Temporal Reorganization of Articulation to an Artificial Palate

Damir Horga[†], Marija Hunski[‡] and Jelena Ivičević-Desnica[*]
†Faculty of Philosophy, Department of Phonetics, University of Zagreb
‡Orthodontic Clinic, Zagreb
[*]Speech therapist, Zagreb
E-mail: dhorga@ffzg.hr

ABSTRACT

Speakers make effective adaptation to unfavourable articulatory conditions and they successfully compensate for the perturbation. The influence of artificial palate (6-mm thick in the region of the alveolar ridge) on the reorganization of articulatory movements when speakers practise pronunciation with the artificial palate is investigated. Five female students of normal articulatory and hearing status pronounced the test sentence 10 times in a row in four sequences with one-hour pronunciation practice with the artificial palate. Four pronunciation conditions were realized depending on perturbation and practice. The acoustic analysis of temporal parameters was done on the spectrographic and sound wave representations. In general, results showed that the temporal articulatory program and execution are very stable and that only some sounds are disturbed by the perturbation provoked by the artificial palate. Pronunciation practice can, to a certain level, improve the perturbed pronunciation with the palate.

1. INTRODUCTION

Stability and variability of movements are frequent issues in the research into the human motor behaviour in general and particularly in speech. The speech movements and their acoustic consequences are studied with the aim to understand the neurological mechanism of articulatory programs controlling the speech articulation. Though great variability of speech articulation is present between different speakers, within one and the same speaker, and in different speaking conditions the final articulatory result is fairly stable. The concept of *motor equivalence* was created on the basis of these observations and it is defined as the ability of the motor system to produce the same articulatory and acoustic result despite great movement variability of separate components (articulatory organs) in articulation of a particular multidimensional articulatory movement [1,2]. That kind of covariability is present in the movements of different articulatory organs (lips, jaw, tongue, pharynx, larynx, chest) which can compensate for inadequate movements of some parts of the motor system and lead to the adaptation to various speaking conditions. Consequently, the output of the articulatory motor system is realised as a complex movement in which the structure of its potentially free components is controlled. The representation of the articulatory sound movement as a complex structure based on compensatory and synergic mechanisms producing the relevant shape of the articulatory passage is also called *articulatory gesture* or *coordinative structure* [5,6,16,17].

Compensatory movements were investigated by means of various kinds of articulatory perturbations when the speaker strives to neutralize the negative influence of the perturbation. The bite-block [7,8,11,12,14,19], lip tube [18], artificial palate [3,4,9] and dynamic, and unexpected loading of the articulator [1,2] were used. The experiments with the articulatory perturbation aimed to answer the questions whether the compensation for a perturbation is immediate and complete [14,15], whether it is possible to improve the pronunciation despite the perturbation by means of pronunciation training [3], whether there are differences between speakers in their skilfulness to compensate for the perturbation [20] and how various speech segments are influenced by the perturbation [15,19]. Adaptation to a perturbation can be viewed as a transformation system developing new chunks of the articulatory program evoked by the changes of the articulatory passage due to the perturbation.

2. PROBLEM

Several issues about the influence of the articulatory perturbation provoked by the thick artificial palate on the speech temporal parameters were considered. Are the compensatory mechanisms immediate? Do the speakers improve their pronunciation after speech training with the artificial palate? Finally, does pronunciation become natural after the artificial palate is removed and is the negative effect of the perturbation thus erased?

3. METHOD

3.1 SUBJECTS

Five female students of the Philosophy Faculty in Zagreb (Croatia), aged 21 to 24 years, participated in the experiment. Their first language was Croatian, and they had normal speech and hearing.

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3.2 SPEECH MATERIAL, PERTURBATION AND TRAINING OF ARTICULATION

An artificial palate was constructed for each subject from dental acrylic. The palate was manufactured in such a way that a 6-mm ridge extruded at alveolar ridge. The palate thickness was reduced to 1-mm at the distance of the third molars. The palate was fitted with ball claps. Figure 1. illustrates the palatal configuration in mid-sagittal and inferior views [3].

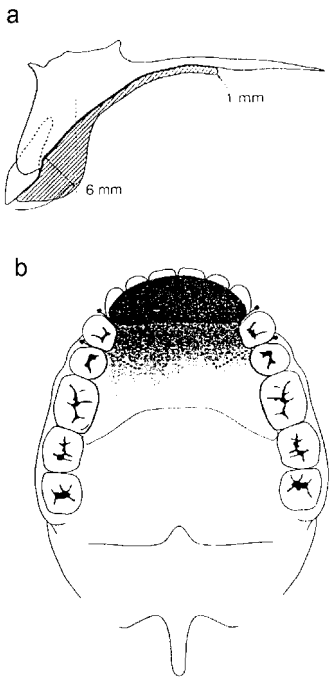

Figure 1: Artificial palate configuration in mid-sagittal (a) and inferior views (b) [3].

The subjects pronounced the sentence *Sigurno će kiša padati čitavu noć (It is certainly going to rain the whole night.)* 10 times in a row in four sequences. In the first sequence it was articulated without any perturbations. In the second sequence it was pronounced with the artificial palate without training. Then the subjects read a handbook text about statistics with the palate and in the third sequence they repeated the sentence after that training with the palate. Finally, in the fourth sequence they repeated the sentence without palate immediately after the one hour perturbation period. Thus four articulatory conditions were considered depending on perturbation and training conditions:

1. natural articulation without artificial palate and without training (NAP-NTR),
2. articulation with the palate and without training (AP-NTR)
3. articulation with the palate after a one-hour training (AP-TR),
4. articulation without palate after a one-hour training with the palate (NAP-TR).

3.3 PROCEDURE AND DATA ANALYSIS

The speech material was recorded on a CD in sound-proof booth. The sentences were articulated at a natural rate and the uniform rhythm was realised by a short light signal which flashed every 5 seconds for every sentence. The recorded material was digitised and the sound wave form and spectrographic representations were used to measure the duration of the segments by a phonetician. The following variables were considered: duration of the sentence, duration of the words, duration of segmental categories and duration of the separate segments.

The significance of the differences between mean values of the chosen variables for different perturbation and training conditions was determined by the one-way analysis of variance (ANOVA).

4. RESULTS AND DISCUSSION

The results showing the differences between separate conditions of articulatory perturbation and training are displayed in Table 1. The results are represented as the mean duration of a sound in ms in every variable. The variables are organized in four levels: 1. the whole sentence (*/Sigurno će kiša patati čitavu noć/*) , 2. phonetic words (*/Sigurno će / kiša / patati / čitavu / noć/*), 3. sound categories (plosives, affricates, fricatives, nasals, sonorants, vowels) and 4. separate sound segments. For every variable the one-way analysis of variance (ANOVA) was carried out to test the significance of difference in four perturbation and training conditions.

Though it was expected that the perturbation due to the artificial palate will significantly influence the temporal characteristics of the speech, the results of the present investigation show that the influence is not substantial in any condition. The results show great stability of temporal characteristics of the articulatory program and execution.

There was no significant influence of experimental conditions on speech temporal characteristics on the level of the whole sentence and phonetic words. Within sound categories only the nasals are longer in the perturbed pronunciation and shorter after the removal of artificial palate compared to the natural and perturbed pronunciation.

It was expected that the separate sounds would be distorted by the palate and especially those with the place of articulation in dental and alveolar regions. That was found for the sounds [tʃ] and [n] but not for the sounds [s], [ʃ], [t], [d] and [r]. The difference is significant also for the burst of sound [k] and only for one of four [a] sounds though their place of articulation is not alveolar. In the sounds where the difference between the conditions is significant in the articulation with the palate the occlusion of [tʃ] was prolonged but its friction was shortened. The burst of [k] and the sounds [n] and [a] are prolonged in conditions of perturbed pronunciation.

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The re-establishing of the unperturbed pronunciation after speaking with the palate usually shortens the pronunciation and makes it more similar to the natural one.

VAR	NAP-NTR		AP-NTR		AP-TR		NAP-TR		F	p
	M	s	M	s	M	s	M	s		
SENT.	68,4	5,0	70,6	5,2	70,6	9,8	68,0	7,4	1,03	0,42
WOR1	64,8	5,6	65,3	837	64,7	10,9	61,8	10,5	1,04	0,41
WOR2	69,9	7,1	74,1	4,3	74,3	10,4	72,4	7,5	0,77	0,53
WOR3	58,0	5,1	59,7	6,2	62,2	11,2	59,7	8,9	0,93	0,46
WOR4	60,4	3,2	62,2	4,6	60,4	7,6	58,9	5,3	0,92	0,46
WOR5	111,5	10,0	116,2	11,7	116,2	11,5	111,5	10,5	1,40	0,29
PLOS.	88,1	6,2	89,9	8,7	91,3	10,3	87,6	7,6	0,45	0,72
AFFR.	155,5	7,2	152,5	19,2	156,1	11,0	150,5	9,0	0,65	0,60
FRIC.	139,9	14,8	134,2	19,4	140,7	20,5	137,5	21,9	0,79	0,52
NAS.	63,0	9,9	78,7	10,3	66,9	12,2	57,7	14,3	5,19	0,02
SON.	45,1	4,8	44,4	6,9	41,4	9,8	41,4	6,4	1,81	0,20
VOW.	69,6	4,7	73,2	4,0	72,8	11,0	71,6	7,7	0,40	0,73
ke	47,2	7,5	52,9	11,6	45,7	8,4	45,4	8,4	4,1	0,03
tʃo 2	54,0	9,2	65,5	19,6	59,9	19,2	50,7	16,4	2,7	0,09
tʃe 2	82,0	8,6	64,3	13,3	71,4	5,7	80,9	4,7	5,5	0,01
tʃo 3	83,0	12,3	109,4	42,6	100,9	4,3	72,4	14,0	3,52	0,05
tʃe 3	138,8	21,8	109,5	25,3	122,7	9,2	139,3	15,3	3,30	0,06
n 1	51,5	10,4	63,3	13,0	51,6	7,9	44,3	11,1	5,86	0,01
n 2	74,5	15,8	94,1	16,2	82,4	17,3	71,1	18,8	2,77	0,09
a 4	61,1	10,4	69,6	5,9	65,1	12,7	59,0	7,7	3,3	0,06

Table 1: Mean values (M), standard deviations (s), F test and significance (p) of the segment duration for the chosen variables in four experimental conditions: without artificial palate and without training (NAP-NTR), with palate and without training (AP-NTR), with artificial palate and with training (AP-TR) and without palate after training (NAP-TR). The variables are as follows: SENT - sentence, WOR - phonetic words (1-5), PLOS - plosives, AFFR - affricates, FRIC - fricatives, NAS - nasals, SON - sonorants, VOW - vowels, ke - burst of [k], tʃo - occlusion of [tʃ] (2,3), tʃe - friction of [tʃ] (2,3), n – duration of [n] (1,2), a - duration of [a] (4).

It was found that in spontaneous speech with the mean syllable duration of 213 ms and standard deviation of 67 ms the coefficient of variability is 31% [10]. But if the speakers are asked to maintain the constant rate of speech the variability can be significantly reduced, as it was case in our experiment, where the variability coefficient for the sentence was between 7.2% without perturbation and 13.8% with perturbation. That shows that even in the case of articulatory perturbation the speaker can produce stable rate of speech. Koževnikov and Čistovič [13] assumed that the temporal characteristics of speech production are governed by the rhythm generator creating precise and firm temporal patterns on the level of a sentence and of phonetic words. The results of this experiment support that view point. It also seems that some other articulatory parameters like spectral and aerodynamic characteristics and spatial precision of articulatory movements of speech segments could be disturbed by such artificial palate to a larger extent than temporal ones [3].

In conclusion it is possible to say that temporal parameters of articulation under the influence of artificial palate are not disturbed compared to natural pronunciation especially in longer units (sentence and phonetic words). Temporal caracteristics of affricates and nasals are distorted by the palate more than the other sounds when they are treated separately. Men can produce, from the temporal point of view, very stable articulatory movements based on the generator of rhythmic patterns that are resistant to the perturbation provoked by artificial palate applied in this investigation. The results also show immediate and high adaptive and compensatory capacities of articulatory mechanisms.

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