SOUND SHAPE OF LANGUAGE AND CEREBRAL ASYMMETRY

VADIM DEGLIN OLGA TRACHENKO TATIANA CHERNIGOVSKAYA

Lab.of Brain Functional Asymmetry, I.M.Sechenov Institute of Evolutionary Physiology and Biochemistry, Acad.of Sciences, Leningrad, USSR 194223

ABSTRACT

The purpose of the study was to analyze cerebral asymmetry in speech sound processing. It is suggested that difference in hemispheric ability is of a qualitative nature: left hemisphere provides for correct phonemic analysis while right hemispheric competence is in prosodic arrangement of speech material, its quick global recognition. The research was performed in normal subjects and in patients of psychiatric clinics after unilateral electroconvulsive therapy.

In the beginning of the century the outstanding neurophysiologist I.P.Pavlov and the no less prominent hand in the science of language L.V.Shcherba were surprisingly unanimous in suggesting that tc know the laws of a functioning system one must examine its disturbances. I.P.Pavlov's words refer to the complex forms of brain activity, while the words of L.V.Shcherba - to language. Emerging in the middle of the century, neurolinguistics seems to integrate both applications of the idea. On the one hand, while studying disorders of speech processing caused by pathology it reveals cerebral organization of speech functions, on the other - the data obtained in this way explain many disputable questions of linguistic system structure. Among the founders of neurolinguistics one can name two eminent experts of science of this century - philologist R.Jakobson and neuropsychologist A.Luria. It was they who demonstrated the great value of "negative data" - both linguistic and cerebral.

Aphasiological tradition has postulated that all linguistic skills are the functions of the left hemisphere (LH), while the right hemisphere (RH) has nothing to do with language. The last decades produced a lot of data undoubtedly prov ing the fact of RH involvement in speech processing. Nowadays it is a generally accepted thesis though accompanied by alternative viewpoints: (1) the abilities of RH are duplicating those of LH, the difference lying in the degree of functions duplication (in full or in part); (2) the difference in hemispheric abilities is of qualitative nature - each contributing to speech activity. We adhere to the second viewpoint. The purpose of the present research was to reveal the involvement of each of the two hemispheres in phonetic material processing. Two procedures were used.

I. Monaural testing of normal subjects. The method enables one to see the hemispheric dominance for verbal processing (perception). Lists of words and nonsense words were presented monaurally to both left and right ear in turn. Reaction time (latent period between stimulus and response) was registered. A hemisphere was decided to be dominant for the analysis if reaction time for the stimulus heard from contralateral ear was shorter.

II. Testing of linguistic skills after unilateral electroconvulsive therapy, used in psychiatry. The seizures were administered to patients of psychiatric clinics. By this means develops a situation when for 30-50 min one hemisphere of the patient is suppressed and incapable of normal activity while the other one is intact and even reciprocally aided. Every patient has been subjected to both right- and leftsided shocks; it was possible to juxtapose the suppression effect of LH and RH in one and the same subject, as well as to compare it with speech functions in patient's normal conditions. The table below illustrates monaural testing that points to the fact that there are no significant ear differences in reaction time for presented nouns, adjectives and verbs.

STIMULI	MEAN REACTION TIME		p
	RIGHT EAR	LEFT EAR	
NOUNS	914 ± 5	918 ± 5	>0,05
ADJECTIVES	784 ± 5	789 ± 4	>0,05
VERBS	778 ± 3	773 ± 4	>0,05
Mean reaction time	828 ± 4	827 ± 4	>0,05
NONSENSE WORDS	1022 ± 4	1043 ± 5	<0,001

This suggests that the degree of each hemispheric involvement in meaningful words analysis is the same. The perception of nonsense words produces completely different results: the reaction time is much shorter when these are presented to the right ear, which show s dominating role of LH. It should be mentioned that the reaction time needed to process nonsense words is much longer than that for the meaningful words. The data oftained show two main differences in processing words and nonsense words: (1) words are equally well processed by both hemispheres, while nonsense words involve LH to a much greater degree. (2) To analyze nonsense words one needs more time. What lies at the basis of such a difference? Let us consider the data obtained after the suppression of one of the hemispheres.

The examination of verbal material discrimination revealed that after LH suppression the comprehension of words, logotomes and phonemes (both consonantal and vowel) is impaired. This phenomenon is in no way due to hearing disturbances: the sensitivity tests show no auditory deficit depending on the side of the hemispheric suppression.

Consonant and vowel discrimination analysis gives grounds for understanding the reason of discrimination impairment after LH suppression. Fig.1 demonstates typical failures in recognition of speech sounds, i.e. phonemic substitutions.

It can be seen that in their normal conditions patients substitute back

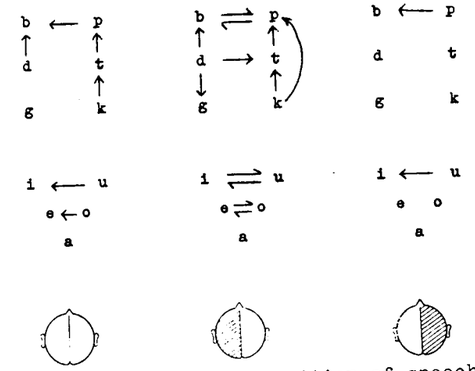

Fig.1. Failures in recognition of speech sounds after unilaterial ECT. Most frequent types. The schemes below represent the state of subjects (inactivated hemisphere is black).

vowels by front vowels, voiceless consonants by voiced ones, dentals by bilabials, velars by dentals. Errors in speech sound recognition are, therefore, in no way due to chance, quite the reverse, they demonstrate a kind of regularity - we see neutralization of some phonemic oppositions. After LH suppression the amount of errors increases along with the widening of the range of errors: front vowels are now confused with back vowels, velars with bilabials, dentals with velars etc. Accordingly LH inactivation leads to a considerable decline in discrimination ability caused by phonological system disorder and incapability of distinctive feature analysis. What is important is that the neutralization of phonemic oppositions observed after LH suppression, is never seen in patents' normal conditions. The change in the ability of speech sounds recognition after RH suppression is of a different nature: its facilitation is illustrated by fig.1. Misinterpretations concern only consonant voicing and mixing of high back or front vowels. Such a facilitation of functions after RH suppression is due to LH reciprocal activation.

Let us consider now the investigation of phoneme boundaries for stationary vowels. We used 46 vowel-like stimuli with constant F3 and F4 and variable F1 and F2. The subject had to classify each presented stimulus as one of the phonemes. The control testing revealed the same general regularities as already observed in investigation on normal subjects. Neither LH nor RH inactivation affected the average formant position. On the other hand there occured remarkable differences with regard to magnitude of uncertainty(fig.2)

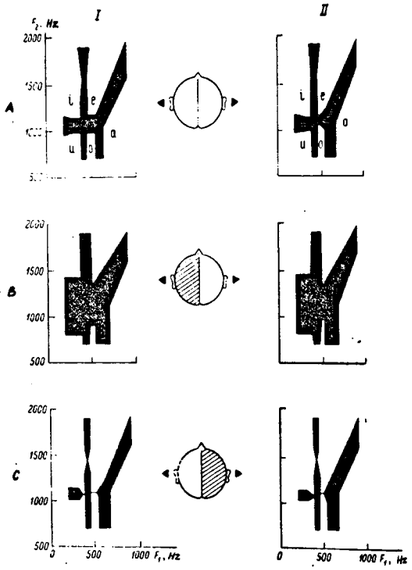

Fig.2. Zones of uncertainty ($\bar{x}\pm\sigma$) in the regions of phoneme boundaries after unilateral ECT. (I) and (II) Performance by the left and right ear respectively. The schemes are the same as in Fig.1.

Thus, after LH suppression the range of areas of uncertainty grew considerably; they were most outspoken in the regions close to F2. In our opinion it is the result of phonemic classification impairment. Knowing that F2 is closely correlated to the dimension front-back we can understand the impairment of front-back vowels discussed earlier. The suppression of RH leads to narrowing (or even disappearance) of the areas of uncertainty, i.e. to the phonemic categorization impairment.

On the whole LH inactivation results in phonological system disorder, reverts the hearing to an infrahuman state when the ability to interpret the significance of F2 is lost. RH inactivation and LH functions improvement leads to phonological coding facilitation even if compared with patients' natural conditions. Thus the research shows that phonological coding is the function of LH. It becomes clear why LH is preferable for perception of nonsense words: to discriminate them one needs the most accurate phonological encoding, since there is no other way for the perception of nonsense words. Then we must assume that RH's speech perception is of a different kind: it proceeds without phonemic encoding. In what way, then? The most probable procedure is to take the word as a whole unit, to use a kind of global, Gestalt perception strategy. There is certain evidence to prove it. The research points to the fact that while discrimination of words and syllables after RH inactivation improves, the number of mistakes of certain types drastically increases: phonemes, syllables and accents could be misplaced and the former ones even totally omitted. Similar mistakes could be found in patients' spontaneous speech production; these are: wrong rhythmical patterns both of words and sentences, monotonous or, vice versa, irrelevantly accentuated speech. Experiments show prosodic perception impairment: with disfunctional RH the identification of intonational patterns - both rendering grammatical meanings - interrogative, imperative and declarative patterns, or, especially, emotional moods - decreases considerably. Under these conditions discrimination of male/female, young/old, familiar/unfamiliar voices becomes impaired.

Fig.3. illustrates the perception of synthetically produced phonemes/a/and/i/ with two varying (high and low) fundamental frequencies.

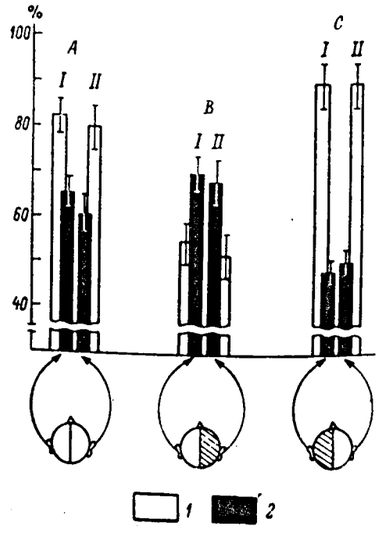

Fig.3. Discrimination of synthetic vowels/a/and/i/ as to their pitch (1) or phonemic quality (2) after unilateral ECT. (I) and (II) and the schemes are the same as in Fig.2.

After RH inactivation the subjects could not determine whether the stimuli were produced by a male or a female but easily identified phonemic quality of the stimuli. On the other hand after LH inactivation the phonemic quality identification was impaired while pitch recognition became more accurate in comparison with patients' normal conditions.

The experiment demonstrates how hemispheric functions specialize even in dealing with the smallest sound segment. We can suggest therefore that it is the RH that is responsible for paralinguistic and prosodic perception. It is well known that prosodic - suprasegmental-features play prominent role in the sound shaping of words - accent contours distinguish individual words, whereas intonation contours distinguish different sentence types. Prosodic features arrange elements to form the units of a higher order: phonemes - to form a word, words - to form a sentence. Consequently the global Gestalt way of perception must be realized by RH structures. However, such a strategy could be used only for previously familiar speech material. It is impossible to discriminate nonsense words using this way of perception.

In relation to the theoretical issues considered in this paper it is obvious that both cerebral hemispheres take part in forming sound shape of language. LH provides for correct phonemic analysis, enabling to reduce sound continuum to functionally relevant segments. The role of RH is to realize global or so called template recognition.

To sum up, the results of the present study suggest that brain has different mechanisms for speech perception. RH mechanism provides for quick orientation in familiar speech material. LH mechanism secures accuracy of discrimination as well as processing of unfamiliar speech samples; but loses in speed of perception. Under usual communicative conditions both mechanisms function simultaneously resulting in optimum speech perception.