Human Physiology, Vol. 30, No. 4, 2004, pp. 403–409. Translated from Fiziologiya Cheloveka, Vol. 30, No. 4, 2004, pp. 32–39.

Hemispheric Asymmetry in Prosody Perception by Healthy Subjects and Schizophrenic Patients

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Received October 28, 2003

Abstract—The interhemispheric interactions in perception of Russian prosody were studied in the norm and in schizophrenia as a clinical model of impaired hemispheric interactions. Monaural presentation of stimuli and binaural presentation in a free acoustical field were used. Sentences with main variants of Russian prosodic intonations were used as stimuli. The response time and the number of erroneous responses were recorded. In binaural listening without headphones, no significant difference in the percent of errors in identifying the emotional prosody was found between healthy subjects and schizophrenics. Compared with the healthy subjects, the patients made more errors in understanding the logical stress and fewer errors in understanding the syntagmatic segmentation. By response time, a significant dominance of the left ear was revealed in the healthy subjects during monaural listening to sentences with emotional prosody and complete or incomplete sentences, whereas no significant ear dominance was found in the schizophrenics. During monaural listening to sentences with logical stress, the response time was shorter when stimuli were presented to the right ear both in the healthy subjects and in the schizophrenics. The results testified that the functional brain asymmetry in schizophrenics is flattened. The flattening was less evident in the perception of a logical stress in a sentence and did not significantly affect the efficiency of identification of emotional prosody and syntagmatic segmentation of a sentence.

The involvement of cognitive functions, such as thinking, memory, and emotions, in the mechanisms of formation of affective speech is one of the main problems of modern psychophysiology. The available data (though few and contradictory) testify to syntactic and semantic disorders of the perception of linguistic information by schizophrenic patients. One of the aspects of this problem is associated with the concept of the functional brain asymmetry. At this point, a kind of functional insufficiency of the right hemisphere and impairment of interhemispheric interactions can be suggested for schizophrenia.

It was found back in the 1970s that perception of emotional prosody is to a great extent associated with the activation of the right-hemispheric structures [1, 2]. As has been repeatedly shown more recently, patients with perceptual aprosody are comparable with those with a right-hemispheric deficit and sharply differ from patients with a left-hemispheric deficit, whereas focal left-hemispheric brain lesions are accompanied by impairment of the recognition of emotional prosody [3–5].

On the whole, studies of speech perception with the method of dichotic listening testify to the flattening of interhemispheric asymmetry in schizophrenics [6–10]. For example, a dichotic presentation of monosyllabic words to such patients has revealed the absence of the right-ear effect [8]. The authors explain this phenomenon by the involvement of not only the left but also the right hemisphere in phonemic and lexical perception of speech sounds [8]. Schizophrenic patients have been presented with faces with different emotional expressions and speech with emotional prosody [9]. It has been found that the patients cope with both tasks worse than do healthy subjects.

However, there are some peculiar features in the performance of schizophrenics. Thus, comprehensive analysis of the results of studies with dichotic listening has not revealed an appreciable difference in functional hemispheric asymmetry between healthy subjects and schizophrenics [10]. However, in schizophrenics, a substantial decrease in the lateralization level has been found in individual tasks, i.e., in dichotic presentation of vowels/consonants or of rhymed words.

We and other authors have shown earlier that the adequate perception of prosody is normally associated with a balanced activity of the brain hemispheres [11–15]. However, there is also evidence that the activity of the brain hemispheres substantially varies depending on the stage of the disease and the structure of the psychopathological defect, in particular, on the severity of affective disorders and thinking impairment. This partly explains the discrepancies in the literature data and suggests that it is necessary to analyze the results of such studies differentially, with consideration for the above clinical factors [16–19].

In this connection, it seems important to study the perception of emotional and linguistic intonations in

Table 1. Distribution of the schizophrenic patients by form of the disease

ICD-10 code	Number of patients
F20.0, paranoid	
F20.00, continuous course	40
F20.01, episodic with progressing defect	12
F20.02, episodic with stable defect	9
F20.03, episodic remittent	3
F20.6, simple	15
F20.8, other	3
F21, schizotypal disorder	12
F25.0, schizoaffective disorder, manic type	3
F25.1, schizoaffective disorder, depressive type	3

clinical cases, i.e., in conditions with impaired thinking and emotions. These disorders are observed, in particular, in schizophrenia, which is associated with problems in identifying general emotional expression [20–22]. Such studies with perception of Russian speech have not been performed thus far.

METHODS

We included 60 healthy subjects (32 women and 28 men) aged from 20 to 55 years (mean 29 years) into the control group. All subjects were native Russian speakers with the normal symmetrical audition.

The group of schizophrenics, with the diagnosis based on the tenth version of the International Classification of Diseases (ICD-10), was made up of 100 patients (48 women and 52 men) aged from 18 to 56 years (mean 31 years) with a disease record from 2 to 23 years (mean 8 years). They all were treated at outpatient department no. 2 (St. Petersburg Psychoneurological Dispensary no. 7). The patients had different forms of schizophrenia and schizoaffective or schizotypal disorders (F20–F25, ICD-10). These diseases were pooled together based on the concept of a single genetic spectrum of schizophrenia [23, 24]. The distribution of patients by the form of the disease in accordance with the ICD-10 criteria is presented in Table 1.

Russian sentences with different functions of prosodic intonation were used as stimuli. We used different affective prosodies (expressing emotional states of surprise, condemnation, bewilderment, etc.), communicative prosody (inducing actions, for example, a question, a request, an order, etc.), logical stress (for example, *Pete will go to the cinema*, i.e., Pete, not Basil, will), syntagmatic segmentation (the sense of the sentence depends on the correct perception of an interval, for example, *punishment impossible, to forgive*), and complete or incomplete sentences. The sentences were pronounced (within the minimum necessary context, afterwards removed) by a professional woman announcer, tape-recorded, and transformed into sound files.

At the first stage of the study, stimuli were applied in a free acoustic field; the sound level and the sound source location were fixed. At the second stage, stimuli were presented monaurally via headphones to the right or the left ear at random. Simultaneously, suprathreshold white noise balanced by the RMS power was applied to the contralateral ear. After listening, subjects selected one of two sentence characteristics displayed on a computer monitor by pressing a corresponding key on the keyboard. The response time and the number of correct responses were recorded. In the common technique of monaural listening, a lower time of response and a higher percent of correct responses to stimuli applied, for example, to the left ear testify that the perception is asymmetric and the signal is processed predominantly by the right hemisphere.

All subjects were tested for the laterality profile with the aim of excluding subjects with left-side sensory and motor dominance from the examination. The healthy subjects were examined using the TOPOS software developed previously [25]. The tests were based on the well-known laterality test batteries adapted for Russian speakers. The schizophrenics were examined similarly with printed copies of the tests at the beginning of the study. The state of patients was assessed by an expert method by qualified psychiatrists. Impairment of thinking was scored as recommended in item 2 (Conceptual Disorganization) of the Positive Syndrome Scale of the Positive and Negative Syndrome Scale (PANSS). Emotional disorders were evaluated with items 1 (Blunted Affect) and 2 (Emotional Withdrawal) of the Negative Syndrome Scale of the PANSS.

RESULTS AND DISCUSSION

Perception of stimuli presented binaurally in a free acoustic field. In the perception of all types of prosody, the mean percents of errors were 27 ± 3% in the healthy subjects and 30 ± 5% in the schizophrenics (the difference was nonsignificant). In the perception of emotional prosodies, the percents of errors were 27 ± 4% in the healthy subjects and 30 ± 6% in the schizophrenics (the difference was nonsignificant). In the perception of logical stress, the percents of errors in the healthy subjects and the schizophrenics were 20 ± 3 and 32 ± 5%, respectively ($P < 0.05$); i.e., the schizophrenics gave significantly more erroneous responses. In the perception of sentences with syntagmatic segmentation, the percents of errors were 26 ± 3% in the healthy subjects and only 12 ± 4% in the schizophrenics ($P < 0.05$). Thus, the perception of sentences with syntagmatic segmentation was significantly better in the schizophrenics than in the healthy subjects (Fig. 1). No significant differences were found in perception of complete or incomplete sentences and sentences with different communicative load. The mean response times of the healthy subjects and of the patients were,

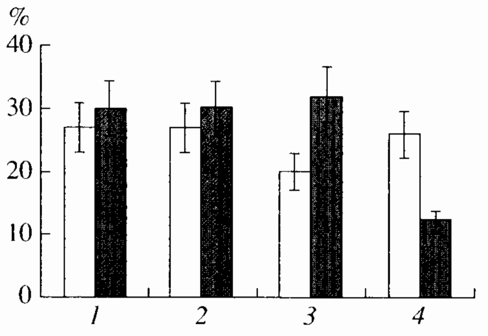

Fig. 1. Percent of errors made by healthy subjects (unshaded columns) and schizophrenic patients (shaded columns) in the perception of intonation contours presented in the free acoustical field ($P < 0.05$). Abscissa: (*1*) all types of prosody; (2) emotional prosody; (*3*) logical stress; (*4*) syntagmatic segmentation.

respectively, 320 ± 20 and 820 ± 60 ms in the perception of all types of prosody, 320 ± 50 and 820 ± 60 ms in the perception of emotional prosody, 380 ± 60 and 870 ± 70 ms in the perception of logical stress, 450 ± 40 and 820 ± 50 ms in the perception of syntagmatic segmentation, 350 ± 40 and 840 ± 60 ms in the perception of communicative sentences, and 330 ± 50 and 830 ± 50 ms in the perception of complete or incomplete sentences. Thus, during performance of tasks of all types, the response time was significantly higher ($P < 0.01$) in the schizophrenics than in the healthy subjects. In the schizophrenics, no correlation was revealed between the percent of errors, reaction time, and disease record.

Monaural listening. In the healthy subjects, the mean response time in the presentation of emotional prosody was 290 ± 20 ms for the left ear and 340 ± 20 ms ($P < 0.05$) for the right ear, which testifies to the analysis of such stimuli predominantly by right-hemispheric structures. In the schizophrenics, the mean response times were 800 ± 70 ms for the left ear and 830 ± 80 ms for the right ear ($P > 0.05$); i.e., there was no significant difference in the involvement of the brain hemispheres in stimuli analysis.

In recognition of complete or incomplete sentences, the mean reaction times of the healthy subjects were 310 ± 30 ms for the left ear and 400 ± 40 ms for the right ear ($P < 0.05$), which testifies to the analysis of such stimuli predominantly by structures of the right hemisphere. In the schizophrenics, the mean reaction times were 810 ± 70 ms for the left ear and 820 ± 60 ms for the right ear ($P > 0.05$). Thus, as distinct from the healthy subjects, the schizophrenics did not display significant interhemispheric asymmetry in the response time during perception of emotional prosodic intonations and complete or incomplete sentences (Figs. 2a, 2b).

In the healthy subjects, the mean reaction times for sentences with different logical stress were 400 ± 20 ms for the left ear and 330 ± 40 ms for the right ear ($P < 0.05$), which testifies to the analysis of such stimuli predominantly by structures of the left hemisphere. In the schizophrenics, the mean reaction times for these stimuli were 890 ± 60 ms for the left ear and 710 ± 50 ms for the right ear ($P < 0.05$). Thus, in the schizophrenics, as in the healthy subjects, there was a dominance of the left hemisphere in the analysis of sentences with logical stress (Fig. 2c). As for the percent of correct responses to sentences presented to the right or the left ear, in all kinds of tasks, no significant difference in the extent of right- or left-hemispheric involvement in the analysis was revealed either in the healthy subjects or in the schizophrenics.

In neither group did men and women differ significantly in the asymmetry coefficient estimated by the response time or the percent of errors.

Among the clinical factors characterizing the patients with schizophrenia, the disease record, the severity of structural thinking disorders, and the emotional deficiency had a significant effect on the linguistic processes examined (Table 2; a positive correlation coefficient testifies to an increase in percent of errors with an increase in the above characteristics; nonsignificant correlation coefficients are omitted). Analysis of the correlation between the percent of errors in responses to sentences with syntagmatic segmentation on presentation to one ear (i.e., mainly to the contralateral hemisphere) and clinical characteristics such as the emotional deficiency, the impairment of thinking, and

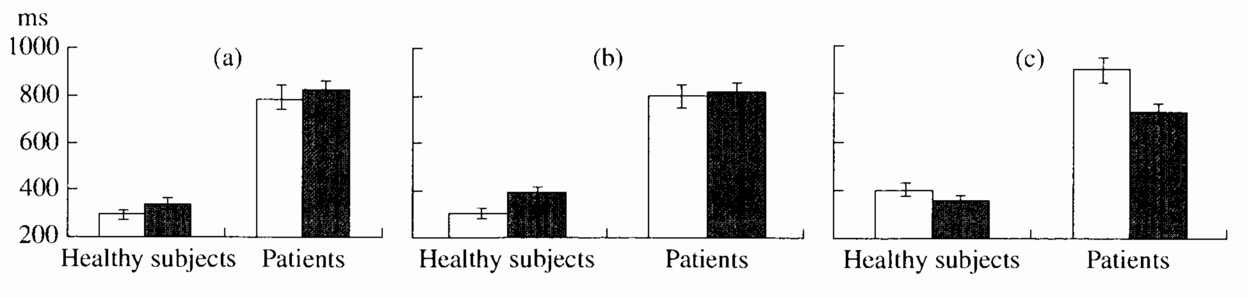

Fig. 2. Response time upon monaural presentation of (a) sentences with emotional prosody, (b) complete or incomplete sentences, and (c) sentences with logical stress to the left (unshaded columns) or the right (shaded columns) ear ($P < 0.05$).

Table 2. Statistical correlations (Spearman's rank correlation coefficients significant at $P < 0.01$) of the percent of errors and the response time observed on monaural presentation of sentences with the clinical characteristics of the schizophrenics

Characteristic	Percent of errors		Response time	
	right ear	left ear	right ear	left ear
Syntagmatic segmentation				
Emotional deficiency	0.7	0.4	0.4	0.5
Thinking disorder	0.7	0.4	0.25	0.25
Disease record	0.4	0.3	0.5	0.4
Emotional prosody				
Emotional deficiency	0.3	–	0.5	0.5
Thinking disorder	0.3	–	0.25	0.4
Disease record	0.5	0.2	0.5	0.5
Logical stress				
Emotional deficiency	0.4	0.3	0.4	0.5
Thinking disorder	0.5	0.3	0.25	0.25
Disease record	0.25	0.5	0.5	0.5
Communicative type				
Emotional deficiency	0.5	0.6	0.5	0.5
Thinking disorder	0.3	0.6	0.25	0.4
Disease record	0.5	0.7	0.6	0.6
Complete/incomplete sentences				
Emotional deficiency	–	–	0.6	0.6
Thinking disorder	–	–	0.4	0.4
Disease record	0.5	0.3	0.7	0.8

the disease record showed that the correlations were significantly stronger for the right ear, i.e., when the sentences were addressed predominantly to the left hemisphere (Table 2). This suggests an asymmetric effect of the pathological process on task-specific cognitive functions (i.e., on perception of sentences with syntagmatic segmentation rather than on general perception).

However, analysis of the correlations between the response time and the disease characteristics revealed only slight hemispheric asymmetry in perception of sentences with syntagmatic segmentation (Table 2).

Concerning the correlation between the functional activity of the hemispheres and the clinical characteristics of the disease in the case of the perception of sentences with different prosodic intonations, a significant coefficient was obtained only for the percent of errors and the disease record and was higher for the left hemisphere (Table 2). As for the response time, moderately strong significant correlations were obtained for all three clinical characteristics under study for both hemispheres. Yet interhemispheric asymmetry in this case was revealed only in correlation with the thinking disorders: the correlation was significantly higher on presentation of stimuli to the left ear (Table 2).

In the case of the perception of sentences with logical stress on presentation to the left or the right ear, analysis of the correlation between the percent of errors and the clinical characteristics revealed significant differences between the activities of the hemispheres as dependent on the disease duration: the percent of errors on presentation of stimuli to the left ear increased with increasing disease record (Table 2). Unlike with the number of errors, there was no significant difference in the involvement of the hemispheres in the perception of prosody (or logical stress) in the case of correlations between the clinical factors under study and the response time (Table 2).

For the perception of sentences with a communicative load, a correlation of the percent of errors with the clinical characteristics was significantly higher for the right hemisphere (Table 2). However, similar correlations calculated for the reaction time and the severity of clinical symptoms revealed significant asymmetry only for the impairment of thinking. In this case, a stronger correlation was observed for the right hemisphere (Table 2).

In the case of recognition of complete or incomplete sentences, significant differences were observed for the number of errors. A longer disease record was associated with the asymmetry, which was due to a greater number of errors in responses to stimuli applied to the right ear. However, the asymmetry in the number of errors did not correlate with the emotional defect or the impairment of thinking (Table 2). As for the response time, rather strong correlations with clinical characteristics were revealed for each hemisphere, but there was no significant asymmetry in this case (Table 2).

Factors such as the form of the disease, its course, and the presence and severity of positive symptoms showed rather weak, nonsignificant correlations both with the number of errors and with the response time in all types of the tasks. The same was true for the effects of age, gender, and the educational level of the patients.

Our findings testify that the recognition of emotional prosody is much the same in schizophrenics and in healthy subjects, which contradicts the presuppositions based on the perceptive emotional disorder commonly accepted for such patients. Results leading to similar conclusions were obtained earlier by some other authors [26]. For instance, audio and video recordings of theatrical scenes that were performed by actors and induced different emotions were presented to healthy subjects and schizophrenics. In this study, the schizophrenics did not differ appreciably from the healthy subjects in emotional identification of these scenes. As follows from a number of works [20–22], schizophrenics have an impaired capability to recognize the emotional expression of the face and gestures. Consequently, it was probably the emotional prosody of the actors that was the basis for the emotional recognition of the scenes played.

However, it is known that the emotional aspect of speech reproduction suffers in schizophrenia [27]. This suggests that the active and better realized processes of the reproduction of emotional prosody are impaired to a greater extent than the processes of prosody perception, which are relatively more automated and realized to a lesser extent. In other words, it seems probable that patients can feel emotions but are incapable of their proper expression in speech, as also observed in other studies [28].

Probably, the impaired reproduction of emotional prosody in schizophrenia is associated, in particular, with motor speech disorders, although a frontal deficit is most likely the chief cause.

The perception of sentences with logical stress demands a more conscious decision. The functional hierarchy of connections between the neural structures and the mechanisms potentially involved in a behavioral act builds up. Eventually, this decreases the reliability of the functional system and increases the probability of regulation failures during slight deviations of metabolic and receptor parameters from the phenotypic reaction norm [29]. The greater percent of errors in identification of sentences of this type by the schizophrenics might be associated with such failures.

The significantly lower percent of errors made by the schizophrenics in recognizing sentences with syntagmatic segmentation is of particular interest. In our opinion, this can be explained by the broken thinking, i.e., ataxia. As applied to the adaptive mode of the activity of the functional system, the influence of collateral excitation of cortical neurons on the neuronal structure accepting the results of action becomes triggering in this case. This influence discords with the afferent stream of electrochemical signals that carry significant information. It can be assumed that it is the associative collateral excitation streams that are to a greater extent responsible for semantic identification of sentences with syntagmatic segmentation. These streams only slightly depend on afferent reinforcement; that is why thinking disorders in schizophrenia do not impair the semantic identification of sentences with syntagmatic segmentation. However, further investigations with other methods (for example, functional brain mapping) are necessary to test this assumption.

Our data indicate that, in schizophrenics, the hemispheres are less specialized and their functioning grows worse with the disease progression. A similar lack of interhemispheric asymmetry in schizophrenia has also been observed in other studies [6, 8, 30–32]. However, in this work, we are concerned with the physiological, rather than clinical, aspect of this problem: we discuss it from the viewpoint of whether the data provide for a better understanding of the patterns of interhemispheric interactions during the perception of prosodic speech characteristics. Physiologically, such a lack of interhemispheric asymmetry can be explained by the formation of new profiles of transmitter–metabolic interactions of hemisphere neuronal populations under conditions of a deviation of the modification variability from the phenotypic reaction norm.

In the schizophrenics, we revealed no functional hemispheric asymmetry in the perception of emotional prosody, whereas right-hemispheric dominance was observed in the healthy subjects. As seen from our data, the capability for perception of emotional prosody decreases for both hemispheres with an increase in disease record and emotional defect. From the facts that the right hemisphere normally predominates in this type of perception and that the asymmetry is lacking in schizophrenics, we can draw the conclusion that the right hemisphere suffers to a greater extent than the left one in schizophrenia. It is possible that the relatively intact binaural perception of emotional prosody in schizophrenics is associated with a compensatory hyperfunctioning of the left hemisphere. This leads to the formation of a pathological brain system with a new profile of interhemispheric interaction. Judging from the responses to stimuli applied in a free acoustic field, this system copes rather effectively with the identification of emotional prosody.

Analysis of the response time revealed a dominance of the left hemisphere during monaural listening to sentences with logical stress in the schizophrenics, who were similar in this respect to the healthy subjects. This confirms our suggestion above that the left hemisphere is to a lesser extent (or at least later) involved in the pathological process as compared to the right hemisphere, which makes compensatory hyperfunctioning of the left hemisphere possible.

The data on the perception of sentences with syntagmatic segmentation by the schizophrenics are the most difficult to interpret in terms of the concept of interhemispheric asymmetry. The problem is that the healthy subjects displayed no significant asymmetry during perception of this kind of prosody. As pointed out above, both hemispheres seem to contribute substantially to the perception of sentences with syntagmatic segmentation. Hence, it can be assumed that a higher functional activity of one hemisphere, the left, is responsible for better perception of these sentences by the schizophrenics as compared to the healthy subjects. Probably, the insufficiency of the right-hemispheric activity in schizophrenia is not general; rather, it seems to be functionally partial, depending on the specific neuropsychological task. It is this approach to interhemispheric brain asymmetry that is adequate from the standpoint of modern neurophysiology.

CONCLUSIONS

(1) Normally, different lateral profiles correspond to the perception of different types of prosodic characteristics of speech: the right hemisphere is involved predominantly in analyzing the emotional prosody and sentences differing in completeness, whereas the left hemisphere significantly dominates in the perception of sentences with logical stress.

(2) In schizophrenia, the functional brain asymmetry in the activity under study is flattened. It can be assumed that the left hemisphere is to a lesser extent involved in the pathological process, which is probably associated with its relative compensatory hyperfunctioning in the analysis of the linguistic structures under study.

(3) Impairment of the interhemispheric interaction in schizophrenia does not decrease significantly the efficiency of identification of emotional prosody and sentences with syntagmatic segmentation.

(4) There is no direct correlation between the efficiency of identification of emotional intonation and the emotional state of the perceiving subject.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research, project no. 03-06-80068.

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