PSYCHOPHYSIOLOGY

Ermakov P.N., Vorobjeva E.V.

Individual profile asymmetry at twins and EEG spectral characteristics at performance of the arithmetic account and verbally-associative activity

Work is executed at support of the analytical departmental target program "Development of scientific potential of the higher school (2009-2010) ("Features of interaction of the big hemispheres at the decision cognitive problems of different level").

In work the purpose of performance of an estimation of the contribution a genotype-environmental factors in interindividual variability of profile asymmetry, and also experimental studying EEG-korrelats of verbal intelligence (on an example of performance of verbally-associative activity and the arithmetic account) at twins with various features of individual profile asymmetry was put. The estimation of heritability of type of functional asymmetry has made 0,26, thus the essential contribution in phenotypic variability of the given indicator is brought by the individual environment (e^2 = 0,74). It is revealed, that degree of expressiveness at examinees of asymmetry of touch and motor and mental functions (a profile of lateral organizations) influences capacity of biopotentials at performance of arithmetic operations of mainly right hemisphere.

Key words: *individual profile asymmetry, EEG, spectral power, twins, verbally-associative activity, the arithmetic account.*

For many researchers today rather pressing question how genes influence behavior, thus on the basis of modern works it is possible to tell with confidence, that such influence is carried out through influence on brain processes (Anokhin A.P., 2009, etc.). The last represent itself as endophenotypes (intermediate phenotypes) mental functions that allows to connect genes and behavior [7]. In J.I. Aleksandrov works it is shown, that at algorithm change training neural maintenance of the given behavior changes. Thus formation of new experience (training) is shown in processes neuronal, behavioral and molecular levels. So, on neuronal level training it is expressed in updating of neuron pulse activity. Changes of a genetic expression in neurons directly provide their specialization concerning elements of individual experience [1].

Studying of frequency-spatial characteristics of spectra power EEG is a modern and actual method of research endophenotypes of cognitive functions, in particular, intelligence. The approach is interesting, allowing to combine an estimation functional asymmetries in work of a brain and revealing lateral profiles of asymmetry of motor, touch and mental functions.

Thus performance of similar work with application twins does samples its especially actual, allowing to predict possibility and restrictions of psychocorrectional and psychodeveloping influence. The purpose of the given work – an estimation of the contribution a genotype-environmental factors in interindividual variability of profile asymmetry, and also experimental studying EEG-correlats of verbal intelligence (on an example of performance of verbally-associative activity and the arithmetic account) at twins with various features of individual profile asymmetry.

Interest proceeding in last years to studying cognitive problematics in brain work has shown efficiency of synthesis of interdisciplinary knowledge. So, results of studying of genetics of animals behavior have allowed to establish, that the parity of genetic and environmental factors at representatives of various branches of an evolutionary tree essentially differs (from practically full genetic determination of behavior at drosofills, by a principle – one allel – one behavioral pattern, before embedding in the genetic program of touch influences which arrive from environment during the critical periods of development – at mammals). The big interest is involved also with works in which results of studying of "culture genes" are resulted, causing success of mastering by animals of one kind of the developed customs and traditions of behavior [19]. At the same time studying of influence of mutations of genes on infringements cognitive functions at rats has shown, that mutations of genes cause infringements of training, memory and a reinforcement [12].

Method. Record EEG was spent under the international standard 10x20; for recording cerebral waves certificated electroencephalograph "Encefalan", the version "Elite-M" 5.4-10-2.0 (13.02.2004) manufactures by "Medicom" Taganrog (Russia) was used. Recording was carried out in the isolated room. Record EEG was spent under the international standard of installation of electrodes under the scheme of 10 %-20 %. For registration of electric activity of a brain 21 electrodes was established (Fpz, Fz, Cz, Pz, Oz, Fp1, Fp2, F7, F3, F4, F8, T3, C3, C4, T4, T5, P3, P4, T6, O1, O2), the monopolar scheme with ipsilateral ear reviewers was applied. EEG electrode impedances were maintained at <10 kΩ. Filtration EEG was carried out in a range of 0,5-70 Hz. It was analyzed background EEG, and also registered in experimental tests. Sequence of functional tests at record EEG: "background", "to open eyes", "to close eyes", test "verbal associations" (inventing of words on the letter "a"), test "the account in mind" (consecutive addition of figure 7). For tracing and suppression of EEG artefacts registration of ECG, EMG, EOG were used. The analysis of a spectrum of absolute power was carried out by comparison of indicators of background test with functional in the same frequency ranges (delta (0,5-4 Hz), theta (4-8 Hz), alpha (8-13 Hz), beta-1 (13-24 Hz), beta-2 (24-35 Hz) ranges. For a profile estimation of lateral organizations the computer program "Profile" was used (Valeology scientific research institute, Russia), allowing to estimate motor, touch and general functional asymmetry. Mathematical data processing was carried out by means of dispersive analysis ANOVA. Computer processing of results was spent under program Statistica 6.0.

Object of research – monozygote and dizygote unisex twins in number of 87 DZ twins pairs at the age from 14 till 26 years (from them male – 43 pairs, female – 44 pairs), 86 DZ twins pairs (male – 40 pairs, female – 46 pairs). Middle age of examinees – 18,9 years.

All examinees without deviations in a state of health, participated in research voluntary. For definition zygosity twins the method of polysimptoms similarities [6] was used; pairs with not clear diagnostics in research did not join.

Results. In table 1 statistical data on expressiveness of functional asymmetries in sample of twins are cited.

Table 1

Distribution of profiles of lateral organisations in group of twins (in %)

Estimated parametres	Domination		
	On the right (the left hemisphere)	At the left (the right hemisphere)	There is no domination (equality of hemispheres)
Manual asymmetry	71,1	0	28,9
Foot asymmetry	78,9	5,3	15,8
Visual perception	50,0	10,5	39,5
Acoustical perception	60,5	18,4	21,1
Thinking	86,8	13,2	0

In table 2 results of the correlation analysis of intrapair similarity MZ and DZ twins on the indicators of functional asymmetry received with use of the computer program "Profile" and an estimation of components of phenotypical dispersion are presented.

Table 2

Intrapair correlations of indicators of functional asymmetry at MZ and DZ twins (under the program "Profile"), the contribution of genetic (h^2), total environment (c^2), individual environment (e^2) components of phenotypical dispersion (*p <0,05; ** p <0,01) *

Indicators	R(MZ)	t(N-2)	p-level	R(DZ)	t(N-2)	p-level	h^2	c^2	e^2
Test Annet	-0,05	-0,14908	0,88	0,03	0,08443	0,93	-	-	-
Tapping test (the right hand)	0,55*	1,10629	0,04	-0,12	-0,39699	0,70	0,55	0	0,45
Tapping test (the left hand)	0,61**	1,51006	0,009	0,50*	1,83001	0,03	0,22	0,39	0,39
Trek test (the right hand)	0,35*	1,04335	0,04	0,53*	1,97234	0,03	0	0,35	0,65
Trek test (the left hand)	0,79**	3,64789	0,01	0,21	0,66915	0,05	0,79	0	0,21
Leading hand	0,76**	3,34664	0,01	0,52*	1,93649	0,03	0,48	0,28	0,24
Leading foot	-	-	-	-0,09	-0,29319	0,77	-	-	-
Leading eye	0,46*	1,45095	0,03	-0,54*	-2,03370	0,03	0,46	0	0,54
Leading ear	0,32*	0,96449	0,04	0,11	0,36507	0,72	0,32	0	0,68
Test for figurative thinking	-0,16	-0,45689	0,55	0,08	0,25105	0,81	-	-	-
Test for verbal thinking	-0,12	-0,35279	0,56	0,43*	1,50086	0,03	-	-	-
Asymmetry factor	0,29	0,84650	0,05	-0,15	-0,49074	0,63	0,29	0	0,71
Type of lateralization	0,26	0,75827	0,05	0,05	0,16290	0,87	0,26	0	0,74

The note: if r(MZ) < 0 or r(MZ) > 2 r(DZ), h^2 equated r(MZ); if r(MZ) < r(DZ), $h^2 = 0$; if r(MZ) < 0, h^2 not calculated [1, p. 288].

Table 2 analysis allows to draw a conclusion that the essential contribution of factors of a genotype is found out for motor asymmetry (manual asymmetry) ($h^2 = 0,48$), touch asymmetry (asymmetry of sight $h^2 = 0,46$, asymmetry of hearing $h^2 = 0,32$). The estimation of heritability of type of functional asymmetry has made 0,26, thus the essential contribution in phenotypical variability of the given indicator is brought by the individual environment ($e^2 = 0,74$).

Dispersive analysis ANOVA for revealing of frequency-spatial features background EEG at persons with different types of laterality is carried out. **Background EEG.** In table 3 results of the one-factorial dispersive analysis of influence of expressiveness manual asymmetries under Annette test at examinees on parametres of absolute power biopotentials of the basic analyzed frequency ranges (significant results are resulted only) (tab. 3) are resulted.

Table 3

Results of the dispersive analysis (an independent variable: expressiveness manual asymmetries under Annette test, a dependent variable – absolute spectral power biopotentials in background EEG, mkv²)

Spectral power of EEG rhythmic components in electrodes	SS	MS	F	p
Theta1 O2	4122,855	242,521	5,66523	0,000013
Theta 2 O2	4280,326	251,784	6,49617	0,000003
Beta1 O2	6842,505	402,500	24,1335	0,000000
Alpha 2 O2	38695,57	2276,21	2,67201	0,008032
Alpha 1 O1	35428,40	2084,02	2,20736	0,026053
Alpha 2 O1	104350,5	6138,27	9,55971	0,000000
Beta 1 O1	1080,496	63,559	3,1561	0,002463
Theta 1 P4	3543,455	208,439	6,6805	0,000002

From table 3 it is visible, that for degree of expressiveness at examinees of asymmetry of touch and motor functions (the profile of lateral organizations) makes authentic impact on estimations of absolute power of biopotentials in a background in theta1 and theta2, alpha1 and alpha2 and beta1 frequency ranges in both hemispheres.

On figure 1 distributions of values of factor of asymmetry (according to the program "Profile") and spectral power of biopotentials in occipital electrodes are presented at registration EEG background. On figure 1 it is visible, that absolute spectral power of biopotentials in alpha2 a range in occipital areas is highest at link sided lateralization signs at examinees.

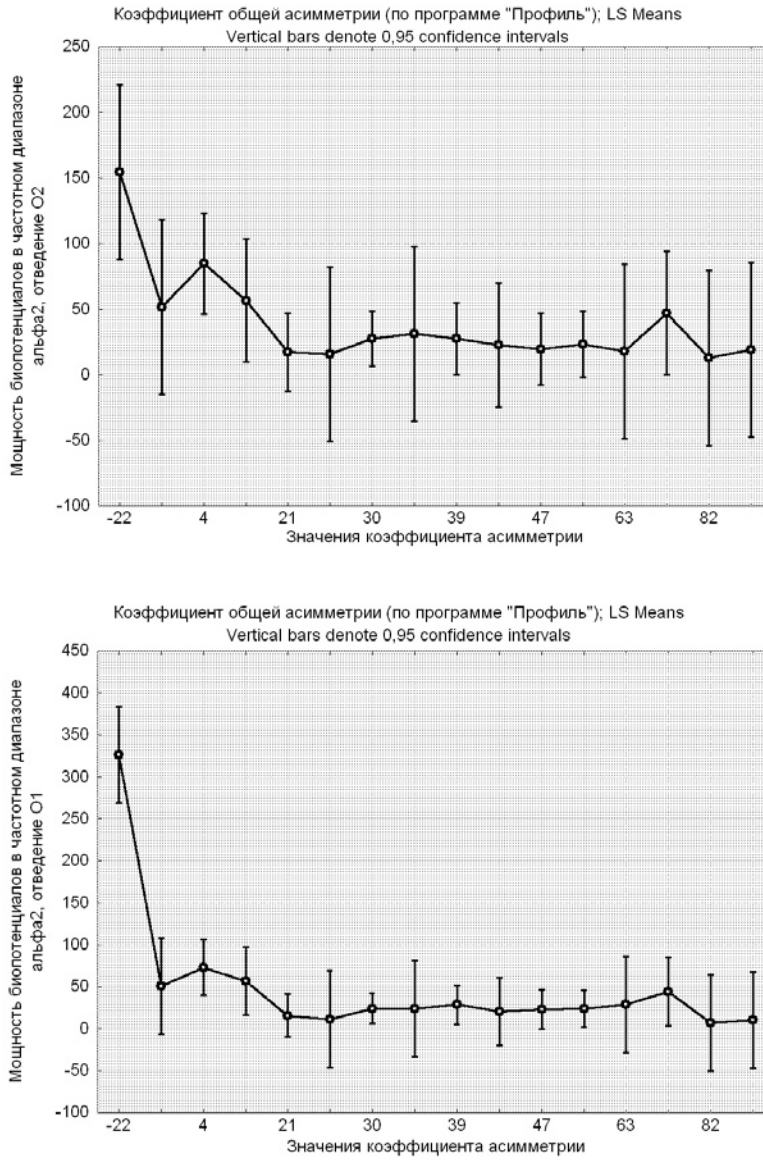


Figure 1. Distribution of values of alpha1absolute power (background, mkv2) depending on value of factor of general asymmetry

On figure 2 interaction of expressiveness of factors of general asymmetry (by results of complete inspection motor, touch and mental asymmetries under the program "Profile"), age and alpha2 absolute power in right and left occipital electrodes (figure 2) is visually presented.

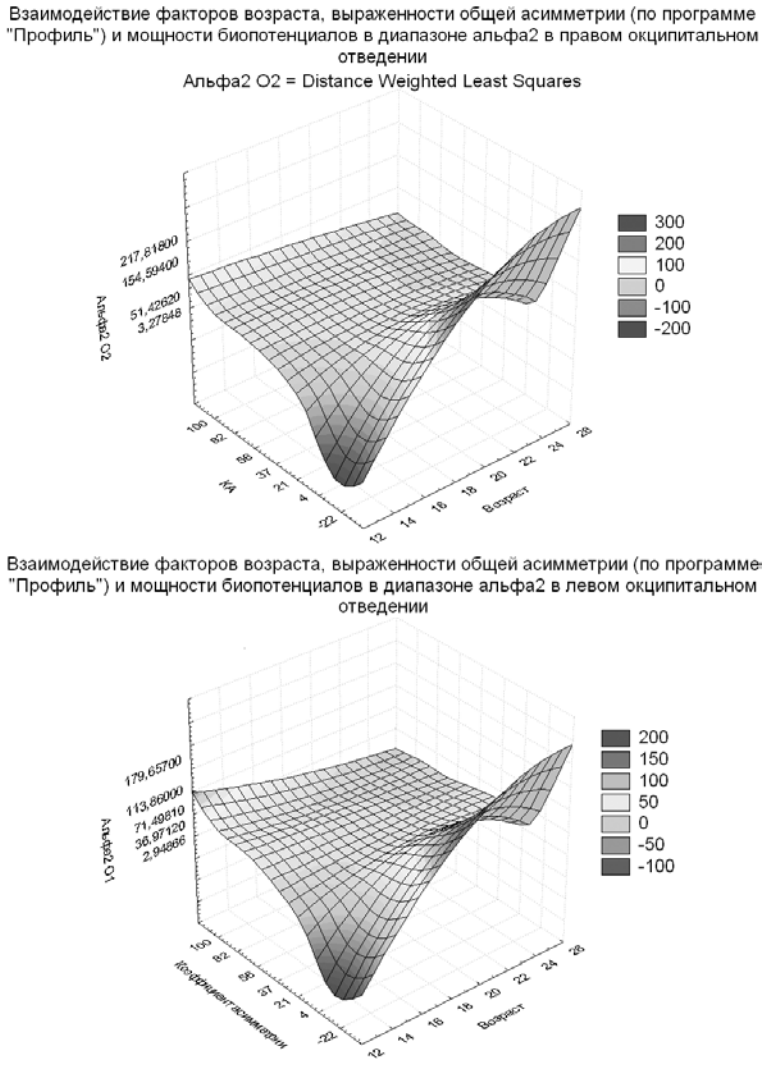


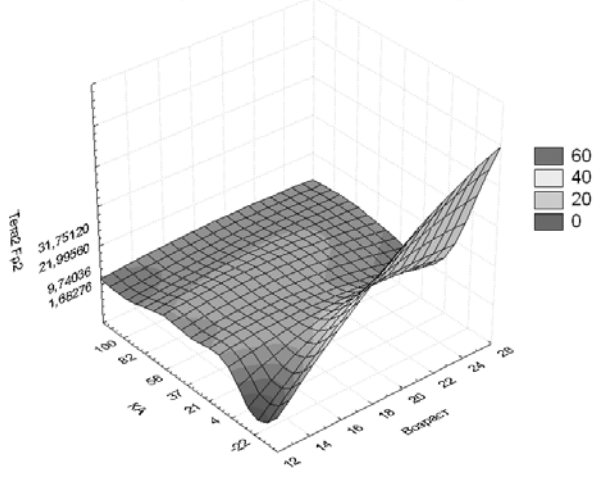
Figure 2. Distribution of values of alpha2 power (background, occipital cortex, μV2) depending on value of factors of general asymmetry and age

On figure 2 it is visible, that absolute power alpha2 rhythm in occipital electrodes is highest at examinees is more senior 20 years with expressed link sided laterality. At expressed right-hand laterality with increase in age of the surveyed there are no significant changes of absolute power of background EEG in occipital electrodes.

EEG in "Association" test. Results of the spent dispersive analysis of influence of an indicator manual asymmetries under Annette test for parametres of absolute power biopotentials of the basic analyzed frequency ranges in "Association" test testify that at performance of verbally-associative activity degree of expressiveness at examinees of asymmetry of touch and motor functions (the profile of lateral organizations) makes authentic impact on estimations of absolute power biopotentials in theta1 and theta2, alpha1 and alpha2 and beta1, beta2 frequency ranges in both hemispheres (except occipital and the right-parietal electrodes). Further we will consider characteristics of spectral power of those frequency electrodes and rhythmic EEG components for which earlier on the basis of application of T-criterion Student authentic change in comparison with a background has been established.

In figure 3 interaction of expressiveness of factors of the general asymmetry (by results of complete inspection motor, touch and mental asymmetries under the program "Profile"), age and absolute spectral power biopotentials in theta2 range in the right and left prefrontal electrodes (fig. 3) is visually presented.

Взаимодействие факторов возраста, выраженности общей асимметрии (по программе "Профиль") и мощности биопотенциалов в диапазоне тета2 в правом передне-лобном отведении



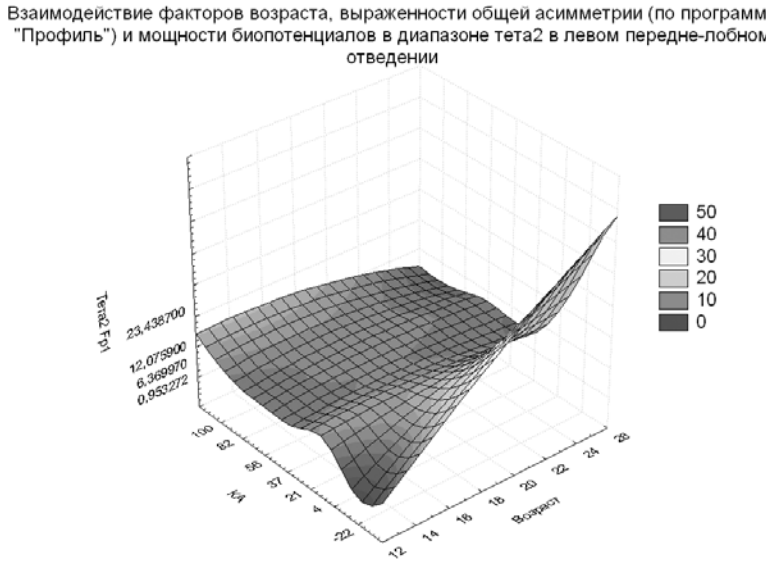
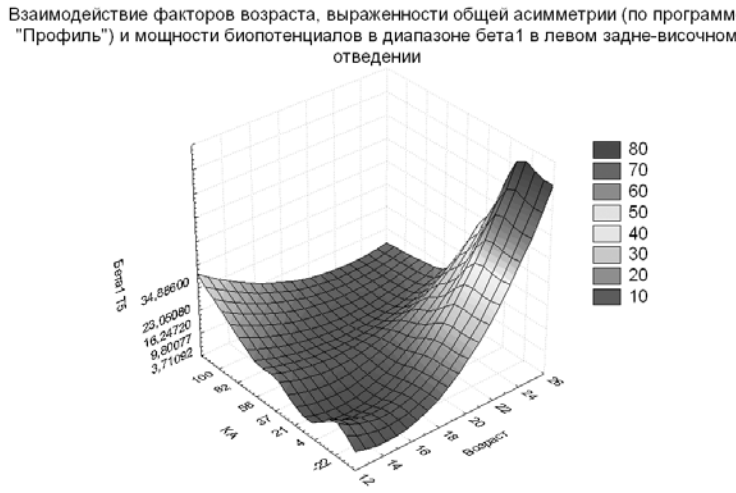


Figure 3. Distribution of values of theta2 power ("Association" test, prefrontal cortex, μV2) depending on value of factors of general asymmetry and age

In figure 3 it is visible, that theta2 absolute power in prefrontal electrodes is highest at examinees is more senior 20 years with expressed link sided lateralization. At expressed right-hand lateralization with increase in age of the surveyed there are no significant changes of absolute power biopotentials of prefrontal cortex at performance of verbally-associative activity. The big synchronization theta2 rhythm in the left prefrontal area in comparison with the right is thus observed.

Interaction of expressiveness of factors of general asymmetry is reflected in figure 4 (by results of complete inspection motor, touch and mental asymmetries under the program "Profile"), age and absolute power biopotentials in beta1 a range in the left and right temporal cortex (fig. 4).



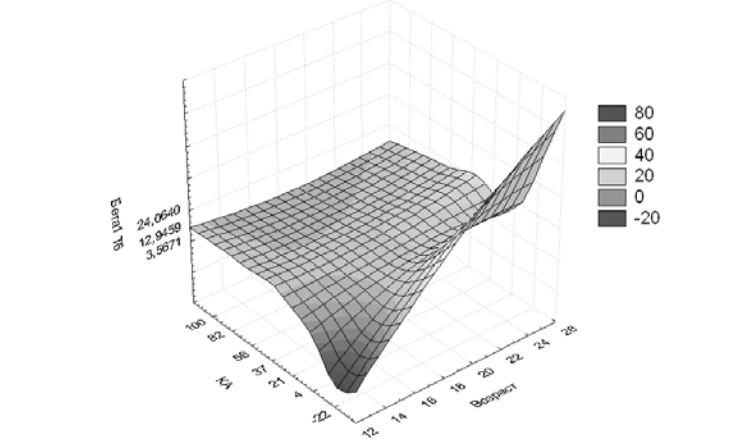


Figure 4. Distribution of values of beta1 absolute power ("Association" test, posterior temporal cortex, μV2) depending on value of factors of general asymmetry and age

The analysis of figure 4 testifies that beta1 absolute power in posterior temporal electrodes is highest at examinees is more senior 20 years with expressed link sided lateralization. At expressed right-hand lateralization with increase in age there are no significant changes of absolute power biopotentials in posterior temporal cortex at performance of verbally-associative activity. In figure 4 also it is visible, that at high degree of expressiveness of "right-hand" signs in a profile of laterality organization

at the age of 13-16 years more expressed synchronization in beta1 a range in the left posterior temporal area in comparison with the right is observed.

Interaction of expressiveness of factors of general asymmetry is reflected in figure 5 (by results of complete inspection motor, touch and mental asymmetries under the program "Profile"), age and absolute power biopotentials in beta1 a range in the left and right inferior temporal cortex (fig. 5).

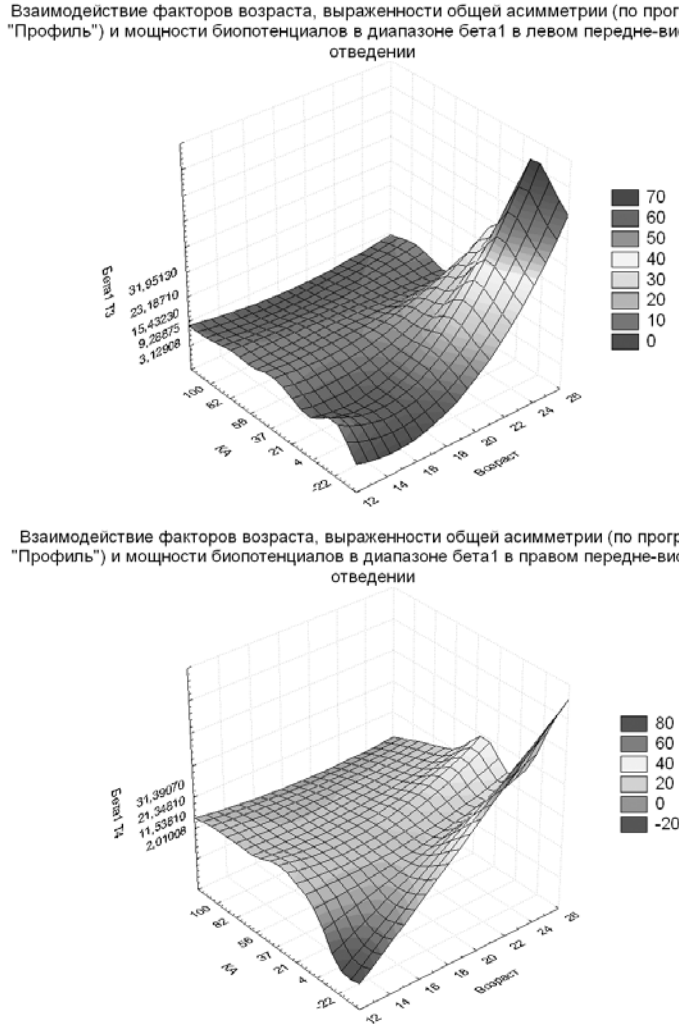
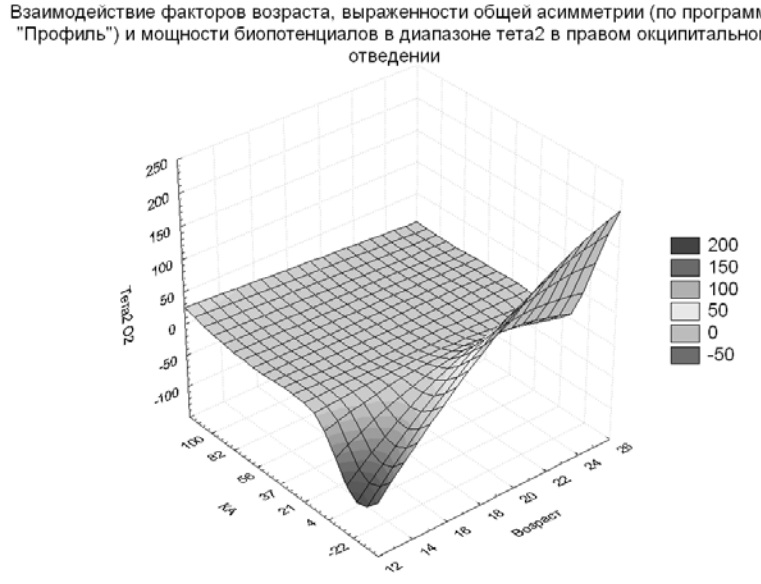


Figure 5. Distribution of values of beta1absolute power ("Association" test, inferior temporal cortex, μV2) depending on value of factors of general asymmetry and age

The analysis of figure 5 allows to conclude, that beta1 absolute power a rhythm in inferior temporal electrodes is highest at examinees is more senior 20 years with expressed link sided lateralization. At expressed right-hand lateralization with increase in age there are no significant changes of absolute power biopotentials of inferior temporal cortex at performance of verbally-associative activity. **EEG in test "the Arithmetic account".** Results of the spent dispersive analysis of influence of expressiveness manual asymmetries on parametres of absolute power biopotentials of the basic analyzed frequency ranges in test "Arithmetic account" testify that degree of expressiveness at examinees of asymmetry of touch and motor functions (a profile of laterality organisation) makes authentic impact on estimations of absolute power biopotentials of mainly right hemisphere (right occipital and parietal electrodes). In figure 6 interaction of expressiveness of factors of the general asymmetry (by results of complete inspection motor, touch and mental asymmetries under the program "Profile"), age and absolute power biopotentials in theta2 and beta1 ranges in the right occipital cortex (fig. 6) is visually presented.



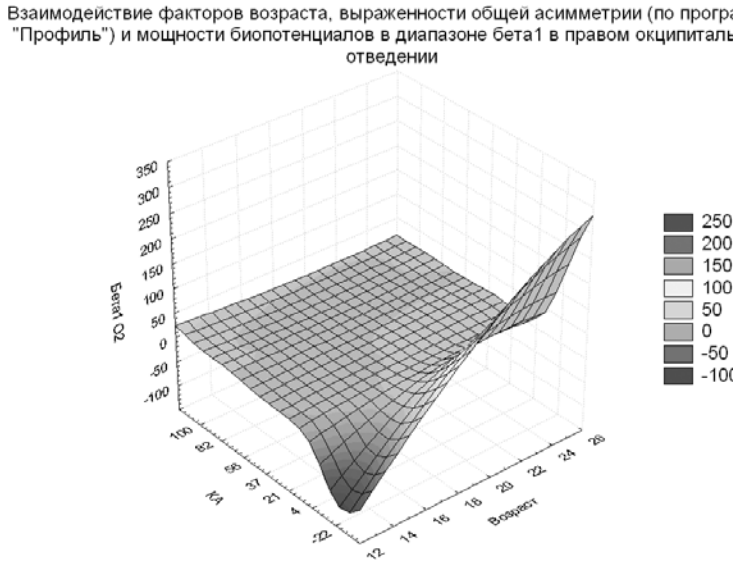


Figure 6. Distribution of values of theta2 and beta1 absolute spectral power (test "Arithmetic operations", the right occipital cortex, μV2) depending on value of factor of the general asymmetry and age

The analysis of figure 6 allows to make the conclusion that absolute power theta2 and beta1 rhythms in the right occipital cortex is highest at examinees is more senior 20 years with expressed link sided lateralization. At expressed right-hand lateralization with increase in age there are no significant changes of absolute spectral power biopotentials of occipital area of the brain at performance of arithmetic operations.

In figure 7 interaction of expressiveness of factors of general asymmetry (by results of complete inspection motor, touch and mental asymmetries under the program "Profile"), age and theta2 absolute spectral power in left parietal cortex (fig. 7) is presented.

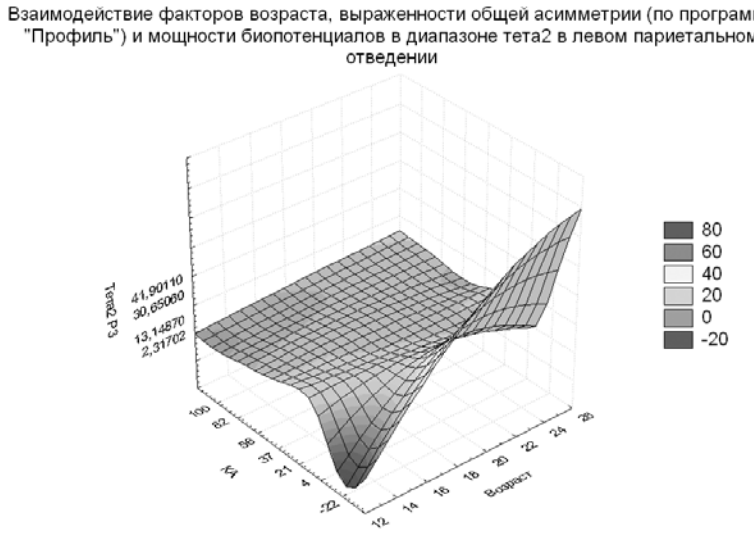


Figure 7. Distribution of theta2 absolute spectral power (test "Arithmetic operations", left parietal cortex) depending on value of factor of general asymmetry and age

The analysis of figure 7 allows to draw a conclusion that, as well as in the previous cases, theta2 absolute power in left parietal electrode is highest at examinees is more senior 20 years with expressed link sided lateralization. At expressed right-hand lateralization with age increase there are no significant changes of absolute spectral power biopotentials of occipital cortex at performance of arithmetic operations.

Further the dispersive analysis of influence of factors of gender, age, an order of a birth of twins (first, second), type of twins (monozygote, dizygote) and their interactions on indicators of asymmetry of the motor, touch and mental functions, the programs received with application "Profile" has been carried out.

It has been as a result established, that factors of a gender and an order of a birth of twins do not render significant influence on indicators of asymmetry of the motor, touch and mental functions, the programs received with application "Profile".

In table 4 results of the dispersive analysis of influence of the factor of age on indicators of asymmetry of the motor, touch and mental functions, the programs received with application "Profile" (tab. 4) are resulted.

Table 4

Results of the dispersive analysis (an independent variable: the age, a dependent variable – the indicators of functional asymmetry received with application of the program "Profile")

Indicators	SS	df	MS	F	p
Test M. Annette	3267,87	40	81,6969	0,446944	0,900676
Figurative thinking	209,00	40	5,2250	1,511536	0,177257
Verbal thinking	181,00	40	4,5250	2,095028	0,053153
Asymmetry factor	15884,88	40	397,1219	2,240931*	0,039061
Type of lateralization	54,96	40	1,3740	0,991593	0,462182

From table 4 it is visible, that the age factor has significant influence on the general indicator of expressiveness of functional asymmetry ($F = 2,24^*$, $p < 0,05$).

Interaction of factors AgexGender of a birth of twins has significant influence on an indicator "Verbal thinking" under the program "Profile" ($F = 2,24^{**}$, $p < 0,01$). Special consideration of the received data has allowed to establish, that at first born twins with age increase twins pairs indicators of verbal intelligence increase.

Also the dispersive analysis of influence of factors of a Gender, age, an order of a birth of twins (first, second), type of twins and their interactions on indicators of absolute power biopotentials has been carried out. In table 5 results of the dispersive analysis of influence of the factor of a gender twins on indicators of absolute power biopotentials (significant estimations are given only) (tab. 5) are resulted.

Table 5

Results of the dispersive analysis (an independent variable: a floor, a dependent variable – indicators of absolute spectral power biopotentials, μV2)

Frequency range, electrodes	SS	df	MS	F	p
Alpha1 O2	952363	262	3634,97	10,03**	0,001
Alpha2 O2	951162	262	3630,39	11,80***	0,0006
Theta1 O1	18992	262	72,49	4,18*	0,042
Alpha2 O1	965892	262	3686,61	5,20*	0,023

Table 5 analysis allows to conclude, that the gender factor has significant influence on indicators of absolute spectral power biopotentials of occipital cortex on the right and at the left in a range theta and alpha. Special consideration of the received data has shown, that at women absolute power an alpha and theta frequencies above, than at men, both in background EEG, and at cognitive loadings.

Discussion. In work Medland S.E. et. al. (2009) the meta-analysis of results twins researches manual asymmetry at the Australian and Dutch twins, and also them siblings is spent. As a result of application of a method of structural modelling efficiency of the model including an additive genetic component (23,64 %) and a component of not divided environment (76,36 %) have been confirmed [8]. According to the data received in our work the contribution of an additive genetic component to distinctions on manual asymmetries has made 48 % that exceeds received Medland S.E. et. al. an indicator.

However, distinctions of distribution of this or that type manual asymmetries in different populations are known. So, for example, in work Sommer I.E., A. Aleman et al. (2008) the distribution meta-analysis "manual asymmetry" depending on an accessory to certain population (the "Western" populations – the USA, Australia, the European countries and the "not Western" populations – Asia, Africa, the near East were compared) is spent. Received Sommer I.E., A. Aleman et al. results testify about more significant quantity left-hand among representatives of the "not Western" populations [9].

Us it is revealed, that at the expressed "right" signs in a profile lateral organizations dynamics of indicators of absolute spectral power is not with the years so essential, as at the expressed "left" signs in a profile lateral organizations. In the latter case the tendency to that at more younger age (13-16 years) at twins the indicators of spectral absolute power corresponding to low standard values are registered, and in more advanced age (22-25 years) – to high standard values for corresponding spectra is found out [2]. The found out increase in absolute total power of electrical activity of brain at subjects with the expressed "left" signs in a profile lateral organisations with increase in their age, presumably, reflects increase of a power metabolism neurons a brain during organism adaptation to environmental influences. The results received by us also can testify that low power level of bioelectric activity of a brain is connected with domination of processes desynchronization, thus high power level of bioelectric activity of a brain is connected with degree of synchronization of activity neuronal ensembles [2]. The data obtained by us that with age increase degree of functional asymmetry grows also, will be co-ordinated with data of other authors (for example, Teixeira Luis A., 2008) [10].

The fact established in given research, that at first-born members of twins pairs more corresponds to advanced age higher indicators of verbal intelligence proves to be true practice of supervision and psychological consultation of twins and their parents [3]. So, first-born twin in pair, as a rule, is more self-assured, more contact in relation to an external social environment at the heart of what lay, probably, its best conditions of prenatal developments. With the years such behavior can lead more to an appreciation of its verbal intelligence in comparison with other twin.

In our work also it is received, that at women absolute power an alpha and theta frequencies above, than at men, both in background EEG, and at cognitive loadings. According to modern representations, synchronization theta a range at steady attention to visual and speech stimulation is connected with productivity of level simultaneous processing of information. Synchronization a rhythm alpha in a situation of steady attention reflects work of the mechanisms connected with brake regulation of processes of processing of the information in a bark of a brain, an irrelevant current problem, and also local activation of separate zones of a bark. Synchronization theta a rhythm in the same conditions is connected with maintenance of deduction of a target of attention [4]. In Razumnikova O.M., Volf N.V., Tarasova I.V. work (2009) with application of dispersive analysis ANOVA data that at performance of the verbal creative task absolute power EEG in a teta1-range raised in comparison with a background ($p < 0,01$) have been obtained, that corresponds also to our data [5].

Conclusions

1. With application classical twins method data that genotype factors bring the essential contribution in phenotypic variability of manual asymmetry ($h^2 = 0,48$), touch asymmetry (asymmetry of sight $h^2 = 0,46$, asymmetries of hearing $h^2 = 0,32$). The estimation of heritability of type of functional asymmetry has made 0,26, thus the essential contribution in phenotypic variability of the given indicator is brought by the individual environment ($e^2 = 0,74$).

2. In background EEG synchronization the rhythm alpha in occipital electrodes is most expressed at twins with prevalence of the "right" signs in a profile латеральной to the organization, thus expressiveness of spectral absolute power a rhythm alpha is stable enough in an age range of 14-26 years. Prevalence of the "left" signs in a profile латеральной the organizations is connected with change of level of spectral absolute power an alpha of a rhythm from low in more younger age range (13-16 years) to rather high at the age of 22-25 years.

3. At expressed right-hand lateralization performance of verbally-associative activity is connected with more theta2 synchronization in prefrontal area, and also more beta1 synchronization in posterior temporal area with left hemisphere domination. Prevalence of the "left" signs in a profile of lateral organizations is connected with change of level of spectral absolute power theta2 and beta1 rhythms from low in more younger age range (13-16 years) to rather high at the age of 22-25 years.

4. Degree of expressiveness at examinees of asymmetry of touch and motor and mental functions (a profile of lateral organization) makes authentic impact on estimations of spectral power biopotentials at performance of arithmetic operations of mainly right hemisphere (right occipital and parietal electrodes).

The received results can be used in practical psychological advisory, psychocorrectional activity, practice of training of schoolboys and students taking into account the revealed laws.

References

1. Alexandrov J.I. System structure of individual experience as reflexion of history of its formation // Almanac "New researches". Materials of the international scientific conference "Physiology of development of the person". – M: Verdana. – 2009. № 2 (19). P. 15–16.
2. Grigorieva V.N. Rehabilitation of patients with chronic forms of diseases of nervous system: clinical-neirophyziological and medico-psychological researches. – M., 2001. – 44 p.
3. Egorova M.S, Zyrjanova N.M., Parshikova O.V, Pjankova S.D., Tchertkova J.D. Genotype. Environment. Development. – M: OGI, 2004. – 576 p.
4. Novikova S.I., Malahovskaja E.V., Pushina N.P., Tsetlin M.M., Filatov A.I., Posikera I.N., Stroganov T.A. Interrelation of spectral amplitude θ and α -ranges EEG with estimations cognitive abilities at preschool age // Physiology of human. – 2009. – V. 35. – # 4. – P. 20–27.

5. Razumnikova O.M, Volf N.V., Tarasova I.V. Strategy and result: Genderual distinctions in electrographic correlates verbal and figurative creation// Physiology of human. – 2009. – V. 35. – # 3. – P. 31–41.
6. Talyzina N.F., Krivtsova S.V., Muhamatulina E.A. Nature of individual distinctions: research experience by twins method. – M: the Moscow State University, 1991. – 192 p.
7. Anokhin A.P. Genetics and development of frontal brain function in adolescence: implications for self-regulation of behavior // Almanac "New researches". Materials of the international scientific conference "Physiology of development of the person". – M: Verdana. – 2009. – # 2(19). – P. 14–15.
8. Medland S.E., D.L. Duffy, M.J. Wright, G.M. Geffen, D.A. Hay, F. Levy, C.E.M. van-Beijsterveldt, G. Willemsen, G.C. Townsend, V. White, AI.W. Hewitt, D.A. Mackey, J.M. Bailey, W.S. Slutske, D.R. Nyholt, S.A. Treloar, N.G. Martin, D.I. Boomsma Genetic influences on handedness: Data from 25,732 Australian and Dutch twin families // Neuropsychologia. – 2009. – V. 47. – P. 330–337.
9. Sommer I.E., A. Aleman, M. Somers, M.P. Boks, R.S. Kahn Gender differences in handedness, asymmetry of the Planum Temporale and functional language lateralization // Brain research. – 2008. – V. 1206. – P. 76–88.
10. Teixeira Luis A. Categories of manual asymmetry and their variation with advancing age // Cortex. – 2008. – V. 44. – P. 707–716.