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Canonical Relations of Sensorimotor Reactions of Multilateral and Bilateral Body Parts

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Abstract
The research study was carried out on a sample of 20 subjects, of male gender, from 20 to 22 years of age. An analysis was carried out in the space of sensorimotor reactions of multilateral and bilateral (parallel, transversal, diagonal) body parts. The evaluation of sensorimotor reactions in multilateral and bilateral body structures was developed through an especially constructed instrumentarium (Kinesiometer, M. Dodig, 1987). The obtained results have been processed by application of canonical correlational analysis (Cooley and Lohnes,1971). Based on maximum cohesion between the pair of linear functions of variable groups that measured sensorimotor reactions (transversal, parallel, diagonal) body parts, a significant cohesion of latent multilateral and bilateral dimensions was obtained. This cohesion undoubtedly indicates the significance of the coherence process of separate and cooperative functions of the right and left cerebral hemisphere which can produce clearly differentiated reactions in terms of multilateral and bilateral body parts. In addition, the sensorimotor reaction is dependent on the speed of change of excitation and inhibitions of those central areals that govern execution of sensorimotor reactions. The matter at hand is sequential regulation that comprises of activation of motor units of various degrees, synergy regulation and tonus regulation which are determined according to both multilateral and bilateral structures.

Key words: canonical correlational analysis, canonical relations, sensorimotor reactions, multilateral and bilateral (transversal, parallel, and diagonal) body parts.

PROBLEM

Oftentimes, the motion of the human body starts with a sensorimotor reaction, when the stimulus via afferent impulses reaches its stimulative threshold in the sensor, the impulses come, carrying data into one or both hemispheres that provide resistance and through efferent fibres a reaction in the effector occurs, reacting to a certain stimulus (1, 5, 6, 8) It is possible to view every process that takes place in the brain through various perspectives where each one has certain pros and cons. That certainly pertains to the problem of interaction cerebral functions in general, and within it collaboration between cerebral hemispheres in solving motor tasks (2,3) This is obviously a highly complex issue whose study requires a combination of various approaches and methods that can jointly offer a model of work and collaboration of the cerebral hemispheres (13, 14, 15) The concept of lateralization of cerebral hemisphere functions pertains to the existence of differences in the functioning of the left and right cerebral hemisphere, that is, the comprehension that the left and right hemispheres are not equally capable of conducting various functions, what implies that in regard to certain functions, one hemisphere (the so-called dominant or specialized hemisphere) is relatively superior to the other hemisphere (11, 12). This phenomenon is also known as functional asymmetry, that is, functional specialization of cerebral hemispheres. Awareness on lateralization of cerebral hemisphere functions and mechanisms of interaction between hemispheres enabled studies and research carried out in those areas, that is numerous methods that are applied within them (7, 9). In terms of unilateral stimulus, the stimulus occurs in just one field, that is, in one hemisphere, where the sensorimotor reaction serves as the subject's response in regard to evaluation of efficacy of a certain hemisphere in the analysis of the stimulus. As far as bilateral stimulus is concerned, where stimulus occurs simultaneously in two fields, that is, in two hemispheres, the situation is somewhat more complex. Namely, it is possible that the differences in success in view of the two hemispheres reflect the differences in the efficiency of the hemispheres for analysis of certain data, but effects of competitiveness between the hemispheres can also have an impact on them. Knowing the anatomical and functional characteristics of cortical and subcortical ties between the hemispheres is important for easier understanding of results obtained from conducted studies on inter-hemisphere interaction. Studies are based on the characteristic of the nervous system that every hemisphere is for the most part tied to contralateral effectors and receptors, so that in regard to the task where receptors are stimulated, on one side of the body, the impact of the subject is dependent on the efficacy of the contralateral hemisphere for analysis of stated data. Multilateral and bilateral presentations of stimulus are possible, depending on whether only one side of the body is stimulated or both sides simultaneously.

In the regulation of sensorimotor reactions a very broad-spectrum integration is carried out, so as to include various regulative mechanisms that represent the prerequisite for conducting and determining the phenomenon of sensorimotor reactions. Since the reactions to the light stimulus of multilateral and bilateral body parts represent the source of a partial joint variability, this study was projected so as to affirm the relations of this area. Considering that the morphological – functional structure establishes the dependency of sensorimotor reactions this study was projected so as to affirm the part of the entire variability divided by sensorimotor reactions of multilateral and bilateral (transversal, diagonal, parallel) body parts to sound stimulus.

METHODS

The sample subjects for this research list 20 subjects, male, ranging from 20 to 22 years of age. The process of collecting data and setting parameters was conducted using an instrument called the KINESIOMETER (M. Dodig, 1987), hooked up to an electronic computer, with an adequate periphery, with application of program support for analogue – digital conversion in the programming language SIMON'S BASIC. The kinesiometer latched to body joints ensured transference of analogue sizes of body part reactions, which transform from electrical signals to digital impulses via an analogue-digital converter. The signal light system is directly connected to the converter, which is synchronized with the measurement system that has a maximum precision measurement of 2-8, i.e. 256 parts of basic value. Measuring was conducted according to a specific program. The subject was situated in an adequate position with the attached instrumentarium and carried out certain reactions with motion (picture 1).

M

Picture 1. Schematic overview of positions (M) multilateral and bilateral (A - transversal, B – diagonal, C – parallel.

1. the subject is placed in a horizontal position on his back, outstretched arms and legs next to his body (the zero position) to which kinesiometers are attached.
2. on a sound signal the subject exerts a reaction with multilateral body parts (simultaneously right arm, left arm, right leg, left leg) and bilaterally (transversal – right and left arm – right and left leg), (diagonally – right arm, left leg – left arm, right leg) and (parallel – right arm, right leg – left arm, left leg) body parts.

Data is collected by measuring, tests are marked with special features where the first letters mark the sensorimotor space (S), the second letter marks the type of stimulus sound (Z), the third and fourth letters mark the body part by which the reaction is realized, right arm (DR), left arm (LR), right leg (DN), left leg (LN) and the fifth letter marks the object of measuring, multilateral (M) and bilateral – transversal (T), diagonal (D) and parallel (P).

1. the variables for evaluation of sensorimotor reactions by multilateral body parts (simuletaneously right arm, left arm, right leg, left leg). 1.(SZDRM), 2.(SZLRM), 3.(SZDNM) 4.(SZLNM)
2. the variables for evaluation of sensorimotor reactions of bilateral-transversal body parts (individually, right arm, left arm, right leg, left leg). 1.(SZDRT), 2.(SZLRT),3.(SZDNT), 4.(SZLNT)
3. the variables for evaluation of sensorimotor reactions bilateral-diagonal body parts (individually, right arm, left arm, right leg, left leg). 1.(SZDRD), 2.(SZLRD),3.(SZDND), 4.(SZLND)
4. the variables for evaluation of sensorimotor reactions bilateral-parallel body parts (individually, right arm, left arm, right leg, left leg). 1.(SZDRP), 2.(SZLRP),3.(SZDNP), 4.(SZLNP)

A canonical correlational analysis (Cooley i Lohnes, 1971) was conducted in terms of analysing data for affirming relations between the sensorimotor reactions of multilateral and bilateral (transversal, diagonal, parallel) body parts. (4) Coefficients of canonical correlation, vectors of transformational coefficients and correlations between variables and canonical dimensions isolated from both groups were analysed. The significance of the coefficient of canonical analysis was tested with Bartlett's method (Bartlett, 1947), with a 0.05 margin of error.

RESULTS

The variable characteristics were determined by a standard descriptive procedure. A group of variables of sensorimotor reactions of multilateral and bilateral body parts in terms of light stimulus (table 1). On the basis of obtained values of the fundamental central and dispersive variable parameters of sensorimotor reactions of multilateral and bilateral body parts, it can be determined that the distribution of results in almost all variables does not significantly deviate from normal distribution. The dispersion of results in terms of arithmetic means indicates that derogation is lesser in all those variables that mostly measured sensorimotor reactions of bilateral body parts.

Table 1. The central and dispersive parameters of variables of the sensorimotor reactions of multilateral and bilateral body parts

Variables:	XA	SIG	MIN	MAX
1. SZNLM	0.3298	0.0669	0.2383	0.4916
2. SZRLM	0.3322	0.0733	0.1934	0.5022
3. SZNDM	0.3233	0.0756	0.2102	0.4613
4. SZRDM	0.2965	0.0696	0.1496	0.4345
5. SZNLT	0.3084	0.0525	0.2237	0.3868
6. SZRLT	0.3297	0.0677	0.2243	0.5103
7. SZNDT	0.2998	0.0574	0.1892	0.4054
8. SZRDT	0.2901	0.0738	0.1752	0.4776
9. SZNLD	0.3005	0.0507	0.2149	0.3961
10.SZRLD	0.3180	0.0448	0.2359	0.4392
11.SZNDD	0.2888	0.0460	0.1892	0.3621
12.SZRDD	0.2919	0.0604	0.1724	0.4124
13.SZNLP	0.3010	0.0572	0.2027	0.3971
14.SZRLP	0.3227	0.0497	0.2383	0.4205
15.SZNDP	0.2940	0.0696	0.1425	0.3994
16.SZRDS	0.3049	0.0718	0.1612	0.4355

Key: SZLNM - sensorimotor reaction left leg multilaterally, SZLRM - sensorimotor reaction left arm multilaterally, SZDNM - sensorimotor reaction right leg multilaterally, SZDRM – sensorimotor reaction right arm multilaterally, SZLNT - sensorimotor reaction left leg transversally, SZLRT - sensorimotor reaction left arm transversally, SZDNT - sensorimotor reaction right leg transversally, SZDRT – sensorimotor reaction right arm transversally, SZLNP - sensorimotor reaction left leg parallel, SZLRP - sensorimotor reaction left arm parallel, SZDNP - sensorimotor reaction right leg parallel, SZDRP – sensorimotor reaction right arm parallel, SZLND - sensorimotor reaction left leg diagonal, SZLRD - sensorimotor reaction left arm diagonal, SZDND - sensorimotor reaction right leg diagonal, SZDRD – sensorimotor reaction right arm diagonal,

XA – arithmetic mean
SIG – standard deviation
MIN – minimum
MAX - maximum

Cohesion of variables intended for measuring sensorimotor reactions of multilateral and bilateral (transversal, parallel and diagonal) body parts, emit data that the area is homogeneous, what is an undoubted indicator of solid cohesion within the area. According to the obtained correlation coefficients, it can be assumed that a significant role is played by the central nervous system, made up of hundreds and thousands of separate neuron groups. The motor processes and constructions, such as the sensorimotor reaction, velocity, motion coordination and others can be tied to the functioning of certain cerebral parts. The interaction of the two hemispheres and the cooperation between hemispheres determines one of the basic mechanisms that enables continuity and complexity. Namely, in terms of simple tasks, the resources of one hemisphere are enough for its analysis, so an intra-hemispheric analysis model is dominant in this case. This primarily refers to multilateral structures characterized by simultaneous motion of all body parts and bilateral characterized by motion of certain body parts in pairs.

Table 2. The matrix of correlational coefficients of the sensorimotor reactions of multilateral and bilateral (transversal, parallel, and diagonal) body parts

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1. SZNLM	1.00															
2. SZRLM	.37	1.00														
3. SZNDM	.91	.45	1.00													
4. SZRDM	.69	.85	.72	1.00												
5. SZNLT	.13	.58	.18	.48	1.00											
6. SZRLT	.39	.50	.32	.54	.50	1.00										
7. SZNDT	.32	.27	.46	.40	.74	.44	1.00									
8. SZRDT	.46	.47	.40	.64	.51	.93	.51	1.00								
9. SZNLD	.08	.37	.12	.29	.75	.16	.49	.23	1.00							
10.SZRLD	.09	.51	.07	.32	.48	.36	.26	.32	.23	1.00						
11.SZNDD	.25	.23	.52	.30	.39	.18	.71	.30	.17	.28	1.00					
12.SZRDD	.38	.25	.38	.47	.59	.29	.60	.48	.79	.20	.22	1.00				
13.SZNLP	.16	.59	.21	.50	.59	.06	.31	.20	.65	.31	.36	.43	1.00			
14.SZRLP	.23	.57	.17	.49	.32	.22	.15	.26	.37	.55	.14	.36	.68	1.00		
15.SZNDP	.36	.22	.48	.36	.39	.11	.64	.24	.37	.13	.66	.42	.51	.45	1.00	
16.SZRDP	.43	.36	.42	.53	.58	.27	.62	.44	.49	.41	.50	.65	.63	.65	.67	1.00

Key (see Table 1)

In general terms, the structure of the matrix of inter-correlation of variables indicates that the variables within the context of multilateral body parts and variables of bilateral – parallel and transversal body parts assemble within their groups, which is not the case with diagonal body parts. In the area of multilateral reactions, discrimination is determined with four cerebral processes that occur simultaneously, while in the case of bilateral reactions, discrimination is determined with two cerebral processes that occur simultaneously. It is important to emphasize that the primary anatomical physiological structure connecting the two hemispheres is a callused body comprised of several groups of fibre in charge of conveying various types of data. Its frontal part, genu, serves to connect the pre-frontal area, followed by the truncus fibres which connects the rear upper frontal regions, and the motor, as well as the somatosensory cortex. Thereafter, a body part of the callosum that connects the temporal-parietal-occipital area, and the splenium, which serves as a link between the rear part of the temporal-parietal-occipital area, as well as the rear vertex and temporal region. Thus, certain cerebral regions are connected with inter-hemispheric fibres that take up a precisely defined area in the callused body, where the fibres linking the various cerebral parts barely overlap. Although the callused body mostly stands out as the primary structure which enables the interhemispheric data transfer process, it is clear that a series of subcortical fibres and paths also participate in the data transfer. Out of those paths, the frontal commissure is mentioned most of the time, a characteristic topographic organization of inter-hemispheric fibres.

Canonical relations of sensorimotor reactions of multilateral and bilateral- transversal body parts

Sensorimotor reactions of multilateral and bilateral-transversal body parts explain canonical relations with two canonical roots (table 3). The canonical correlational analysis of the aforementioned two variable groups showed that at the level of significance testing P = 0.00 a significant cohesion between the first pair of canonical factors exists. The obtained results show a relatively good cohesion (0.92) and with a significant contribution to the joint variance of 85 %. The second canonical correlation belonging to the second canonical factor has a somewhat lesser cohesion (0.78) with 60 % of joint variance, on a significance level of P = 0.03.

Table 3. The canonical correlations, the roots of the canonical equation and tests of significance of canonical roots in areas of multilateral and bilateral-transversal body parts

	C2	C	L	X2	D. F.	P
1	.8451	.9193	.0423	45.847	16	.0001
2	.6042	.7773	.2734	18.803	9	.0269
3	.2119	.4603	.6909	5.362	4	.2521
4	.1234	.3513	.8766	1.910	1	.1670

Key: C2 – eigenvalue; C – canonical correlation; L – Wilks lambda; X2 – Chi – square; DF – D. F.; P – sing. level

The first canonical dimension in the area of sensorimotor reactions multilateral body parts is defined with variables that measured multilateral sensorimotor reactions with right leg, left arm and right arm with a negative algebraic sign. In the area of variables that measured sensorimotor reactions of bilateral-transversal body parts, the first canonical dimension is determined by the left arm, right leg and right arm with a negative algebraic sign (table 4).

Table 4. The vectors of transformation into canonical variables (W) and canonical factors (F) are isolated in the area of sensorimotor reactions of multilateral and bilateral-transversal body parts

	W1	W2	F1	F2
1. SZNLM	-1.15666	0.07185	-0.57174	2.17295
2. SZRLM	-1.65609	-0.89412	1.12084	0.32898
3. SZNDM	1.33979	-0.92116	1.56155	-1.06310
4. SZRDM	1.20177	2.18142	-1.10655	-0.89306
5. SZNLT	-1.09970	0.48082	0.01212	-0.96603
6. SZRLT	-1.28777	-1.39898	1.28396	1.52077
7. SZNDT	1.07334	-0.55377	0.95422	0.12008
8. SZRDT	1.21835	2.15044	-1.27174	-0.57304

Key (see Table 1)
W1 - canonical variables

F1 - canonical factors

The variable in the multilateral area that measured the sensorimotor reactions with the left leg and right leg with a negative algebraic sign has significant projections on the isolated second canonical dimension. The second canonical dimension in the bilateral-transversal area is defined by the measure that measured sensorimotor reactions of the left arm and left leg with a negative algebraic sign.

Canonical relations of sensorimotor reactions of multilateral and bilateral-diagonal body parts

The relations of sensorimotor reactions of multilateral and bilateral-transversal body parts, can be explained with one canonical root (table 5). The canonical correlation of the canonical dimension pair explains the largest part of covariability of analysed variable groups which amounts to 86 % and the obtained cohesion of the first linear functions which amounts to (0.93), with a significance level of P = 0.00.

Table 5. Canonical correlations, roots of the canonical equation and significance tests of canonical roots in the area of multilateral and bilateral-transversal body parts.

	C2	C	L	X2	D. F.	P
1	.8585	.9266	.0511	43.134	16	.0003
2	.4950	.7035	.3609	14.779	9	.0972
3	.2792	.5284	.7145	4.874	4	.3005
4	.0086	.0928	.9914	.126	1	.7231

Key (see Table 3)

The isolated canonical dimension in the area of sensorimotor reactions of multilateral body parts is defined by a variable that measured multilateral sensorimotor reactions with the right hand (table 6).

Table 6. The vectors of transformation into canonical variables (W) and canonical factors (F) are isolated in the area of sensorimotor reactions of multilateral and bilateral-diagonal body parts.

	W1	F1
1. SZNLM	-0.93829	0.30519
2. SZRLM	-1.66676	0.36001
3. SZNDM	1.10670	-0.40122
4. SZRDM	1.50169	0.74312
5. SZNLD	-1.01050	-0.07182
6. SZRLD	-0.53390	0.67623
7. SZNDD	0.49680	0.92505
8. SZRDD	1.17414	-0.90565

Legend (see Table 4)

In the area of sensorimotor reactions of bilateral-diagonal body parts, the largest projection to the isolated canonical dimension has the sensorimotor reaction of the right and left hands.

Canonical relations of sensorimotor reactions of multilateral and bilateral-parallel body parts

The canonical correlation of the first pair of canonical dimensions isolated from the variable group amounts to (0.79) with 62 % of extracted joint variance). Obtained results show a significance level of P = 0.05.

Table 7. Canonical correlations, roots of canonical equation and significance tests of canonical roots in the area of multilateral and bilateral-parallel body parts.

	C2	C	L	X2	DF	P
1	.6187	.7866	.1702	25.676	16	. 0518
2	.3606	.6005	.4464	11.694	9	.2311
3	.2708	.5204	.6982	5.209	4	.2665
4	.0425	.2063	.9575	.630	1	.4272

Key (see Table 3)

In the area of sensorimotor reactions with multilateral body parts the first canonical dimension is defined by the sensorimotor reactions of the right leg, left leg and right arm with a negative algebraic sign (table 8).

Table 8. Vectors of transformation in canonical variables (W) and canonical factors (F) isolated in the area of sensorimotor reactions of multilateral and bilateral-parallel body parts.

	W1	F1
SZNLM	-1.11074	-1.01522
SZRLM	-0.44903	-0.00130
SZNDM	1.87319	1.35760
SZRDM	-0.71082	0.55683
SZNLP	-0.28476	0.47858
SZRLP	-0.51906	-0.12192
SZNDP	1.28305	0.77877
SZRDP	-0.84608	-0.03780

Key (see Table 4)

While in the area of variables of bilateral – parallel body parts, sensorimotor reaction of the right hand and considerably weaker left leg have significant projections in regard to the isolated canonical dimension. The obtained results indicate that the two answers, which cross themselves while simultaneously originating from the same stimulus, represent the primary reason of occurred connections within these areas. Effective functioning of the perceptive system to sound stimulus, the speed of emission signal from the receptor (channel flow, efficiency of data decoding device and efficiency of data transmission), the speed of synaptic signal transmission (the number of synaptic relations and flow through the synaptic barrier) as well as the efficient functioning of commissural relations between hemispheres present the primary reason for obtained results. Thus, sensorimotor reactions of the organism are neither a simple nor elementary feature of the organism, regardless of the nature of simplicity. This ability, before, was just a special mode of functioning of an entire system for reaction regulation and control.

The obtained cohesion of latent multilateral and bilateral (transversal, diagonal and parallel) dimensions undoubtedly indicates the significance of the coherence process of separate and cooperative functions of the right and left cerebral hemisphere that can produce clearly differentiated reactions with bilateral body parts. Although within certain similarities of hemisphere specializations, a clear preference of the right side and the prevalence of the lower limbs is indicated. The obtained cohesion in this area undoubtedly indicates the significance of the left and right cerebrum hemispheres which produces clearly differentiated evolved potentials for solving sensorimotor reactions. The larger cerebral specialization hemisphere is parallel with a clear preference of lateralization of the left hemisphere (what is provoked by execution of task presented by the right lateral structures).

CONCLUSION

The research was carried out with the goal to affirm a part of the entire variability separated by the sensorimotor reactions of multilateral and bilateral (transversal, parallel, diagonal) body parts. The research study was conducted on a sample of 20 subjects, of male gender, ranging from 20 to 22 years of age. The process of collecting data and setting parameters was conducted by using an instrument called the KINESIOMETER (M. Dodig, 1987.), hooked up to an electronic computer, with an adequate perifery, with application of program support for analogue – digital conversion in the programming language SIMON'S BASIC, which enabled an analogue – digital conversion of results. Data about sensorimotor reactions of multilateral and bilateral (transversal, diagonal and parallel) body parts was obtained through measuring. The relations within the stated area were affirmed via the technique of canonical correlational analysis (Coolly and Lohnes,1971). On the basis of maximum cohesion between the pair of linear functions two groups of variables that measured sensorimotor reactions of multilateral and bilateral (transversal, diagonal and parallel) body parts, were extracted in the area of multilateral and bilateral-transversal body parts of two canonical characteristic roots. In the area of bilateral – diagonal and bilateral – parallel body parts, one characteristic canonical root per area was extracted. The obtained results indicate a topological and functional dependency of sensorimotor reactions of multilateral and bilateral body parts. An efficiency of functioning of the emission signal speed and the speed of the synaptic transmission (the number of synaptic ties and flow through synaptic barriers), efficient functioning of commissural relations between the hemispheres and the efficiency of afferent and efferent paths directed towards multilateral and bilateral body parts can probably be found at the basis of these indicators. The basic reason of obtained functional dependency between the sensorimotor reactions of multilateral and bilateral body parts lies within the structure for excitation regulation and partly excitation intensity (activation of motor units) of varying degrees, synergic regulation and tonus regulation which are also determined according to multilateral and bilateral structures.

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