ACTA Vol. 11, No. 3, 2013, 269-278
NEUROPSYCHOLOGICA

Received: 08.11.2012
Accepted: 28.10.2013

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METHODICAL AND METHODOLOGICAL PROBLEMS IN THE STUDY OF FUNCTIONAL BRAIN ASYMMETRY IN THE MODERN NEUROPSYCHOLOGY

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SUMMARY

Background: Diagnosis of interhemispheric asymmetry is an actual problem of modern neuropsychology. The researches show that tests meant for the diagnosis of one type of functional asymmetry often produce inconsistent results. We conducted a study to see how the results of different tests for the diagnosis of interhemispheric asymmetry are interconnected. The additional objective is developing a method, involving the calculation of tests weight.

Material/ Methods: The study involved 116 subjects aged 16 to 23, including 37 men and 79 women. Test persons performed the following tests and analyses: A.P. Chuprikov questionnaire, ”Napoleon pose”, ”Applause”, ”Crossing of fingers”, ”Aiming” and ”Rozenbakh test”, dichotic listening to assess audioverbal asymmetry (20 subjects did not have it).

Results: Significant correlations were obtained only between self-report, Chuprikov questionnaire and ”Crossing of fingers” test, and between the results of Rozenbakh test and dichotic listening. The ”Crossing of fingers” test correlates with other manual tests negatively. This indicates that at crossing the fingers on the top there is a finger of nonleading hand.

Conclusions: The concept of the independence of manual, audioverbal and visual fields is likely to be changed. The new method of evaluation of the integral index of asymmetry can be used to divide subjects into groups according to the degree of functional brain lateralization. The evolutionary approach using achievements of comparative physiology can be used as a methodological basis of human interhemispheric asymmetry studies.

Key words: interhemispheric asymmetry, functional brain lateralization, differential neuropsychology, neuropsychological tests

INTRODUCTION

Diagnosis of interhemispheric asymmetry is of great importance both for clinical examination, and for neuropsychology of norm. A.R. Luria (1980) noted that the lack of our knowledge in the extent of dominant hemisphere for different individuals and for different functions creates considerable difficulties at clinical study of patients with local brain lesions. The increasing interest in the problem of interhemispheric asymmetry and in the methods of its measuring in modern differential neuropsychology makes urgent rethinking and development of the existing evaluation methods of lateral brain organization.

At the end of XXth century in the Russian neuropsychology it was proposed to evaluate the interhemispheric asymmetry by ”hand-ear-eye” approach. E.D. Khomskaya and I.V. Efimova (1989, 1991) proposed the concept of the profile of lateral organization (PLO), which means the combination of motor and sensory asymmetries. The method of PLO determination is based on the following principles: the use of three types of asymmetries: manual, audioverbal, visual; the assessment of not only the fact of asymmetry, but also its extent; the recognition of varying significance of manual, visual and audioverbal asymmetries. The possible 27 options of the profile of lateral organization of the brain can be combined into five main types: the ”pure” right-handers, right-handers, ambidexters, left-handers and ”pure” left-handers. Studies carried out using this method provided extensive information on the relation of the brain lateral organization with different psychological characteristics (Khomskaya, Efimova, Budyka, Enikolopova, 1997, 2011). The further development of the problem of functional brain asymmetry was in the works of V.A. Moskvin and N.V. Moskvina (2011). They found that lateral symptoms are of heterogeneous nature. Experiments confirmed the existence of the following conditions that affect the laterality: genetic (or inherited), pathological (largely associated with pre-and perinatal brain lesions), forced (due to loss or defect of the peripheral analyzer or leading limb) and functional related to learning activity or particularities of sensorimotor coordination at implementation of certain activities. Of course, these types of lateralization may be differently related to psychological phenomena. Commonly used methods of interhemispheric asymmetry diagnosis not always make it possible to differentiate the types. This makes it difficult to develop the fundamental laws describing the relationship of interhemispheric asymmetry with the psychological characteristics. In addition, Moskvin and Moskvina (2011) are among the first to point out the inconsistency of the results of neuropsychological tests designed to diagnose the same type of asymmetry. For example, after N. Sakano (1982) they pointed out the inconsistency of the ”Napoleon pose” test (”Crossing of hands”) to assess motor manual asymmetry, as it reflects the relative dominance of the frontal areas of the brain. Difficulties in the application of this test are also related to the fact that there is still no single opinion on whether to pay attention to the hand on top, or the elbow lying down on top.

THE AIM OF THE STUDY

The fact that the various neuropsychological tests, conceptually designed to assess one type of asymmetry, do not always give consistent data, making it impossible to sum up the results.

We conducted a study to see how the results of different tests for the diagnosis of interhemispheric asymmetry are interconnected.

MATERIAL AND METHODS

The study involved 116 subjects aged 16 to 23, including 37 men and 79 women. According to self-report, 98 persons were right-handed, 10 – ambidexters, and 8 – left-handed. Test persons performed the following tests and analyses: A.P. Chuprikov questionnaire (Russian analogue of M. Annett questionnaire), manual asymmetry tests – ”Napoleon pose” (on the elbow), ”Applause”, ”Crossing of fingers,” visual asymmetry tests – ”Aiming” and ”Rozenbakh test”, dichotic listening to assess audioverbal asymmetry (20 subjects did not have it).

The correlation between the results of the tests was assessed using Cramer’s V-coefficient, the sign (positive or negative) of the correlation coefficient was determined by the Spearman coefficient. Before evaluating the correlation, Chuprikov questionnaire results and the results of dichotic listening were transferred from raw scores to scale ”right-hander – ambidexter – left-hander” according to the accepted rules. Chuprikov questionnaire: from 24 to 8 points – right-hander, from 8 to -8 points – ambidexter, from -8 to -24 points – left-hander. For dichotic listening: right ear coefficient over 4 – right-hander, from 4 to -4 – ambidexter, less than -4 – left-hander.

RESULTS

The results are shown in the Table 1.

As it can be seen from the Table 1, significant correlations were only obtained between self-report, Chuprikov questionnaire and ”Crossing of fingers” test, and between the results of Rozenbakh test and dichotic listening. Attention is drawn to the fact that ”Crossing of fingers” test correlates with other manual tests negatively. This indicates that at crossing the fingers on the top there is a finger of nonleading hand. There has been no expected connection between the visual tests ”Aiming” and Rozenbakh test, which, in our opinion, it due to accompanied mixing of the variables at the implementation of ”Aiming” test. This test can give incorrect results at the frequently occurred dysfunction of eyelid part of circular eye muscle innervated by the motor part of the facial nerve. In this case, the subject cannot (or can, but with great effort) close one eye without closing the other, due to pathology of the cranial nerves, and not because of the functional brain asymmetry. It is impossible to separate one reason from the other without special neurological examination. The connection between the Rozenbakh visual test and the results of dichotic listening, designed to determine audioverbal asym-

Table 1. Tests correlation matrix

Test	1	2	3	4	5	6	7	8
1	-	**0.707****	0.08	0.116	**-0.273***	-0,157	0.110	0.186
2		-	0.053	0.194	**-0.227***	-0.121	-0.118	0.21
3			-	0.201	0.094	-0,202	-0.191	0,195
4				-	-0.111	-0.140	0,133	-0.084
5					-	-0.097	-0.084	0,213
6						-	0.114	-0.071
7							-	**0.297***
8								-

* p<0.05 ** p<0.001
1 – self-report, 2 – Chuprikov questionnaire, 3 – "Napoleon pose", 4 – "Applause", 5 – "Crossing of fingers", 6 – "Aiming", 7 – "Rozenbakh test", 8 – Dichotic listening

metry, could indicate the existence of intermodal complex with its functional laterality. Thus, this study showed that the test designed to assess one type of asymmetry, in most cases, do not give consistent results, which may indicate the independence of their diagnostic value.

In the course of study, we found a dichotic listening feature that caught our attention. As you know, this technique was proposed by D. Kimura (1961) to determine the leading ear. The fact that the dichotic test reflects precisely the dominant hemisphere for language was confirmed by almost complete coincidence of the results of dichotic tests with the results of Wada tests. Recently it was demonstrated again (Hugdahl, 2005). In our country E.P. Kok, V.S. Kochergina, L.V. Yakusheva (1971) first introduced the dichotic listening technique. Modification used by the majority of local researchers was developed in the laboratory of neuropsychology of the Faculty of psychology of Moscow State University (Kotik, 1974). With all the advantages of this technique, there are some questions on procedures for its implementation. To eliminate the possible influence of technical artifacts after full listen of all the series earphones were reversed. Thus, each subject listened to a set of words twice, first at the initial position of headphones, then – in the reverse. Our study showed that 52% of subjects show the change in sign of the coefficient of the right ear to the opposite in the second series (after turning the headphones). Probably, the subjects in the second series reproduce exactly the words that clearly heard in the first series by the leading ear. Recognizing even part of a word, heard by the non-leading ear in the second series, they conjecture it correctly, based on the image of the word, embodied in the first series due to the leading ear. This means that to accurately determine audioverbal lateralization it is necessary to prevent a repetition of words after turning headphones or simply not to turn the headphones, because the quality of modern equipment makes it possible to exclude technical artefacts. Despite the fact that the described feature of dichotic listening procedure challenges the results of many studies of the ear asymmetry, it opens up new possibilities for the study of hemispheric interaction. After all, if the recognition of words, applied to the non-leading ear, is based on information received previously by the leading ear, then we are dealing with cerebral comparing of information received by different hemispheres. Thus, knowing the degree of lateralization, as measured by the modified (without repeating the words in the second series) version of dichotic listening, we can then evaluate the hemispheric interaction, using the original version of the method.

Special attention should be paid to mathematical procedures applicable when comparing the asymmetry parameters with the psychological characteristics. This largely depends on whether interhemispheric asymmetry is linearly changed features or there are qualitative differences between right-handers, ambidexters and left-handers. Our researches (Kovyazina, Myachev, Khokhlov, 2012) show that when comparing asymmetry options with psychological characteristics there are relationships that cannot be reduced to a linear dependence, and can be best described by U-shaped functions. In other words, ambidexters are not always the ”middle” between left-handers and right-handers. Apparently, for the number of relations ”type of asymmetry – psychological characteristics” there is a certain asymmetry optimum, that corresponds to the highest values of the investigated psychological characteristic. Such connections are best described by the functions of polynomial regression.

To solve a number of practical problems we shall define a common indicator of interhemispheric asymmetry without definition of functional lateralization of the individual systems. For example, it may be necessary to identify the prevailing cognitive strategies when organizing differential training. To do this, a method based on the achievements of the modern Item-Response Theory (IRT), involving the calculation of tests difficulty, using the logit scale was introduced. Each testing was regarded as one of the items of the test, ”the right answer” was a coincidence with self-report.

The weight of each task is calculated by the formula: ln (p/q), where p – the number of subjects whose results at sampling coincided with the self-report, q – the number of subjects whose results at sampling did not coincide with the self-report. In those samples where it was possible to get one of the three options (right-hander, ambidexter, left-hander), getting the result ”right-hander” or ”left-hander” by ambidexter, as well as getting by right-hander or left-hander the result ”ambidexter”, added 0.5 point both in the numerator and in the denominator. The resulting weight coefficients allowed deducing the formula for calculating the integral index of asymmetry: ”Crossing of fingers” × -0.2513 + ”Napoleon pose” × 0.1252 + ”Applause” × 0.5108 + ”Aiming” × -0.1921 + ”Rozenbakh test” × 0.2907 + ”Chuprikov questionnaire” × 2.8006 + ”Dichotic listening” × 0.5331. Instead of the names of samples, the numbers 1, 0, -1 for the options ”right-hander”, ”ambidexter”, ”left-hander”, respectively should substitute. The results of Chuprikov questionnaire and the dichotic listening should first be transferred from raw points to the ternary scale using accepted intervals (see above). We obtained the distribution of the integral index of asymmetry with the following parameters: 2,5411±1,9274. It is significantly different from normal and largely confirms the existing notions of the distribution of right-handers, left-handers and ambidexters in the population (see the figure). The tested subjects can be divided into groups of right-handers, ambidexters and left-handers by dividing the x-axis into three equal parts. In this case, the boundary between the left-handers and ambidexters will be equal – -1.2125, and between ambidexters and right-handers – 1.7456. Thus, the left-handers would be 8% of the sample, ambidexters – 10%, and the right-handers – 82%.

The full study of interhemispheric asymmetry and its relation to psychological characteristics is impossible without understanding the role that the functional lateralization of the brain plays in human adaptation to various environmental conditions. In modern neuropsychology there is an opinion that functional brain asymmetry as well as sustainable left hemisphere dominance is a particular feature of the human brain, which appeared in anthropogenesis due to the emergence of speech and dextrism. In our opinion, there is every reason to believe that our distant evolutionary ancestors already had brain asymmetry and the issue here is not in the labor force or in the emergence of speech. Vice versa, brain asymmetry of our evolutionary ancestors Homo sapiens sapiens was the

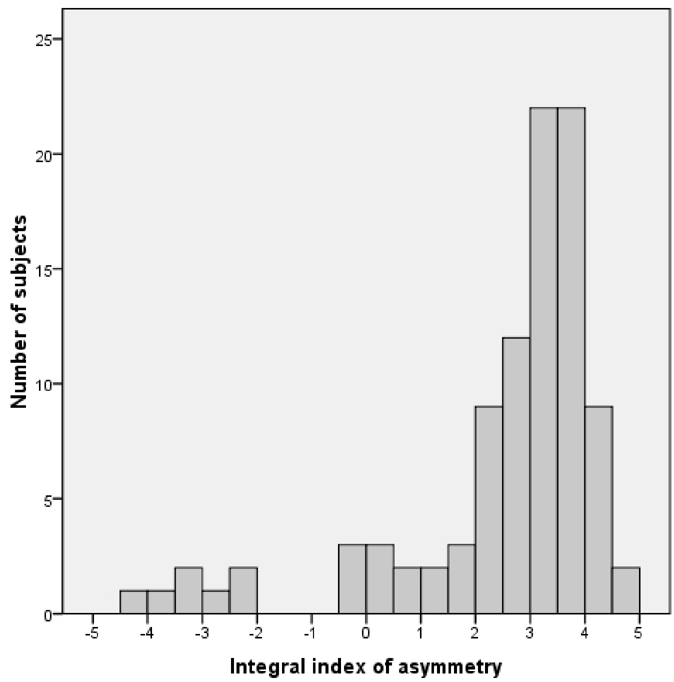

Fig. 1. Distribution of integral index of asymmetry

necessary condition for the development of skills and communication means. Most likely, at its occurrence in the evolution, speech first just used, and only then developed and qualitatively transformed the already existing animal interhemispheric asymmetry. As you know, the asymmetry can be detected already at the molecular level, which allows considering it as a fundamental property of living systems. During the evolution, organisms with different types of symmetry and deviations from it occurred. The creation of basic types of symmetry: spherical, radial, bilateral was mediated by interaction with the environment. Force exposures of environment, primarily due to gravity, were the factors that caused the need to form such a body structure, which provided it with the most complete harmony with the environment. Also, the size of organisms, their capacity for independent movement and a number of other features predetermined the presence of a particular type of symmetry, the evolutionary transition from spherical to the radial symmetric structure and then to the bilateral organization of the body. Evolutionary transformations continued, however, not only in the direction of a balanced structural plan of animals, but also in the direction of asymmetrization. Already in the early stages of evolution, starting with the simplest, in the structure of living organisms there were deviations from perfect symmetry. In most cases, it allowed more effectively adaptation to the needs of the environment and implementing behavioral functions. Radial organisms with multiple symmetry were the dead branch of evolution. Progressive development was usual for bilaterally symmetrical animals with in one form or another functional laterality of the nervous system and the body as a whole. Based on the accumulated data in the literature and the study of the functional asymmetry of animals performed by V.L. Bianki (1985), we can say that the interhemispheric asymmetry is a general property of the brain, characteristic for at least superior vertebrates. A number of review articles (Levy, 1977; Walker, 1980; Andrew, 1983; Geschwind, 1983; Strauss, Kosaka, Wada, 1983) confirm this position.

It seems that evolution was on the way from the symmetrical structure of the body and nervous system to the gradual growth of asymmetry, which allows more efficient survival in the conditions of natural selection. The following rule can be traced: the more specific functional asymmetry is typical for some form, the more complex forms of behavior demonstrate its representatives. As for dextrality, it is a specific norm not for all wildlife, but it is more common than left-handedness. It makes us think that the asymmetry itself is a much more ancient mechanism than its direction, which is largely determined by environmental rather than genetic factors. Following the same logic, one can expect that at some stage in the evolution, dextrality was placed on a genetic level, providing organisms with greater opportunity for survival in dextral oriented environment. Despite evident phylogenetic preconditions to functional asymmetry, the origin of lateralization of purely human functions is still a controversial issue. V.S. Rotenberg (1979, 2001) distinguishes between two opposite ways of information processing, typical for a person and with local attachment to hemispheres. The left hemisphere of all varieties of real and potential links selects few internally consistent, not mutually exclusive, and based on that creates unambiguous context. The right hemisphere ”grasps” reality in all the contrariety and ambiguity of links and forms multi-valued context.

We believe that the need for unambiguous context was the factor that led to the consolidation of dextrality as the species norm. This is directly related to the essential characteristic of human adaptation, which distinguishes it from the rest of the animal world. The whole history of the evolution of hominids was aimed at saving energy and intellectual resources of the brain (Savelev, 2010). Social life provoked the desire to minimize the intellectual efforts. Since the beginning of modern human, in populations of sapiens there is constant strict artificial selection for ”sociality”. The method of external storage and transmission of biologically relevant information occurred; it reduced the role of individual abilities. Such artificial selection started to eliminate individuals with individualized behavior forms, giving reproductive advantage not to the most capable individuals, but to those who could maintain the existing in the group behavioral skills and relationship forms. In our opinion, the development of the left hemisphere was necessary because, according to V.S. Rotenberg hypothesis (1979, 2001), it provided the creation of unambiguous context. Namely, the production of unambiguous signs and symbols contributed to improving of intra-group communication and ensured the maintenance of the social structure of sapiens. This gave rise to hemispheric relations structure that we can see today. Recently, we together with A.I. Lakhmetkina made an experiment the results of which prove this assumption. Using the evaluation method of the integral coefficient of asymmetry, the subjects were divided into two groups that differ in the degree of cerebral lateralization. The group had team games, the success of which depended on the ability to quickly create unambiguous context. Throughout the game time, the group consisting of members with large integral asymmetry coefficients, showed a more effective implementation of the objectives, showing high level of group cohesion and the ability to quickly come to a consensus. Their opponents, in most cases, could not reach a single solution.

In our opinion, the use of the methodological basis of the theory of evolution will allow making a fresh look at the results of hemisphere asymmetry studies. A comparison of the features of adaptation of living organisms at different stages of evolution, with the asymmetry of their nervous system, opens up new possibilities for the interpretation of the relationship between different types of functional asymmetry of the brain with the psychological characteristics of a person.

CONCLUSION

The revision of methodic and methodological problems of functional brain asymmetry in modern neuroscience, we shall point out that the work in this area is far from its completion. It is now clear that methods used in the neuropsychological studies of hemisphere asymmetry have many defects. The dominant concept of the independence of manual, audioverbal and visual fields is likely to be significantly changed in the near future. As long as there is no effective method of non-invasive diagnosis of functional asymmetry, the reliability of which will be confirmed by neuroimaging studies and mathematical modeling, we have to use the existing tests. However, we shall each time specify the particularities of diagnosis and consider the results of tests separately to avoid mixing of variables. The addition of the results of tests is only possible at the administration of empirically derived weight coefficients. The method of evaluation of the integral index of hemisphere asymmetry, proposed in this paper, can be used to divide subjects into groups according to the degree of functional lateralization of the brain, for example, at the organization of differential training and staff selection.

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