of mechanisms of motor adaptation related to the presence of neurological disorders and their possible impacts on intelligibility.

The incorporation of analytical procedures for vowel variability represents an important step forward in our understanding of the mechanisms of vowel production in persons with PD. The question broached here addresses not only restriction of motor mobility, but also the possible relationship between intelligibility and articulatory stability.

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