SOME ASPECTS OF 21 SPOKEN BULGARIAN CONSONANTS PERCEPTION

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ABSTRACT

The perceptual organization of 21 spoken Bulgarian consonants and the distinctive features have been determined using similarity and dissimilarity data drawn from two perceptual experiments with 200 Bulgarian native speakers.

INTRODUCTION

In the past decade research in speech perception has utilized information-transmissions, cognitive strain in short-term memory, linguistic, psychophysical, and reaction-time methods to gain insight into speech processing. In addition, there are many variants to the methods of measurement in psychophysics which include absolute judgement or direct estimation, scaling of paired comparisons, and triadic comparisons. An extensive review of many of these approaches can be found in Singh /22/ and Dauhauer and Singh/6/. In studies investigating the constituents of the phonemes the common elements have been the articulatory and acoustic features of the input stimuli. In general, the distinctive features have been consistently retrieved. Collectively, these studies appear to have established their psychological reality and perceptual independence relative to the input stimuli /29,28,17,21/.It has been determined as well that a hierarchical structure exists within the phonological domain of distinctive features/25/. Utilizing some aspects of the above mentioned methods and on the basis of experimental results /2,3,1,5,18,19,20,26,27/ a model of the phoneme as theoretical construct was developed/14/. The phoneme is represented as a three-space unity in which the physical reality of the speech unit, the phonological construct of the phoneme, and the perceptual speech sound space of Subjects are described as sets of acoustic, distinctive, and psychological features, respectively. It is suggested that relations and correspondences exist among all types of features and spaces.

The acoustic features could be represented by one or more physical properties of the speech unit (segment) which are changeable in time. Sources of these changes could be several physiological and geometrical parameters, as well as some physical phenomena (the form and size of the vocal tract, "basis of articulation", the transition from one target configuration to the next). All processes attending articulation and coarticulation contribute to the variation of the acoustic features on the time-axis too. Our understanding of the acoustic feature character is very close to Stevens's view /25/. We assume that:1.An auditory system could give a distinctive response not only to the sound itself, but also to each physical property of the sound and its change in time, according to the psychophysical laws. 2.There are many invariant acoustic properties(physical ones) associated with each acoustic feature. 3.The simultaneous appearance of some physical properties and their variations could cause changes in the perception of other physical properties (a high frequency signal of great intensity is perceived as a lower frequency signal). A support of the third assumption has been found out in an investigation of the Bulgarian vowels. For the acute vowels /i/ and /e/ the third formant F3 influences the first formant frequency F_1/14/. The acoustic features can be measured objecively. They form an n-dimension physical space with its axes corresponding to the number of features. The allophones corresponding to the phoneme variants can be presented as a set of points in a fixed region of that space. The distinctive features characterize the phoneme as linguistic construct/9/. Each distinctive feature has its acoustic and psychological correlates. The type of the acoustic correlate depends on the phoneme in which the distinctive feature is realized. Up to some limits, the variations of the acoustic features (correlates) cause changes in the grade of the distinctive feature in the phoneme. In other words, the quality and variations of the physical properties of the acoustic correlates are transformed by the phonological system/15/ into an estimation of the distinctive feature gradation. The degree of the distinctive features in phonemes which are found in different languages is different due to phonological system distinctions.

The psychological features are characteristics of the perceptual speech-sound space of the Subjects. These features have correlates both in physical and phonologic al spaces and are represented as orthogonal axes. Their number defines the space dimensionality ana depends on the properties significant of the phoneme classification. The "psychological phoneme" occupies well confined "psychological region"which is invariable with respect to the psychological axes even in case the coordinate system is rotated or translated. The phonemes of the vocal and consonant systems can be studied within the framework of the model. Relations among physical, distinctive and psychological features of Bulgarian vowels have been found out. It has been established /4/ that the perceptual space of the spoken vowels is two-dimensional and the second formant frequency F_2 is an acoustical correlate of the distinctive feature grave-acute and the first psychological axis. As a result of another investigation/12,13/ the first formant frequency F_1 has been defined as an acoustic correlate of the distinctive feature compact-diffuse and of the second psychological axis (r=-0,97). The analysis of experimental data /7,8/ reveals that the perceptual space for whispered and sung vowels is two-dimensional. All spoken, whispered, and sung allophones of each vowel perceived were situated in a fixed region. The results support the hypothesis of the psychological reality of the phoneme (the "psychological phoneme") and we have good grounds for considering the phoneme not only as "the highly serviceable tool by which we describe our speech samples" and "a basic pragmatic function in speech"/11,p.59/ but also as a cognitive structure with its own complex dimensions.Twenty-one Bulgarian consonants have been studied by using multidimensional scaling technique/5/. The purpose of the present study is to determine the organization of 21 spoken Bulgarian consonants and their features in the perceptual space.

METHOD

Subjects. Subjects were randomly selected students from four classes of the Technichal School of Electronics in Sofia(N==100) and from four classes(N=100) of the Polytechnical School in Roman. All the students were 16-18 years old Bulgarian native speakers.

Stimuli. A stimulus set consisted of 210 pairs of CV-syllables. In each syllable the Bulgarian consonants /b/,/v/,/g/, /d/,/ʒ/,/z/,/k/,/l/,/m/,/n/,/p/,/r/,/s/, /t/,/f/,/h/,/ts/,/dz/,/tʃ/,/dʒ/, and /ʃ/ were uttered with the vowel /ə/ in the way they were spelled in the Bulgarians alphabet. The pairs were recorded with a microphone feeding high-fidelity stereo tape recorder "Jupiter"-202. The stimuli were uttered at a confortable loudness level by a female Bulgarian native speaker born in N West Bulgaria.

Procedure.Experiment I.The experimental set was presented auditory to a hundred students from the Technical School of Electronics. The Subjects were asked to give similarity judgements for each consonant pair using a 7-point scale whose categories were marked verbally by phrases (and by corresponding numbers running from 1 to 7) in the direction of increasing similarity.The scale was anchored on the left with the phrase "Not at all similar"(number 1) and on the right with the phrase"Very similar" (number 7). The Subjects were instructed to write down on the answer sheet their assessments of similarity between the consonants in each pair using the respective numbers. Experiment II. The same experimental set was presented auditory to a hundred students from the Polytechnical School in the manner described above. Only the scale was anchored with the phrase "Not at all different on the left (number 1) and "Very different" on the right (number 7).

RESULTS

Two symmetric matrices (of similarity - Table 1a and of dissimilarity - Table 1b,respecively) were obtained as a result of the two experiments. The matrices were analyzed by the method of Johnson's Hierarchical clustering scheme. The hierarchical clustering tree in Fig.1 proceeds from the analysis of the similarity matrix. The branches of the tree differ in lenght as contrasted with the common hierarchical clustering tree.

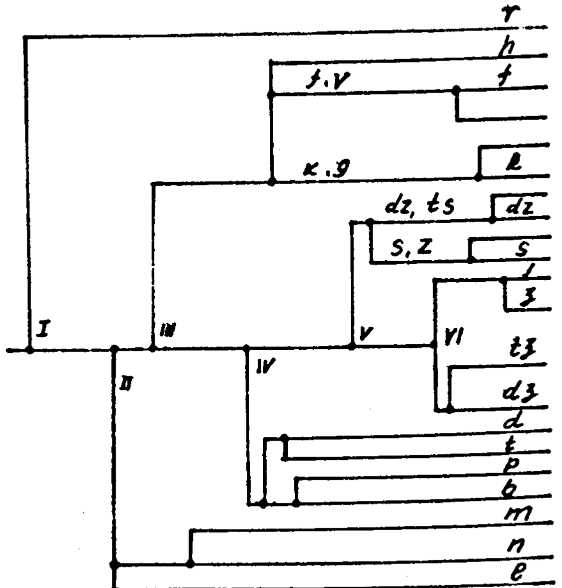

Fig.1. Representation of similarity between Bulgarian consonants as hierarchical clustering scheme

Table 1a. Matrix of Similarity for 21 Bulgarian Consonants
/Scores run from 1(lowest similarity) to 7(highest similarity)

1b \ 1a	b	p	v	f	g	k	d	t	ʒ	ʃ	z	s	dz	ts
b		5,25	3,96	3,53	3,55	2,99	4,49	3,92	2,57	2,55	2,51	1,78	2,89	2,61
p	3,27		3,59	4,20	3,26	3,02	3,48	3,71	2,17	3,31	2,09	2,07	2,24	2,81
v	4,75	4,70		5,72	2,79	2,26	3,12	2,56	2,26	2,76	2,46	2,51	2,47	2,27
f	4,39	4,26	3,11		3,21	2,85	2,91	3,65	2,67	4,14	2,76	3,63	3,01	3,56
g	4,48	4,65	4,87	4,47		5,89	3,48	3,38	2,86	1,95	2,64	2,49	3,17	2,63
k	5,29	4,91	5,47	5,14	3,39		3,11	3,18	2,15	2,73	2,22	2,65	2,02	2,36
d	4,59	4,58	4,78	4,81	4,42	5,33		5,17	2,80	2,24	3,42	2,57	4,36	2,66
t	4,29	4,26	5,14	4,85	5,76	5,08	3,34		2,98	3,69	2,40	3,40	3,34	4,30
ʒ	5,29	5,56	5,58	5,07	5,27	5,33	4,85	5,43		5,97	4,75	3,33	4,36	3,37
ʃ	5,23	4,64	5,15	4,17	5,26	5,09	5,00	4,06	3,12		3,74	5,03	3,33	3,76
z	5,10	5,22	5,45	5,35	5,11	5,26	4,60	5,43	3,45	4,29		5,76	5,45	4,53
s	5,63	5,31	5,24	4,77	5,26	5,28	5,06	4,87	4,73	3,60	3,02		4,95	5,32
dz	4,95	4,90	5,42	5,26	4,86	5,38	4,54	4,92	3,54	4,68	3,90	3,86		5,92
t	5,65	5,25	5,42	4,83	5,37	5,41	5,22	4,43	4,63	4,38	3,93	3,19	2,98	
d	4,82	5,36	5,47	4,85	4,90	5,58	4,48	4,93	3,54	4,99	3,80	4,91	3,47	4,09
t	5,42	5,27	5,48	4,97	5,14	4,94	5,01	4,79	4,57	3,57	4,67	4,80	4,07	3,96
h	5,30	4,41	4,65	3,52	4,71	4,27	5,05	4,03	5,17	3,79	4,92	4,60	5,16	4,92
m	4,99	4,88	4,91	5,75	5,43	5,18	5,32	5,45	5,83	5,02	5,61	5,28	5,51	5,91
n	4,86	4,64	4,99	5,04	5,07	5,04	4,91	4,85	5,46	5,05	5,52	5,35	5,33	5,61
l	4,75	5,06	5,04	5,16	5,26	5,20	5,39	5,25	5,48	5,20	5,38	5,63	5,67	5,69
r	5,72	5,57	5,35	5,15	5,57	5,60	5,93	5,61	5,68	5,23	5,51	5,54	5,72	5,57

Table 1b. Matrix of Dissimilarity for 21 Bulgarian Consonants
/Scores run from 1(lowest difference) to 7(highest difference)/

The 21 Bulgarian consonants are classified in six clusters /Fig.1) which are equivalent to different consonant classes. The hierarchical tree in Fig.2 is an upshot of the dissimilarity matrix analysis. The branches are represented by both the correlative pairs/dz,ts/,/s,z/,/ʃ,ʒ/,/f,v/ and /h/, /d,t/,/b,p/ and the groups/n,m/./l/./r/.

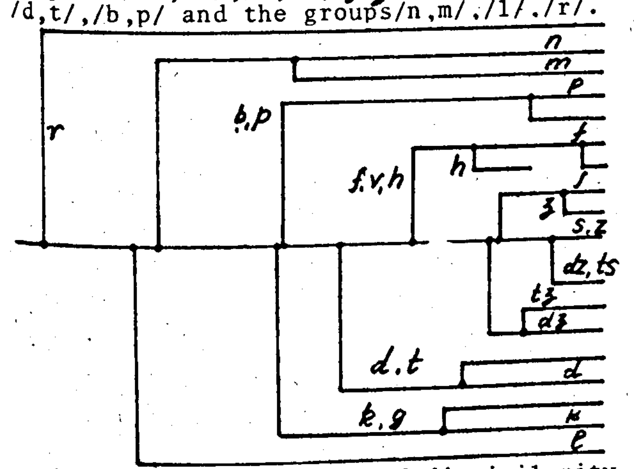

Fig.2. Representation of dissimilarity between Bulgarian consonants as hierarchical clustering scheme

DISCUSSION

In this section we relate the present results to the representation of consonants in terms of clusters and trees, and the concepts of family resemblance and prototypicality on the basis of Tversky's contrast model/23/. There is well-known correspondence between the classes and features or properties of the objects belonging to the class. This correspondence provides a direct link between the clustering approach to the representation of proximity data and the contrast moael. The feature tree can be interpreted as a hierarchical clustering scheme

Table 2.Characteristics of Bulgarian consonant classes

Class	Family resemb.R	Prototypicality P
I	2,22	
II	3,44	2,38n,2,36m,2,13l
III	3,90	3,25f,3,25h,3,12k,3,11g,2,87v
IV	4,34	3,41b,3,28d,3,20t,3,11p
V	5,08	3,89ʃ,3,87dʒ,3,81ʒ,3,66tʃ
VI	5,32	4,08dz,4,01s,4,94ts,4,93z

Note. The calculations of R and P were conducted according to /23/

Table 1 (continued)						
d	t	h	m	n	l	r
2,78	2,50	2,70	2,90	2,70	2,61	1,77
1,95	2,66	3,58	3,08	2,87	2,67	2,20
2,20	2,28	3,23	2,72	2,84	2,91	2,23
2,67	3,14	4,81	1,85	2,43	2,80	2,59
3,12	2,85	3,64	2,31	2,94	2,20	2,14
2,26	3,05	4,58	2,51	2,94	2,57	2,17
3,79	2,72	2,81	2,31	3,17	2,19	2,05
3,46	3,84	4,10	2,67	2,48	2,29	2,50
5,33	3,93	3,09	2,20	2,16	1,90	2,01
4,53	5,07	4,42	2,35	2,54	2,38	2,33
4,73	3,01	2,96	2,04	2,37	2,16	2,09
3,35	4,95	3,82	2,28	2,22	2,30	2,23
5,32	4,58	2,91	2,02	2,58	1,70	1,87
4,61	4,55	3,57	1,88	2,41	1,71	2,32
	5,64	2,71	2,09	2,24	1,86	2,08
3,29		3,26	2,12	2,42	1,79	2,10
4,87	4,63		2,04	2,83	1,80	2,71
5,39	5,72	5,39		3,91	3,17	2,29
5,16	5,20	4,92	4,25		3,24	2,21
5,46	5,37	5,47	5,00	4,83		2,44
5,20	5,42	5,32	5,73	5,26	5,40	

where each arc lenght represents the weight of the cluster consisting of all objects that follow from that arc. It is known that similarity is a relation of proximity that holds between two objects or concepts, prototypicality (P) is a relation between an object (concept) and a class, family resemblance (R)is a network of similarity relations that link the various members of the class. Clusters form so as to maximize similarity of objects within the class and dissimilarity of objects from different classes, therefore the class with higher fa mily resemblance separates earlier in clust ering. Table 2 reflects the measures of family resemblance of the consonant classes, and the prototypicality of the class members. The relation between family resemblan ce and each cluster is represented graphically in Fig.1. The arc lenght of the clusters is inverse to R and shows that the class with the highest R forms first. The correlative pair including the class member with the highest prototypicality attracts the nonpaired members (the pair/f,v/ attracts /h/). The order of the correlative pairs separation from the tree stem (Fig.2) is closely related to the pair similarity and the difference (S-D) between similarity and dissimilarity. The correlation between pair similarities and differences (S-D) is -0,94. There is no correlation between pair similarities and dissimilarities (r =-0,50), and between pair dissimilarities and differences (S-D)(r =076).These findings imply that the salience of the feature changes in the pair so that difference(S-D)and similarity remain in linear relation.

The organization of the 21 Bulgarian consonants in the perceptual space can be well interpreted in terms of the proposed phoneme model. In support we would like only to mention that there are relations among psychological axes, family resemblance, features, and physical properties of the consonants, and that time is the link connecting difference (S-D), order of pairs separation, and the distinctive feature of voicing.

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