Variables for the study of the temporal organization in speech disorders

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Abstract

The aim of this study is to examine the fluent speech of people who stutter and adults with developmental apraxia of speech comparing them with individuals with normally developing speech. In a *corpus* of recorded sentences, an acoustic study proceeded in order to examine their temporal aspects of production. The duration of vocalic and consonantal segments, the syllables and trissylablic word as well as the articulatory rate and the average proportion of vocalic intervals (%V) constitutes indices of how the different individuals organize their verbal production.
Key words: Speech, duration, rhythm, apraxia, stuttering

1. Introduction

Time is an essential dimension of speech. Among others, the temporal organization of production reflects the speaker's communicative competence. This must be the main reason for the durational parameter be frequently altered on the speech problems such as apraxia of speech and stuttering.

Clinical entities such as the developmental apraxia and stuttering offer attractive for the comprehension of underlying neurobiological process of speech. The speech production problems which are commom to those individuals give us evidences of the existence of an upper level articulatory organizer [11]. These two speech disorders are not restricted to the articulatory aspects of production but also to the suprasegmental aspects as well. Clinical observations indicate that both have speech rate problems. What we don't know is in which aspects those two are the same and in which aspects they differ one from another. In order to get a better understanding, each one of these speech communication problems must be examined and then compared to one another as well as to a control group.

Developmental apraxia of speech is a neurologically based disorder which interferes in the individual's ability of performing voluntary oral speech gestures although the same movement can be preserved on automatic basis. In the area of stuttering, there is not a single definition. The major line of research over the last three decades has investigated the motor control problem as being one of the causes of the disorder. The fact is that because of the similarities on the profile of those two populations, we may attribute the encountered deficits to the same hierarchical level of speech programming, that is the pre-articulatory sequencing [11].

It seems that at this level of the speech motor control, there is a dissociation between the prosodic and segmental programming. It is believed that the pre-articulatory representation contains information on syllable structure and segment composition. When speakers with disorders allocate more resources to the specification of individual syllables it results in syllable lengthening and long intersyllabic pauses. Therefore, the paradigm of resource allocation is the one which better explains the prosodic and segmental problems found on both stuttering and apraxia of speech.

2. Methodology

For this study we recorded the production of 2 adults with stuttering, 2 with apraxia of speech and 2 normally developing speech adults who participated as a control group.

The *Corpus* of this study was organized in a set of sentences for a reading task. The samples were collected individually in a sound proof cabin, using a DAT (Digital audio tape) TDC-D7 model and a microphone ECM/Sony. The sentences were edited on .wave format using the Sound Forge 6.0 program. Over the recorded sentences, an acoustic study proceeded. The acoustical analysis was done through the *Winpitch Easy Prosody* [7] and the statistical analysis in the *Mini TAB* program.

Considering the number of variables, we constructed our *corpus* taking into account of the following facts:

- the segmental composition
- the syllable structure of the word (CV *versus* CCVC)
- the length and stress pattern of the words (trissylables)
- the length of the sentences (15 syllables)
- the number of syllables per foot (3 and 4 syllables)

The sentences construction which took into account the aspects related above lead us to 35 sentences as follows:

- *o rochedo distraiu o piloto de corrida* (the rock distracted the formula one driver);

The subjects were asked to produce each sentence preceded by the carrying phrase "Eu soube que..": ("I came to know that.....")

In designing such *corpus*, we have the purpose of establishing a very constricted rhythmic pattern that can be described by the metric staff bellow:

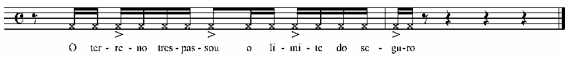

Figure 1 – The rhythmic pattern of the sentences

The metric staff above is an example of a subjective isochrony which leads us to perceive the existing intervals between stressed syllables as being the same in time. This would require that the unstressed syllables be produced in a faster manner when they are in a greater number.

According to Barbosa [1] there has been a great difficulty to characterize the languages rhythm based on the isochrony described by Pike [8]. For that researcher, the interest in the study of languages rhythms was renewed only after Ramus *et al*. have proposed a new model in 1999. This model which is based on the speech production is also consistent with perception aspects of speech. According to these researchers, up to the second month of life, the infant can differentiate his language from others taking into account only the vowel and

the consonant intervals of the continuing speech. The segmental variables used by infant to derive information about speech rhythm and by Ramus [9] to distinguish rhythm of 8 different language might help us to compare the speech rhythm of our experimental groups. These acoustical variables are the proportion of vocalic intervals within the sentence (%V) and the standard deviation of the duration of consonantal intervals within each sentence (ΔC). Therefore, in this study we intend to examine, from the acoustic phonetic point of view, how people with speech disorder organize temporarily their production.

2.1. Measures: methodological decisions

The utterances were segmented based on the spectrographic, oscilographic data and on auditory basis as well. The segment duration were measured manually and checked again by the time we were taking the word measures. A difference superior to 50 ms between the word measure and the sum of the individual segments was the criteria to do the measures again.

The disfluences were considered in their total duration. For the statistical analyses we decided to consider the shorter instances of disfluency, which always tend to be the last repetition of a series of repetitions. It seems that in the disordered speech, the syllable repetition works as a practice which makes the last tentative always be the more efficient production from the duration point of view. The following example is one of various that shows this pattern:

	*o bi*lhete		
	/o/	/b /	/i/
1st attempt	215 ms	152 ms	189 ms
2nd attempt	107 ms	84 ms	102 ms

Pauses were considered as the intervals of silence and respiratory as well For speech rate, we decided to do articulation rate measure. This was taken as the best estimate of time in speech execution since it is calculated by the total time of an utterance divided up by the total number of syllables after pauses and instances of disfluency have been taken away. Our main concern is to describe the fluent speech of people with communication disorders. It is not of worth saying that people who stutter have a reduced speech rate. What we really want to know is if they are still slow when their fluent speech is considered. This is one of the great contributions the acoustical studies can bring to the area as long as pauses and the instances of disfluency can be measured and then discarded for statistical procedures.

3. Results

This section contains the durational results of segments, syllables and words produced by normally developing speakers and those with speech problems as well as measures of speech rhythm described elsewhere (%V e ΔC).

3.1. Duration of speech segments: the vowels

In a first inspection we can see that vocalic segments are elongated in the production of people with speech disorder comparing with those of the control group (from now denominated C for the control group; A for the apraxia group and S for the stuttering group).

In a detailed exam we find that the apraxia group produced the longest vowels regarding any other group. The graphics below contain the average values of the 7 (seven) oral vowels of BP for the comparison of groups C and A.

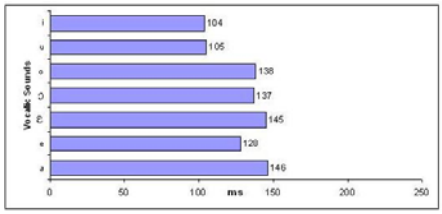

Figure 2 - Average duration of vowels- group C

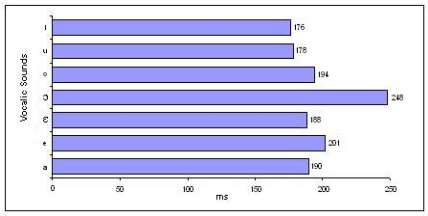

Figure 3 - Average duration of vowels- group A

3.2. Duration of speech segments: the consonants

For the consonants, we find the same tendency that is, the segments are elongated on pathological speech. However, groups with disorders behave differently one from another. Apraxia group follows the normal tendency of keeping unvoiced fricatives longer than any other consonant. They also show unvoiced fricatives longer than unvoiced occlusive and those longer than any other voiced segments.

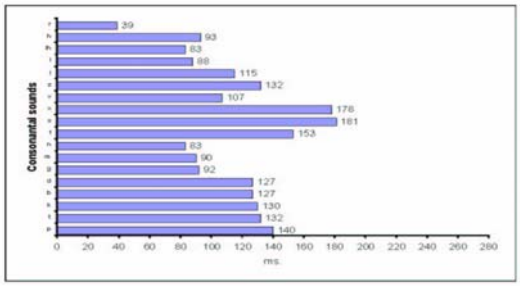

Figure 4 – Mean duration of consonants in group C

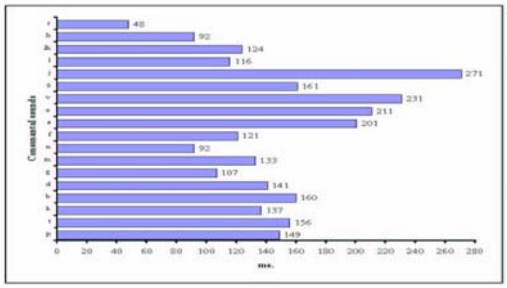

Figure 5 - Mean duration of consonants in group S

On the other hand, stuttering group (as showed above) has the consonants longer than any other group. In addition to that,

this group does not follow the normal tendencies that are determined by place, manner and voicing of the sounds.

3.3. Duration of unstressed syllables

Groups A and S showed average of unstressed syllables significantly higher than the Group C (S= 270.1 ms; A=246.3; C=150.9 ms). Moreover, individuals who stutter exhibited the higher average and the higher values of standard deviation.

3.4. Duration of stressed and unstressed syllables

The extra time required for the disordered speech groups can also be examined regarding to the relative contribution that stressed and non-stressed syllables have for the total utterance. Examining these variables we find out that the stuttering group stays much more time on the unstressed syllables than any other group. The unstressed syllables occupy 47% of their utterance total time in contrast to 53% on stressed syllabes. Brazilian Portuguese is a language for which duration is the acoustical correlate of stress [5]. Therefore, making the difference between stressed and unstressed syllable is a very important ability to have.

Our study has showed that people who stutter are not able to establish this important contrast the language demands from them. Brown (1945) has already argued that stuttering is a problem of making the physiological modifications in order to stress the right units in the utterance. In the apraxia of speech this difficulty in establishing contrasts has also been identified [3]. If, by one hand, proficient speakers of PB produce a stressed syllable twice as long as the unstressed one [11], ten-year-old speakers of PB produced non-stressed syllables corresponding to 4/5 of the duration of a stressed one.

3.5. Average duration of syllables

The previous results have shown that people who stutter keeping themselves longer in the unstressed syllables. If we examine the stressed and nonstressed syllables altogether, the stuttering group is still slower than any other group. It's interesting to remember that the entire data considered for the statistical analysis are based only on the fluent speech.

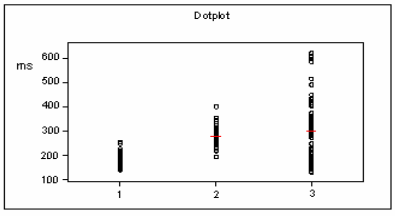

Figure 6 – Articulation rate: Mean duration of syllables and scattering of data for the groups C (1), A (2), e S (3)

Although people who stutter are slow in their fluent speech, they can also be very fast speakers, even faster than normally speech developing group. People with apraxia never reach this condition. They are consistent slow speakers and they are not variable in their behavior. That was in fact an interesting result we found. As we can see on FIG. 6, the smallest values the apraxia group reached are still elongated compared with those values of the other groups.

3.6. Duration of stressed syllables in the utterance

These results are, at least, very curious. We compared the average duration of the stressed syllables over the utterances. Actually, we wanted to test the hypothesis that foresees that, in a series of stressed syllables of an utterance, the last one is the longer [4]. The results have showed that this behavior hold truth only for the group C. On the tables below we have the U-test for the groups. On the bottom line we have the nuclear syllable compared to the mean of the all preceding syllables.

Table 1 – Mean duration of stress syllables: group C

	U-test	p-value
1-4	4146	**0,000**
2-4	4927	0,5432
3-4	3613	**0,000**
m-4	27809	**0,000**

Table 2 – Mean duration of stress syllables: group A

	U-test	p-value
1-4	5325	0,1045
2-4	4670	0,2776
3-4	**4271**	**0,006**
m-4	2897	0,3623

The results demonstrate that the groups with speech disorder differ in time just the 3rd and 4th syllables in their production. Although the data is insufficient, these results point to the fact that these groups might have a limited anticipated control [look-ahead] for speech. It seems to be the case that the normally developing individual initiates a 15 syllable sequence production establishing already the difference between the first and the last stressed syllable. For the speech disordered individuals this anticipating control is limited to an interval of 3 syllables, which is the existing period of the *corpus* of this study.

3.7. Duration of trisyllable words

In this section we examined the behavior of words of equivalent number of syllables which occupy different position in the utterance. The trisyllable words are referred to as SN1 (noun phrase), V (verbal phrase), SN2 (noun phrase 2 as a direct object) e SN3 (prepositional phrase).

Individuals with stuttering as those of the group C were able to promote acceleration followed by a disacceleration along the utterance. SN1, SN2 and SN3 averages correspond to the following values in milliseconds: 526> 474<640 for the group C, and 805>743<882 for group S. The group A could not implement an acceleration followed by a disacceleration found in normal speech (852 >785 =785).

3.8. Proportion of vocalic intervals (% V)

In this section we examined the proportional contribution of vowels for the total duration of an utterance. Adopting the Ramus' correlates of linguistic rhythm, we have tried to insert our experimental groups into the rhythmic continuum proposed by these researchers.

The instrumental data obtained for our group C allowed us to insert them into the continuum that those researchers used to describe the 8 languages they examined. Although our *corpus* was not the same of that study, we consider our results representative of the PB rhythm. Our Group C could be allocated in the syllabic extreme of the continuum. Although

BP has been considered by some authors a stress-timed language, it differs from the PP for being the latter a language strongly characterized by vowel reductions and therefore classified as a stress-timed language.

Table 3 - Table of eight languages from Ramus' study and PB data for the group C in the present study

Languages	%V (SD)	ΔC (SD)
English	40.1 (5.4)	5.35 (1.63)
Polish	41.0 (3.4)	5.14 (1.18)
Dutch	42.3 (4.2)	5.33 (1.5)
French	43.6 (4.5)	4.39 (0.74)
Spanish	43.8 (4.0)	4.74 (0.85)
Italian	45.2 (3.9)	4.81 (0.89)
Catalan	45.6 (5.4)	4.52 (0.86)
Braz.Portuguese	**48.5 (3.5)**	**4.44 (0.35)**
Japanese	53.1 (3.4)	3.56 (0.74)

The pathological condition precludes us to allocate these individuals on the Ramus's continuum of speech. Because of people who stutter keep themselves in the consonantal segments and also because they are extremely variable in their speech production, their data can be allocated only in a distorted manner on the ΔC axis. On the other hand, the apraxia group keep themselves in vowels and therefore occupy the extreme axis of vowel proportion (%V).

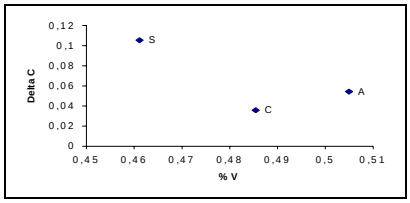

Figure 7 – Variables (ΔC - %V) for groups S, C and A

4. Discussion

In the last two decades there has been an intense debate about the nature of the underlying mechanisms of communication disorders. We share this concern and we have tried to examine the speech control in its temporal aspects in the present investigation.

Temporal facts underlying the problems of apraxia and stuttering might be the motor reason by nature (instead of a linguistic one). People who stutter obtained the longer and the more variables mean duration, followed by the apraxic group. The inconsistent pattern of behavior expressed in the higher standard deviation indicates the greater difficulty of production which reinforces the motor point of view about the problem.

The variability found in stuttering group data is widely mentioned in the literature of apraxia [11]. The motor perspective for the problem of apraxia relies not only on the variability these people show but also on their great difficulty in the performance of verbal and non-verbal oral movements. The motor control for speech requires an extremely high level of coordination and precision, both within and between individual speech articulators. A characteristic which credits the motor view for the problem has to do with the difficulty people with apraxia exhibited to produce and maintain appropriate voicing during speech attempts, evidence very common in our data.

The results of this study confirm our initial assumption that speech rate is a central matter for the disordered speech. Although the experimental groups present an overall elongated speech, their patterns of behavior in time manifest themselves in different ways. This difference is expressed in the syllable internal organization. The speech in apraxia is characterized by the vowel domain. For those people, the vocalic intervals (%V) are longer than for any other group. On the other hand, the speech in stuttering condition is dominated by the consonants.

What those disordered groups have in common is the lack of anticipated control for speech. The motor planning/programming impairment manifests itself in the bulk of the data. In the behavior of the stressed syllables, we find evidences of their difficulty in anticipating speech events. Speech disordered groups distinguish in duration only the penultimate from the final stressed syllable in the utterance. The group C was the only one who demonstrates what the nuclear stress rule foresees [4]. This same group behaves in the way Lindbloom et al. described in 1981. Studying the Swedish phonology, these researchers found a very recurrent pattern of a moderate initial lengthening and a final drastic lengthening, no matter if words or any other longer units of enunciation were being considered. The duration is always determined by anticipated compensation (number of succeeding elements) and by a retarded compensation (number of preceding elements). This phenomenon makes the medial segments be always the shortest one because they are compressed by the anticipated and retarded effects altogether. In the present study, groups with disordered speech were unable of implementing theses compensatory behavior in the examined units.

5. References

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