Hearing Impairment and the Perception of Speech Sounds

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1. Epistemological issues

Multi Dimensional Scaling (MDS) methods commonly used in phonetics impose two basic assumptions:
1. *Symmetrical Distances*
2. *Homogeneous Samples*

to enable the analyst to develop perceptual maps of stimuli, the dimensions of which are assumed to represent the attributes along which each stimulus is compared (Shepard, 1972).

These assumptions constitute two heavy constraints upon empirical results:
1. the number of times stimulus 'i' is perceived 'j' by experimental S's is not necessarily equal to the number of times stimulus 'j' is perceived 'i' by the same subject: imposing that d(ij) = d(ji) implies that the specific nature of the stimuli is significantly altered.
2. assuming that S's are similar obviously precludes any further analysis of S's characteristic to explain dispersion of perception: moreover analyses of perceptual diversity do *not* use the same class of data as joint space configurations (respectively quadrant I and IV in Coombs' classification of data: Coombs, 1964).

2. 'Nearest neighbour'

Two French statisticians (Chandon and Pinson, 1981) have proposed a method encompassing these two heavy assumptions. In (very) short, this technique is included in the proximity analysis paradigm. When matrices of occurrence Mij are formed for two S's, A and B, a distance between A and B is calculated: this distance is the summation of the difference of observations elevated to square, in each cell (i,j) of the matrix for individual A and its homolog for B.

$$dAB = \sum_{MAT} \sum_{RON} \sum_{COL} (Cij\,(A) - Cij\,(B))^2$$

This method enables us to stress the *individual differences* of S's (instead of assuming sample *homogeneity*) and real distances between stimuli (without artificial symmetrization).

3. Research objectives

1. Since they assume sample homogeneity, researchers using MDS methods cannot take into account inter-individual differences: for a given group of individuals having similar audiometric test results, the whole perceptual configuration is necessarily attributed to common audiometric characteristics (Bilger and Wang, 1976). Not only the perceptive configuration is altered by artificial symmetrization, but the assumed homogeneity involves a very heavy assumption: auditive perception is strictly a peripherical phenomenon. This paper shows that individuals with similar audiometric patterns do not perceive similarly identical stimuli.
2. More specifically, the assumed relation between audiometric scores and perceptive behavior leads to the conclusion that hearing impaireds hardly perceive acute sounds (e.g. Schultz and Kratt, 1971; Pascoe, 1975; Barth and Chulliat, 1980). We challenge this specific relation with a distinctive feature analysis.

4. Study

12 French speaking adults whose better ear's threshold was at least 30 dB, were presented 36 monosyllables of CV type (both fricatives and occlusives) combined with vowels /a, i, u/.

These monosyllabic words were recorded by a male voice and presented 5 times in a random order to the individual subject through headphones; the sound level was adjusted by the individual subject to a comfortable level during a familiarization period.

Each subject had to cross the word which he/she believed to have heard among a choice of six words, printed in a form handed to the subject. Each word presentation was preceded by a warning light.

Data: The data were organized in 72 square matrices (six for each of the 12 S's as shown in the next table, table I).

The 'i-j' cell of the square matrix is the number of times the word 'i' has been perceived as the word 'j'.

5. Results

a. Interindividual audiometric differences

The 'nearest neighbour' technique, based upon the calculation of a distance from one individual to the other, allows us to construct a tree of proximity between individuals as shown in the next figure (figure 1).

Table I. Results subjects # 1

	P	T	K	B	D	G		P	T	K	B	D	G		P	T	K	B	D	G
PAS	2	2	1	0	0	0	PIE	5	0	0	0	0	0	POU	4	0	1	0	0	0
TA	0	5	0	0	0	0	TI	0	5	0	0	0	0	TOUX	0	5	0	0	0	0
CAS	0	0	5	0	0	0	QUI	1	0	4	0	0	0	COU	0	0	5	0	0	0
BAS	0	0	0	5	0	0	BIS	0	0	0	5	0	0	BOUE	0	0	0	5	0	0
DA	0	0	0	0	5	0	DIT	0	0	0	0	3	2	DOUX	0	0	0	0	5	0
GARS	0	0	0	0	0	5	GUY	0	0	0	0	1	4	GOÛT	0	0	0	0	0	5
	F	S	CHV		Z	J		F	S	CHV		Z	J		F	S	CHV		Z	J
FA	3	2	0	0	0	0	FIT	5	0	0	0	0	0	FOU	5	0	0	0	0	0
SA	0	5	0	0	0	0	SI	0	5	0	0	0	0	SOU	0	5	0	0	0	0
CHAT	0	0	5	0	0	0	CHIE	0	0	5	0	0	0	CHOU	0	0	5	0	0	0
VA	0	0	0	5	0	0	VIE	0	0	0	5	0	0	VOUS	0	0	0	5	0	0
ZA	0	0	0	0	5	0	ZI	0	0	0	0	5	0	ZOU	0	0	0	0	5	0
JAS	0	0	0	0	0	5	GIT	0	0	0	0	0	5	JOUE	0	0	0	0	0	5

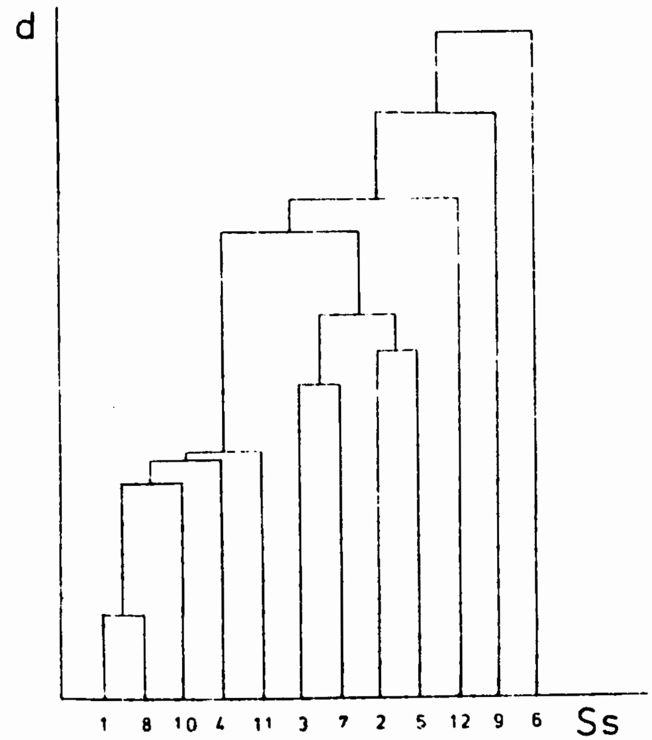

Figure 1. The tree of proximity with the nearest neighbour analysis.

This technique enables us to classify our impaired S's with the data of the perceptual test, without having to take into account their audiometric data.

A close examination of these audiological data shows that there is *no evident relationship with the classification based on the perception tests.* Individuals classified as similar for their perception of words have no comparable audiological characteristics in terms of threshold and discrimination. On the contrary some individuals with similar audiological data were classified in different groups through the nearest neighbour technique and the perceptual data.

b. Interindividual perceptual differences

The second way we used to analyze our data was a 'distinctive features' approach. Through this technique we tested the assumption that acute sounds are least successfully by the hearing impaired.

Our data were organised in two by two matrices as shown in Table II. The row represents the presence of feature 'F' on the first row and the absence of this feature 'F' on the second row, for the word emitted. The columns represent, for the word perceived, the presence of the feature 'F' on the first column and the absence of this feature 'F' on the second column.

Table II. A Distinctive Feature Matrix

	F	NF	
F	N-x	x	N
NF	y	M-y	M

We have chosen a classification as proposed by Jakobson and Halle (1967)
[p,b,f,v] as 'GRAVE'
[t,d,s,z] as 'ACUTE'
[k,g,ʃ,ʒ] as 'COMPACT' rather than non-grave/non-acute.

We also have pooled the 'VOICED' data which means that [b,v,d,z,g and ʒ] are in the same group.

For each row we were able to fix thresholds beyond which we can state the results are not randomly distributed according to chi-squared tables. Thus with the error data (x,y) we draw a graph as shown next figure (figure 2).

Here we have 4 areas but only 3 deserve attention:

- area 1 where there is no confusion:
  'F' is perceived as 'F'
  'NF' is perceived as 'NF'
- area 2 where there is no confusion on 'NF' but where 'F' is significantly perceived as 'NF'
- area 3 where there is no confusion on 'F' but where 'NF' is significantly perceived as 'F'

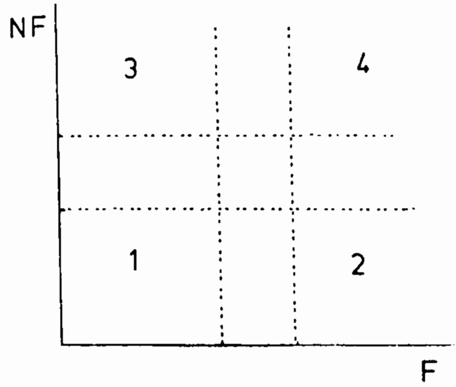

Figure 2. Graph of the distinctive features analysis.

A thorough examination of our data shows that not all features do bring about the same confusion. The next figure (Figure 3) describes the hierarchy of confusion.

The less successfully perceived sounds are grave and not acute, but there

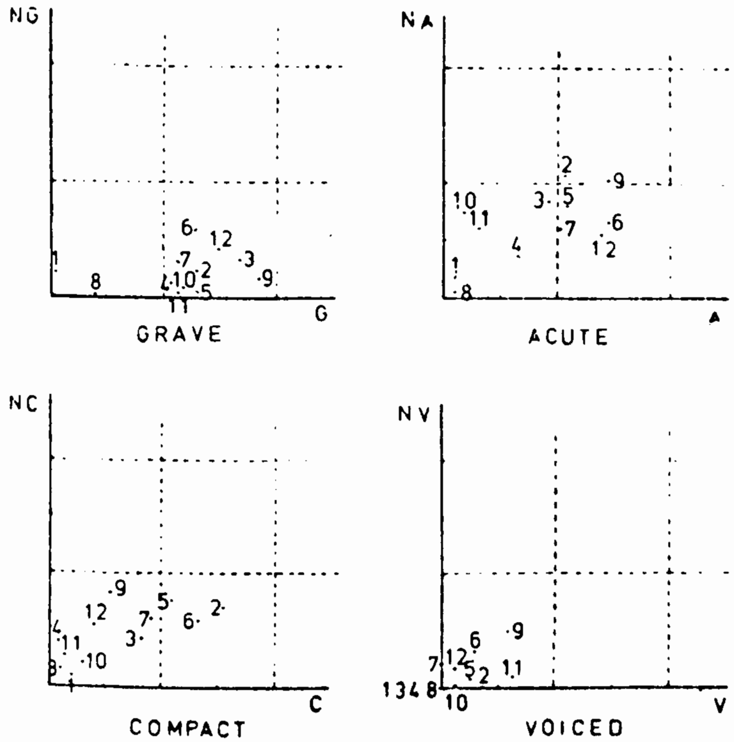

Figure 3. Results of the distinctive features analysis.

sounds are less successfully perceived than the compact one. The voiced sounds appear always to be recognized as voiced.

The different groups established by the nearest neighbour analysis could also be identified in this distinctive features analysis and shows the relationship between those two techniques.

6. Conclusion

The two techniques used (i.e. 'nearest neighbour' and 'distinctive feature') enable phoneticians to classify individuals when using perceptual data only.

Those techniques are superior to the MDS (multidimensional scaling analysis) since the researchers are not compelled to use big samples and do not force data into a statistical technique by artificial symmetrization.

We are inclined to think that audiological data cannot predict perceptual behavior mainly because hearing impaired individuals develop personal strategies of compensation since perception is a *central cognitive process* whereas audiological data concern physiological and peripheral processes.

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