FORMANT STRUCTURES OF VOWELS PRODUCED BY STUTTERERS AT NORMAL AND FAST SPEECH RATES

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ABSTRACT

The aim of this study is to analyse the steady—state portion of the first two formants (F1) and (F2) in the production of [CVp] sequences, containing vowels [i, a, u] pronounced in two speech rates (normal and fast), by groups of untreated and treated stutterers, and control subjects. Comparing data between the three groups of speakers, a reduction of vowel space is observed for stutterers at a normal speaking rate. When speech rate increases, no reduction of vowel space is noticeable, contrary to treated stutterers and controls.

Keywords: formant, stutterers, centralization, speech rate.

1. INTRODUCTION

The purpose of this investigation is to analyse the formant structure of vowels produced by stutterers and treated stutterers, by comparing their data with those of control subjects. Moreover, the effects of speech rate acceleration on the formant structures of the vowels will be studied for the three groups of speakers.

We chose to analyze French oral vowels [i, a, u], from spectographic data, in two self-selected speech rates: a normal-conversational speech rate and a fast one. The choice of these three vowels is justified by the fact that they represent extreme positions of the French vowel space. Studying them allows exploring the limits of the maximum vocalic space.

Concerning control subjects, many studies ([4] for example) have shown that an increase of speech rate could provoke a compression of durations and a reduction of the vowel space, *i.e.* a certain centralization of vowels in this space. However, this centralization phenomenon was only observed for two vowels, *i.e.* for [i] and for [u].

What would the result be for stutterers or former stutterers, knowing that the majority of studies [3] has shown a centralization of the vowel space in normal speech rate condition for stutterers? In this perspective, a Blomgren and *al*. recent work [1] confirmed a reduction of the vocalic triangle in fluent speech of stutterers. However Prosek and *al*.'s work [5] contradicted such conclusions, as no vocalic centralization appeared in fluent or disfluent stutterers' speech.

The present investigation is of double interest: a) it attempts to provide additional data concerning a possible vocalic triangle reduction for stutterers in normal speech rate; b) it tries to verify whether an "undershoot" phenomenon in fast speech would appear or not.

Our hypotheses are: a) a more restricted vocalic space should be noticed in stutterers' fluent speech, *i.e*. speech without stuttering; b) consequently, no further vowel centralization should be observed when stutterers speak faster, in cases where the vowel space is already remarkably reduced in normal speech.

2. EXPERIMENTAL PROCEDURE

2.1. Speakers and corpus

Nine adult speakers from 25 to 30 years, included three control subjects without speech disorders, three stutterers and three treated stutterers. Each speaker had to pronounce sentences containing a [CVp] sequence ten times, where C was either [p], [t] or [k] and V [i], [a] or [u]. They had to repeat the nine following sentences in normal and fast speech rates:

1. C'est une pipe à Bordeaux.
2. C'est une pape à Bordeaux
3. C'est une poupe à Bordeaux.
4. C'est une type à Bordeaux.
5. C'est une tape à Bordeaux
6. C'est une toupe à Bordeaux.
7. C'est une kippa bordeaux.
8. C'est une coupe à Bordeaux.

9. C'est une cape à Bordeaux.

Repetitions were recorded with a Sennheiser e845S microphone, which was connected to a computer (Sound Card RealTek AC97) by using Audacity (Sampling frequency: 44100 Hz – 16 bits).

Findings graphically represented in this article relate to data from three groups: a control group (CG), an untreated stutterers' group (NTS) and a treated stutterers' group (TS). It should, however, be recalled that each group only comprised three speakers, which is not sufficient enough to allow considering results presented here as being robust.

2.2 Acoustic measures and vocalic space

2.2.1. Acoustic measures

Data were analyzed with the speech editor Praat©. Only fluent sequences were considered. Measures of F1 and F2 were extracted at the centre of the vowel. Such values could provide information about the vocal tract shape [6].

2.2.2. Calculation of vowel space

The area of the triangle in the F1xF2 space was calculated.

This value (in kHz²) provides information about space used to obtain the distinction between vowels.

3. RESULTS

3.1. Sequences [pVp]

Figures 1 and 2 show average values of the first two formants of vowels [i, a, u] pronounced by the three groups in normal and fast speech rate, respectively.

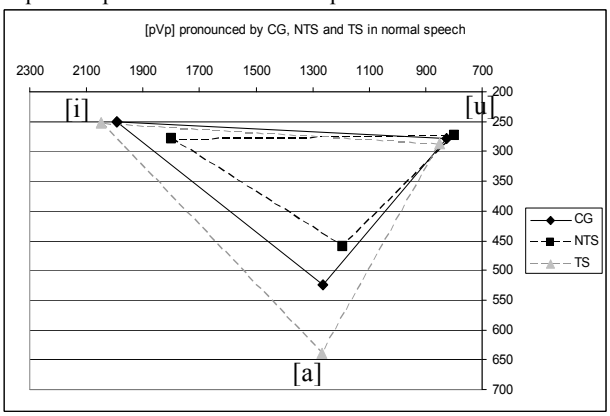
3.1.1. Sequence [pip]

For vowel [i], the mean value of F1 was 251 Hz, F2 1991 Hz for the control group (CG). The same sound was evaluated with a first resonance at 278 Hz and a second one at 1799 Hz for the stutterers (NTS). Therefore, the main difference between the two productions comes from F2, *i.e.* tongue advancement in the oral cavity. Thus, the tongue seemed to be in a less anterior position for group NTS.

The productions of treated stutterers (TS) looked like productions of control speakers (CG), since the first formant is at 252 Hz and the second one at 2047 Hz. The non-pathological subjects and the treated stutterers present the same results relating both more or less to aperture of oral cavity and "forward – backward" movement of tongue-body.

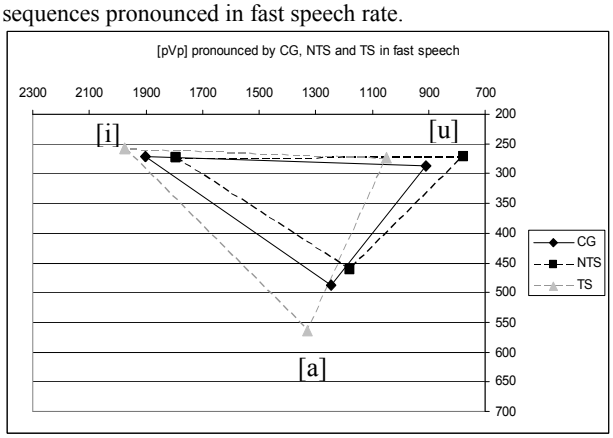
In summary, values of vowel [i] are similar for the treated stutterers and controls but not for stutterers, because the latter presumably show lesser tongue-body advancement.

Figure 1: Vocalic triangle CG, NS and NTS for the [pVp] sequences pronounced in normal speech rate.



Increase in speech rate only provokes a minor increase of the F1 value from 251 Hz to 272 Hz when the control group speaks faster. F2 decreases to attain 1902 Hz in fast speaking rate. The same phenomenon was observed for TS. F1 increases very slightly in fast speech rate (257 Hz) and F2 decreases to 1976 Hz. This fact is not confirmed for the stutterers: a stability of F1 (278 Hz *vs*. 274 Hz) and F2 values (1799 Hz *vs*. 1792 Hz) is noticed in normal and fast speech rates.

Figure 2: Vocalic triangle NS, CG and NTS for the [pVp] sequences pronounced in fast speech rate.



Consequently, no significant difference appears between the productions of vowel [i] in normal speaking rate and fast speaking rate for stutterers.

3.1.2. Sequence [pap]

For non-pathological speakers pronouncing [a], F1 is at 525 Hz and F2 at 1264 Hz. These values differ from those of stutterers, since the F1 mean value was 459 Hz and 1193 Hz for F2 in normal speech

rate. F1 and F2 values were respectively 639 Hz and 1266 Hz for the group of treated stutterers.

Therefore, tongue elevation seems to be higher for NTS, and lower for TS.

When speech rate increases, it is mainly the value of the first formant which is modified, since it decreases from 525 Hz to 487 Hz. The second resonance remains stable (1264 Hz in normal speech rate *vs*. 1246 Hz). Some modifications were observed for the same vowel in the treated stutterers' speech. Thus, the value of F1 diminishes (639 Hz *vs*. 565 Hz) when the speaker is given instructions to speak as faster as possible. Another modification occurs when F2 values are compared across normal and fast speech rates (respectively 1266 Hz and 1329 Hz). Similarly, no significant difference was noted when the stutterer's speech rate increased, F1 gliding from 459 Hz to 462 Hz and F2 from 1193 Hz to 1177 Hz. These results confirm data reported in the literature, *i.e*. no centralization for vowel [a] (Lindblom [4] and Ferbach-Hecker [2]).

3.1.3. Sequence [pup]

The first formant average value of vowel [u] produced by the control group was 278 Hz. No difference was revealed for the stutterer, with measures at 274 Hz, contrary to the treated person, with F1 at 286 Hz.

F2 was measured at 826 Hz for CG, at 850 Hz for TS and at 799 Hz for NTS.

To sum up, the production of [u] is identical for the stutterers and control speakers, even if F2 is slightly lower for the treated stutterers.

Accelerating speech rate provokes a slight modification of [u] for the control group. F2 increases from 826 Hz to 911 Hz. However, this difference is not significant (because of a relatively high standard deviation) and must be carefully considered. F1 is located at 287 Hz when speech rate increases. Similar remarks can be made for TS, since F2 was 1050 Hz in the same condition. Finally, it is interesting to note that F1 and F2 values are comparable for stutterers in the two speech rates: F1 attains 274 Hz in normal speech rate and 272 Hz in fast speech rate, F2 corresponds to 799 Hz, when subjects speak without tempo instructions and to 776 Hz when they are asked to speak quickly.

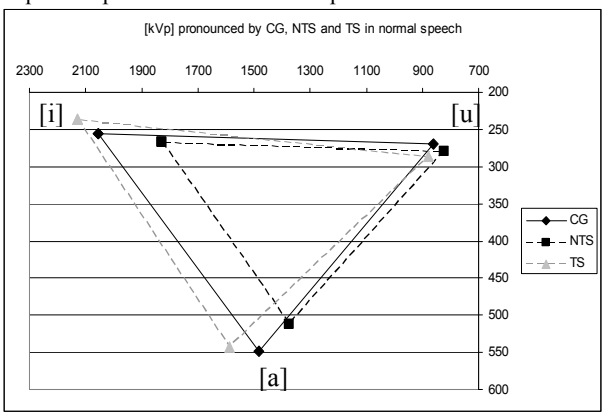
3.2.Sequence [kVp]

Figures 3 and 4 show average values of the first two formants of vowels [i, a, u] pronounced by the three groups in normal and fast speech rates, respectively.

3.2.1. Sequence [kip]

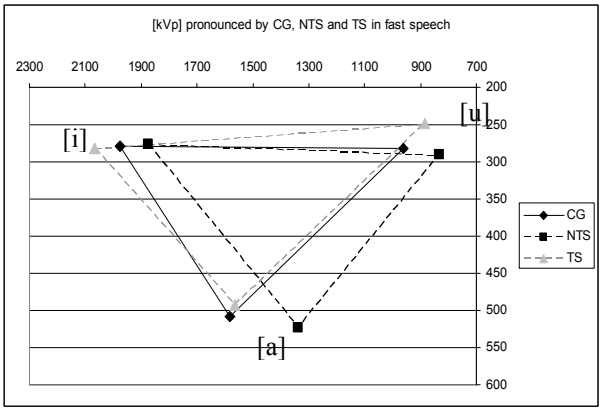
In this sequence, the main difference between control speakers and stutterers comes from F2, *i.e*. in the "anterior-posterior" axis. Tongue body position thus seems to be in a more anterior position for control speakers and treated stutterers than for untreated stutterers.

Figure 3: Vocalic triangle CG, NS and NTS for the [kVp] sequences pronounced in normal speech rate.



The acceleration of the speech rate involves a slight modification of the formant structure of [i] for CG and TS groups. If centralization of vowel [i] is observed for these two groups, the same observation is not valid for stutterers. Indeed, a modification of F2 is visible, but this mean value seems higher in fast speech. Nevertheless, this measure remains lower than results obtained for the CG and TS groups.

Figure 4: Vocalic triangle CG, NS and NTS for the [kVp] sequences pronounced in fast speech rate.



3.2.2. Sequence [kap]

The three groups adopt different strategies in producing vowel [a] in this sequence.

When speakers talk faster, it is possible to distinguish stutterers from controls and treated stutterers. Whereas F1 decreases for NS and for TS at a fast speaking rate, the same parameter slightly increases for NTS.

3.2.3. Sequence [kup]

Vowel quality was comparable for control speakers and treated and untreated stutterers in this sequence in a normal speaking rate.

In fast speech rate, the second resonance is modified: F2 for CG increases in fast speech rate, while F1 is stable. With regards to TS, a similar trajectory is visible for F2, but F1 diminishes at a fast speaking rate. For NTS, F2 does not vary significantly in this fast speech condition.

Vowel quality seems to differ between control speakers, treated stutterers and untreated stutterers in fast speech rate.

3.3. Comparison of areas of the vowel space

It is important to notice that calculation of vowel space area has no functional significance in itself; it serves as an index of the general pattern of change in the vowel space.

Analysis of the area of the vocalic triangle in sequences [pVp] reveals higher values for control speakers and treated stutterers, compared with results obtained for stutterers. For CG, the area is 0.15 kHz², for TS, it is 0.22 kHz² and for NTS, it is 0.09 kHz². As regards CG and NTS, the area decreases in fast speech rate: measures for CG and TS correspond respectively to 0.10 kHz² and to 0.14 kHz² when speaking rate increases.

Comparison of the vocalic triangle area for stutterers does not show any difference between the two speech rates: 0.09 kHz² in normal speaking rate, and 0.10 kHz² in fast speech rate.

Consequently, the area of the vowel space is systematically smaller for stutterers than for the other speakers in normal speech rate. In fast speech, the areas of vowel space are comparable for all groups.

Similar patterns have been obtained for the [kVp] sequences.

Table 1: Comparison of the vocalic triangle areas.

Area (kHz²)		CG	NTS	TS
[pVp]	Normal speech rate	0.15	0.9	0.22
	Fast speech rate	0.10	0.10	0.14
[kVp]	Normal speech rate	0.17	0.12	0.18
	Fast speech rate	0.11	0.13	0.13

4. CONCLUSION

The formant structure of vowels [i, a, u] is similar for treated stutterers and for control subjects, but it is different for stutterers. It is F2 that is especially responsible of this configuration: it suggests fronting of the tongue.

Furthermore, an "undershoot" phenomenon has been observed for controls and treated stutterers in a fast speaking condition. This centralization is not noticed in non-treated stutterers' speech, since the vocalic triangle area is similar in the two rate conditions. Thus stutterers do not use variations of vowel space when they speak faster.

5. REFERENCES

[1] M. Blomgren M. Robb and Y. Chen. A note on Vowel Centralization in Stuttering and Nonstuttering Individuals. In *Journal of Speech, Language, and Hearing Research*, volume 41, pages 1042-1051, 1998.

[2] V. Ferbach-Hecker. La résistivité de la qualité des voyelles orales du français. In *SCOLIA*, volume 20, pages 115-134, 2005.

[3] R. Klich and G. May Spectrographic study of vowels in stutterers' fluent speech. In *Journal of Speech and Hearing Research*, volume 25, pages 364-370, 1982.

[4] B. Lindblom Spectrographic study of vowel reduction. *JASA*, Volume 35, No.11, 1773-1781, 1963.

[5] R. Prosek A. Montgomery B. Walden and D. Hawkins. Formant frequencies of stuttered and fluent vowels. *Journal of Speech and Hearing Research*, volume 30, pages 301-305, 1987.

[6] K. Stevens and A. House. Development of a description of vowel articulation. In *JASA*, volume 27, pages 484-493, 1955.

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