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Methods of dichotic listening as a research methodology for hemispheric interaction

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Experimental data was obtained from a dichotic listening test by patients with unilateral brain lesions and corpus callosum pathology (agenesis, cysts, degenerative changes, etc). Efficiency index analysis shows that interhemispheric interaction in the audioverbal sphere depends to a greater extent on the right hemisphere state. The dichotic listening technique is not an informative means of studying hemispheric interaction, since it does not allow a clear distinction between hemispheric symptoms and symptoms of pathology of the corpus callosum. Thus, violations of hemispheric relations caused by disorders of the corpus callosum and cerebral hemispheres change worth more right hemisphere activity.

Keywords: interhemispheric interaction, brain pathology, dichotic listening

Dichotic listening is one of the most widespread procedures for studying interhemispheric interaction in the audioverbal sphere. Specific peculiarities of interhemispheric interaction during audioverbal information processing distinctly reveal themselves when analyzing the efficiency indices of dichotic stimuli reproduction (Goldberg, 2003: Moskovichute, Golod, 1989). For this reason, special attention is paid to analysis of the efficiency coefficient (the quantity of correctly reproduced words — C_{Ef}). C_{Ef} reflects each hemisphere's contribution to these processes. Total C_{Ef} is estimated in order to evaluate the efficiency of the reproduction of dichotic stimuli originally produced on both ears. C_{Ef} of the right ear and C_{Ef} of the left ear serve to evaluate the reproduction efficiency of words perceived by the right or left auditory canal to determine the quality of participation of the hemisphere that is contralateral to the ear in the audioverbal processes:

$$C_{Ef} = S / tqw \times 100\%,$$

where S is the the sum of correctly reproduced words, and tqw is the total quantity of sample words.

The experiment results and the estimated coefficient of the right ear (CRe), which is calculated by the following formula (Kotik, 1974):

$$CRe = (\Sigma Re - \Sigma Le) / (\Sigma Re + \Sigma Le) \times 100\%,$$

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where ΣRe is the total number of correctly reproduced words presented to the right ear, and ΣLe is the total number of correctly reproduced words presented to the left ear.

Method and participants

In this work, the dichotic listening method of D. Kimura (Kimura, 1961), adapted to the Russian language by Kotik B.S. (Kotik, 1974), was employed to study interhemispheric interaction in audioverbal processes. The experimental procedure consisted of 13 productions of verbal stimulus material. During the first series a participant perceived four dichotic pairs of words through headphones. The participant was asked to identify all the words heard before the next production. Then the earphones were switched around, and the procedure was repeated (the second series). Only the first series' results were taken into consideration, as the reproductions in the first and second series differed qualitatively from each other, i.e. during the second series there was a substantial increase in the quantity of words reproduced by the left ear. In some cases the sign of the coefficient changed from the right ear to the opposite side. It was presumed that during the second series of the experiment, the indices of functional asymmetry influenced the learning processes. This fact had already been observed by Russian and international researchers (Moskovichute, Golod, 1989; Golod, 1992). In their studies, V.I. Golod repeatedly noticed that productivity indicators playback dichotic stimuli presented can be used not only to assess hemispheric asymmetry, but also to determine the level and degree of preservation of the functional capabilities of each hemisphere (Golod, 1992, p. 48-49).

Participants. There were four groups of participants formed for examination. All of the participants were dextral. The healthy group consisted of 50 persons — 20 males and 30 females — with ages ranging from 16 to 52 years. The group of patients with pathological process localization in the left hemisphere (later as "left-hemispheric") consisted of 21 persons — 12 males and 9 females with ages ranging from 21 to 67 years. This group included patients with epilepsy (11 persons) and persons who have suffered strokes (10 persons). In the second experimental group there were patients with right-hand-side localization of a pathological process (later as "right-hemispheric"): 23 persons — 13 males and 10 females with ages ranging from 18 to 72. This group also included patients with epilepsy (15 persons) and persons who have suffered strokes (8 persons). The third experimental group consisted of participants with corpus callosum pathology (later as "CC group"): 18 persons — 12 males and 6 females with ages ranging from 15 to 64 years.

The procedure in this study consisted of 13 presentations (subseries) of verbal stimulus material through headphones. Each subject was brought against sub 4 dichotic word pairs. Before each presentation there was a 20-second pause, in which the subjects were asked to name them all the words they heard, in any order.

Subjects were given a neutral instruction: "Now both your ears will hear different words. You must listen to them carefully and memorize them, and during the pause, tell me everything you remember. Try not to focus on just one ear." The headphones were then swapped (from left to right and from right to left), and the procedure was repeated (the second series of experiments). A training series to adapt to the dichotic listening test situation was offered. For analysis, only the first series of indicators of dichotic listening were taken. It is assumed that the second series of experiments on the performance of functional asymmetry affect the learning process (Moskovichute, Golod, 1989; Goldberg, 2003).

Results and discussion

In the healthy group, total C_{Ef} was in the value range of 27.89–52.89% (mean 40.58%). C_{Ef} of the right ear — 15.39–69.23% (mean 45.54%). C_{Ef} of the left ear — 13.46–57.69% (mean 35.62%). In the left-hemispheric group total C_{Ef} was in the value range of 17.31–42.31% (mean 28.16%), C_{Ef} of the right ear — 1.92–67.31% (mean 32.97%), C_{Ef} of the left ear — 1.92–51.92% (mean 23.35%). In the right-hemispheric group total C_{Ef} came to 15.39–50% (mean 34.74%), C_{Ef} of the right ear — 15.39–100% (mean 50.92%), C_{Ef} of the left ear — 0–50% (mean 18.56%). In the CC group the value of total C_{Ef} was in the range of 11.54–53.85% (mean 32.93%), C_{Ef} of the right ear — 3.85–75% (mean 35.82%), C_{Ef} of the left ear — 1.92–61.54% (mean 30.04%). Most of the correctly reproduced words were found in the healthy group, and the lowest number were in the left-hemispheric group, which is clear from the mean values of total C_{Ef}. In other words, reproduction efficiency in the course of task fulfillment saw the worst decrease in case of left hemisphere pathology (prepotent in speech in most cases). At the same time, the functional capabilities of both the left and right hemispheres changed in all the groups of participants with the brain pathology. There were statistically significant differences found in the reproduction of words with the trend of the right ear prevailing over the left one ($U = 583.5$; $p < 0.001$). The efficiency of each acoustic canal significantly differed from the index of total efficiency (C_{Ef} and C_{Ef} of the right ear: $U = 793.5$; $p = 0.002$; C_{Ef} and C_{Ef} of the left ear: $U = 775.5$; $p = 0.001$). In fig. 1 it is clear that more words were produced by means of the right ear than by the left one (the right-ear effect). The greatest number of participants were concentrated in the third interval (40 to 60%) according to the values of C_{Ef} and C_{Ef} of the right ear, in the second interval (20 to 40%) — according to the values of C_{Ef} of the left ear. Let these intervals be considered as normative. One could also see in the picture that the participants were in the range of values from 20 to 60% according to all the efficiency coefficients. In the ultimate intervals, the percentage of participants was approaching or equal to zero. In the left-hemispheric group, in comparison with the healthy group, we observed a statistically significant fall according to all the efficiency coefficients (C_{Ef}: $U = 98.5$; $p < 0.001$; C_{Ef} of the right ear: $U = 292.5$; $p = 0.003$; C_{Ef} of the left ear: $U = 226.5$; $p < 0.001$). There, differences in words reproduction by means of acoustic canals continue to prevail towards the right ear. There was no activity of the right hemisphere, which would have borne a compensatory character owing to the earlier-proven fact of inhibition of the symmetric parts of the safe right hemisphere by the focus in the left hemisphere (Traugott, 1986). One could presume that as a consequence of inhibition, the right hemisphere functioning decreased, and the noise-proof feature was broken (the two acoustic canals play the role of noise to each other), as it was the right hemisphere which played an important role in these processes (Balonov, Deglin, 1976). The efficiency reduction of the both acoustic canals due to the lesion of a dominant-in-speech hemisphere was called dominance effect. However, the reduction in reproduction efficiency was expressed to a greater extent in the right acoustic canal, which was termed focus effect (fig. 2). Fig. 2 shows that in comparison with the healthy group, curve C_{Ef} of the right ear and C_{Ef} of the left ear remained in the normative range, but the percentage of participants in these intervals decreased especially in the distribution of C_{Ef} values of the right ear. Also, the percentage of participants with a low efficiency substantially increased in the distribution of total C_{Ef}. Consequently, in view of the reproduction efficiency reduction in the both acoustic canals, the total efficiency of method fulfillment also fell, which was reflected in way the C_{Ef} curve shifted towards the lesser interval in fig. 2. Thereby, under the concentration of the participants in one of the intervals (20 to 40%) the left ear's efficiency coincided with the total efficiency of the method's fulfillment.

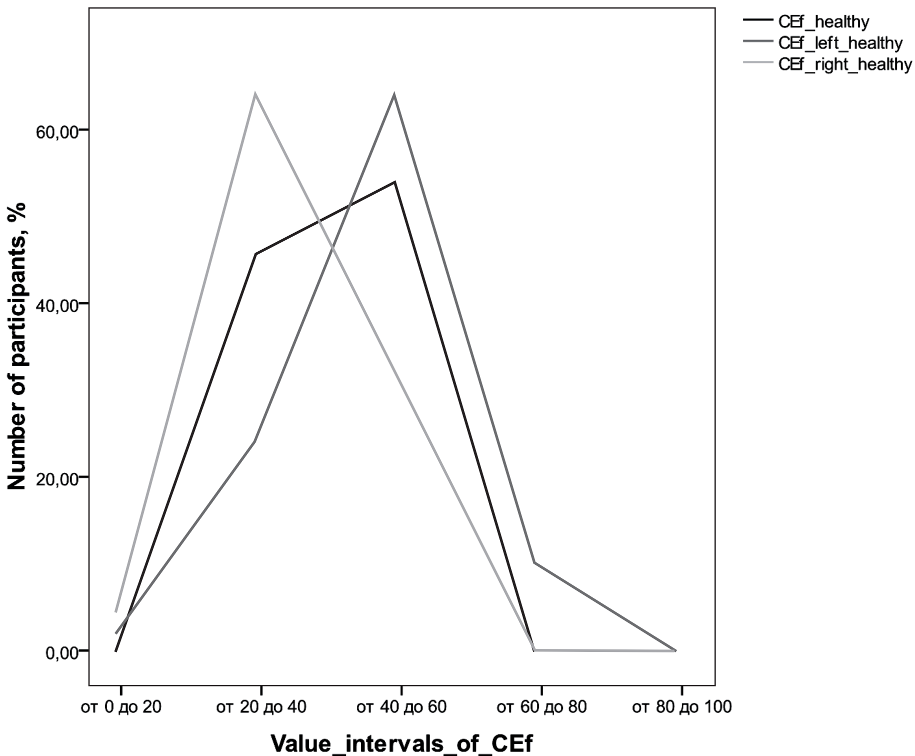

Figure 1. The distribution of the efficiency values among the participants of the healthy group. (Here and later: C_{Ef} right – C_{Ef} of the right ear, C_{Ef} left – C_{Ef} of the left ear)

One could presume that the right hemisphere made more of a contribution to reproduction efficiency. Thus, in the case of the left hemisphere lesion, we watched symptoms which could stand for several cerebric mechanisms. First, the greater efficiency decrease of the right ear in comparison with the left ear was explained by the focus effect. Second, when we faced an efficiency reduction of both acoustic canals simultaneously, the symptoms could be explained by the dominance effect. However, that could not be the consequence of the dominance effect but of interhemispheric relations derangement. It was well-known that with the left hemisphere lesion, the lesion focus exerted an inhibiting influence on the symmetric parts of the intact right hemisphere (Traugott, 1986). Furthermore, Balonov L.Ya. and Deglin V.L. (1976) revealed that the right hemisphere in the normal state could bring down the excitability of the left hemisphere's speech center, but under the condition of impeded activity of these centers (for instance, interference) and could facilitate their activity, providing noise immunity when perceiving speech sounds. That kind of interaction was designated by the authors as decrement. Subsequently, on having had the left hemisphere affected, there was an activity decrease in the right one. However, at the same time there was a reduction of the facilitation function of the left hemisphere's activity under the impeded condition that caused, once again, a decrease in speech centers' activity of the left hemisphere. Thus, symptoms coming from the right hemisphere with the left hemisphere pathology were explained by disturbed interhemispheric relation.

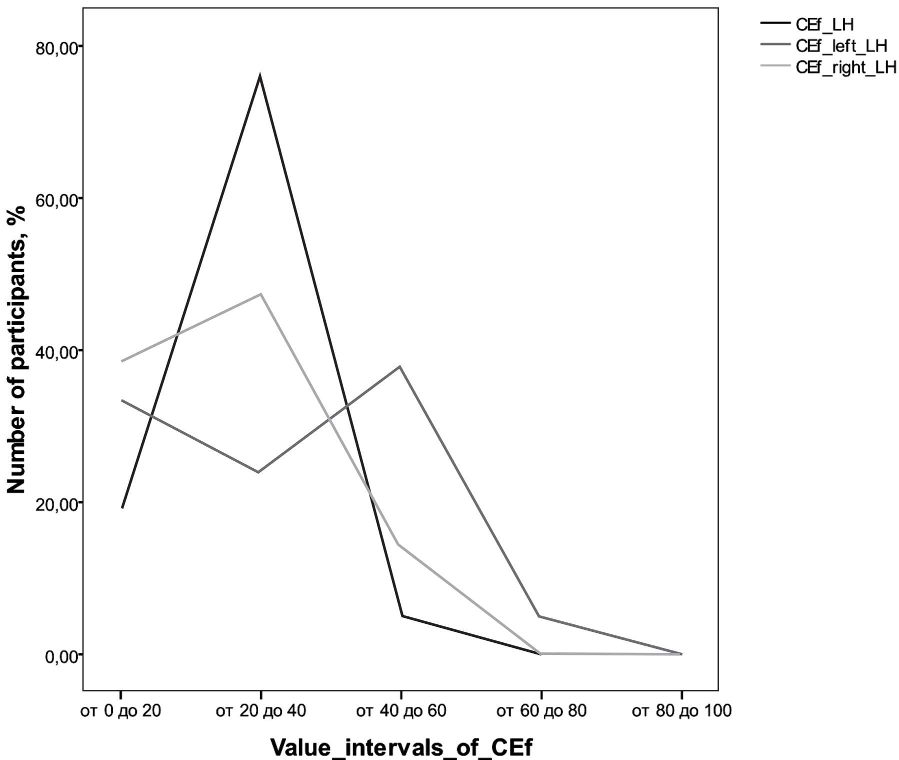

Figure 2. Distribution of the efficiency values among the participants with left hemisphere pathology of the brain

There was an increase in the reproduction efficiency of the right ear and a steep decrease in the reproduction efficiency of the left one in the group with right hemisphere pathology, in comparison with the healthy group (fig. 3). In comparison with the healthy group, C_{Ef} of the right ear remained in the normative interval, nevertheless the percentage of the participants lessened in this range. At the same time, the percentage of the participants with a high efficiency of this acoustic canal rose, up to ignoring the left ear entirely, which was confirmed by the facts of curve C_{Ef} of the left ear shifting towards the minimal interval (0 through 20%) and a rapid rise in the percentage of participants in this range. As a result, the total efficiency of the method fulfillment decreased as well, and the total C_{Ef} curve shifted towards a lesser interval (20 to 40%). There were no significant differences observed in the values of C_{Ef} of the right ear in comparison with the healthy group, but there were when comparing the values of the right-hemispheric group with the healthy one: C_{Ef} of the left ear ($U = 207.5$; $p < 0.001$) and total C_{Ef} ($U = 345$; $p = 0.006$). When comparing efficiency inside the group of right-hemispheric patients, as in the healthy group, all the coefficients significantly differed from one another C_{Ef} and C_{Ef} of the right ear ($U = 134$; $p = 0.004$; C_{Ef} and C_{Ef} of the left ear: $U = 103$; $p < 0.001$; C_{Ef} of the right ear and C_{Ef} of the left ear: $U = 53$; $p < 0.001$). It was noticeable that the efficiency changes of the left ear only were enough for significant differences to also concern the total index of efficiency. This proved the earlier hypothesis about the right hemisphere making a greater contribution to reproduction efficiency.

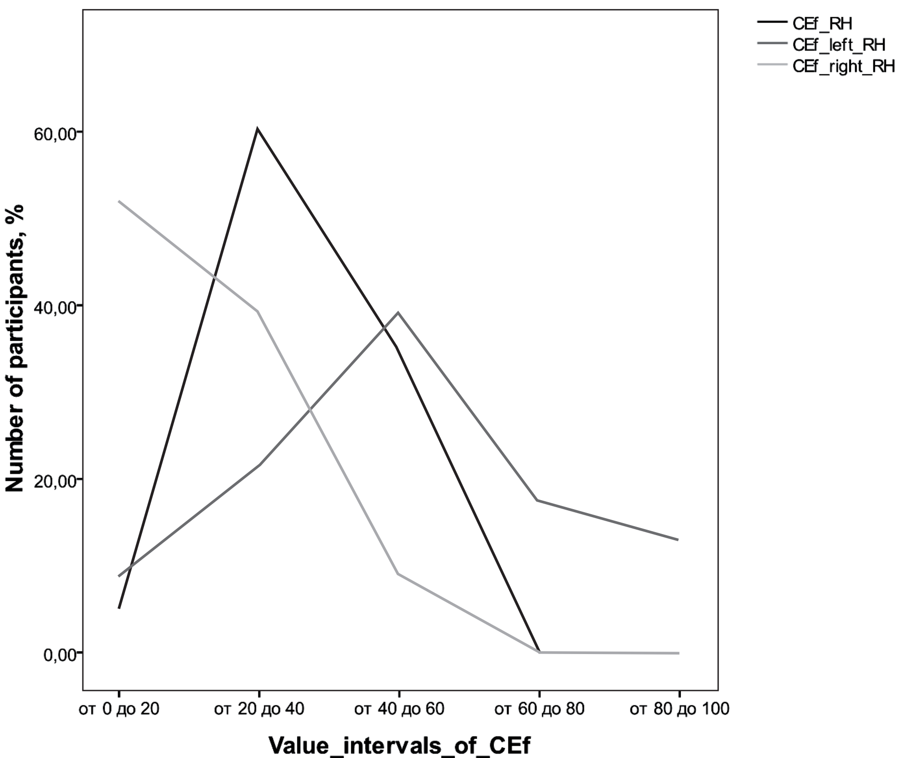

Figure 3. Distribution of efficiency values among participants with right hemisphere pathology of the brain

In this way, in case of a lesion of the right hemisphere, we traced the symptoms coming from the affected hemisphere (focus effect). There was also an increase in the intact left hemisphere's activity. When having one hemisphere's acoustic system inactivated, and the activity of the other's safe acoustic system increased, this kind of interhemispheric interaction was called interaction of the type of reciprocity (Balonov, Deglin, 1976). In the CC group, in comparison with the healthy group, we had a statistically significant reduction of total C_{Ef} and C_{Ef} of the right ear (C_{Ef}: $U=238.5$; $p=0.003$; C_{Ef} of the right ear: $U=264$; $p=0.01$). The reproduction efficiency of the right ear fell to a greater extent, whch resembled the tendencies in the left-hemispheric group. At the same time, differences in word reproduction by means of acoustic canals remained towards the right ear dominating over the left, which didn't achieve the level of statistical significance. Subsequently, acoustic canals became practically level according to reproduction efficiency indices. For the reason of efficiency reduction of both acoustic canals, to a greater extent, of the right ear, there was a decrease in the total reproduction coefficient as well, which once again resembled the picture of reproduction efficiency in the left-hemispheric group in comparison with the healthy group (fig. 4). Fig. 4 showed that in comparison with the healthy group, the curves C_{Ef} of the right ear and C_{Ef} of the left ear remained within the normative intervals (40 to 60% and 20 to 40% accordingly), but the percentage of participants within these intervals decreased, and to a greater extent towards the right ear. The percentage of participants with a low reproduction efficiency increased in both acoustic canals.

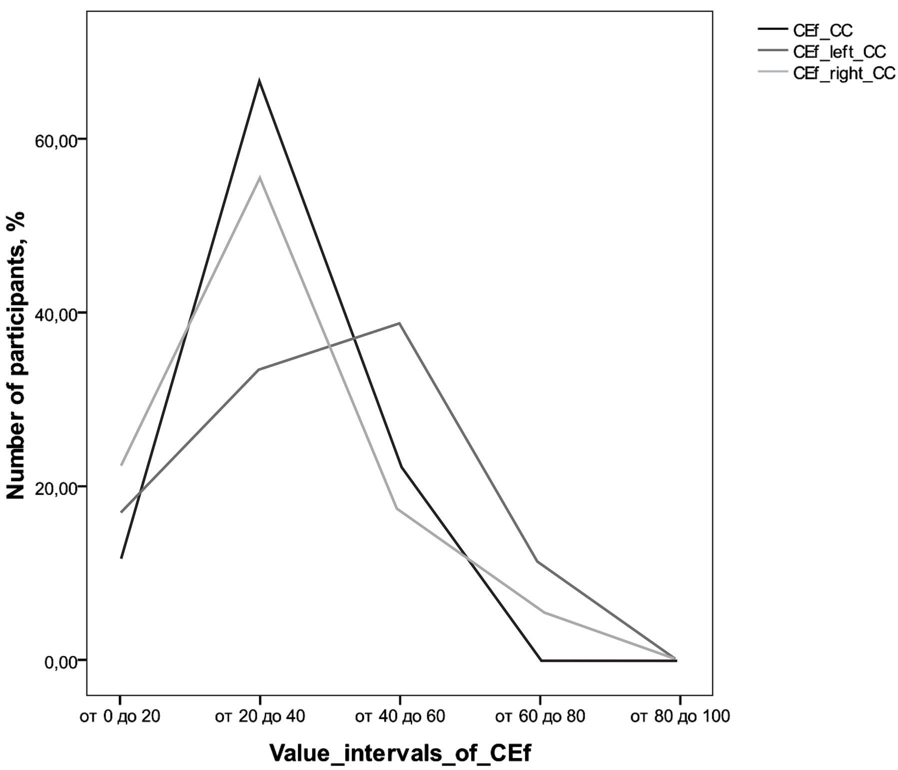

Figure 4. Distribution of the efficiency value among participants with corpus callosum pathology

Thus, in consequence of the reproduction efficiency reduction in the both acoustic canals, the total efficiency of the method fulfillment fell, which is reflected in fig. 4 in the form of the total C_{Ef} curve's shift towards the lesser interval (20 through 40%) in comparison with the healthy group. Thereby, the left ear's efficiency coincided with the total efficiency of the fulfillment of the method of dichotic listening, according to the greatest concentration of the participants in one of the intervals (20 through 40%). In case of corpus callosum pathology there was a derangement of interhemispheric interaction, and a reduction of the right hemisphere's regulation of speech centers, providing facilitation of the right hemisphere's activity under the condition of noise, whereupon we observed the symptoms of the left hemisphere lesion in the CC group. Once again, this proved that the right hemisphere made a greater contribution to reproduction efficiency. So the reproduction efficiency of the right ear in this group of participants did not significantly differ from the corresponding indices in the left-hemispheric group, and the reproduction efficiency of the left ear was to a greater extent drawn to the same in the healthy group, whereupon the total efficiency index decreased to the level of total C_{Ef} in the right-hemispheric group. Thus, we saw that in case of corpus callosum pathology, the left hemisphere suffered in audioverbal processes to a greater extent. All three groups with the brain pathology significantly differed, statistically, from the healthy group according to total C_{Ef}: the left-hemispheric. right-hemispheric and CC groups ($U = 98.5$; $p < 0.001$; $U = 345$; $p = 0.006$; $U = 238.5$; $p = 0.003$). The significant differences in C_{Ef} values were registered between two groups of the patients only: left-hemispheric and right-hemispheric ($U = 138.5$; $p = 0.015$).

Thus, the CC group didn't differ from the left-hemispheric and right-hemispheric ones according to total efficiency indices. However, according to the mean values, the CC group was drawn to the right-hemispheric group. It is shown in fig. 1,2,3,4 that in comparison with the healthy group (40 through 60%) the total C_{Ef} curves of the three groups of patients shifted towards the preceding interval (20 through 40%). Besides, there was an increase in the percentage of the participants with a low efficiency in all the groups of patients, to a greater extent in the left-hemispheric group, and to a lesser extent in the right-hemispheric group, which coincided with the average values of total C_{Ef}. In this way, in spite of pathology, the efficiency of stimuli reproduction within the dichotic listening method decreased, and that took place most likely at the expense of activity reduction of the right hemisphere.

Values of the *coefficient of the right ear* (CRe) for all groups are in the range of –89.47% to 100%. In the group of healthy subjects, the Cre values range from –44.83% to 67.44%. The average value of the Cre in this group is 11.66%. In most cases, the value of this coefficient is positive. 50 people in 9 subjects Cre negative values (from –44.83% to –7.69%), in 2 subjects the factor is 0%, and for the remaining 39 people the values are in the range of 1.82% to 67.44%.

In the group of subjects with left-sided localization of pathological process, CRe values range from -89.47% to 92.59%. The mean value of CRe in the group is 14.16%. Of 21 people, in 7 subjects values Cre negative sign and are in the range from –89.47% to –4.76%, while for the remaining 14 people the values of the Cre and the positive sign are in the range of 4% to 92.59 %.

In the group of subjects with damage to the right hemisphere of the brain, CRe values range from –48.57% to 100%. The mean value of the CRe in the group is 45.54%. Of the 23 people in 3 CRe, test values are negative and range from –48.57% to –11.63%, the remaining 23 people have positive Cre values and are in the range from 2.7% to 100%, with five of them in this ratio at 100%. Thus, in most cases, the CRe is positive.

In the group of patients with pathology corpus callosum, CRe values range from –75% to 83.33%. The mean value of the CRe in the group is –8.9%. Of the 18 persons, values from the CRe 7 subjects are negative and are located in the range from –75% to –12%. The remaining 11 persons are positive in sign, and are in the range of from 2.44% to 83.33%.

Thus, the dichotic listening technique is not an informative technique for studying hemispheric interaction at different etiology pathology corpus callosum. It does not clearly differentiate between symptoms caused by disorders of the cerebral hemispheres. It does not clearly differentiate the symptoms of the disorder hemispheric interaction induced pathology is corpus callosum. The technique clearly demonstrated that hemispheric symptoms included in deficit disorder hemispheric interaction at different etiology pathology corpus callosum are quantitative rather than qualitative differences between the symptoms, syndromes included in the pathology of the cerebral hemispheres.

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