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Relations between Handedness and Motor Abilities in Preschool Children

Gustav Bala[1], Špela Golubović[2] and Ratko Katić[3]

[1] Faculty of Sports and Physical Education, University of Novi Sad, Novi Sad, Serbia
[2] Faculty of Medicine, University of Novi Sad, Novi Sad, Serbia
[3] Faculty of Kinesiology, University of Split, Split, Croatia

A B S T R A C T

Relations between laterality and motor abilities were assessed in preschool children. Study sample included 202 children aged 5–7.5 decimal years. Upper extremity usage and gesture laterality was assessed by a battery of tests and used on children evaluation according to harmonious or inharmonious laterality. The performance of motor tasks that require whole body coordination, the speed of alternating hand motion frequency and the precision of hand aiming were assessed according to the type of laterality. There were no statistically significant sex differences in laterality distribution, and no differences according to laterality harmonization. There was no statistically significant difference in motor test performance between the children with harmonious and inharmonious laterality.

***Key words**: usability laterality, spontaneous laterality, harmonious laterality, dyslaterality, preschool children, motor abilities*

Introduction

Laterality is considered to be outward manifestation of the cortical integrative activity, manifesting the asymmetric action of the brain hemispheres. The initial interpretations of laterality were rather simplified, with cerebral dominance usually referring to the left hemisphere, whereas right hemisphere used to be considered as a subdominant hemisphere. However, neuropsychological studies have recently revealed that both hemispheres function together, while possessing different forms of information processing. Therefore, it could preferably be referred to as a mosaic pattern of the brain hemisphere dominant functions, whereby some functions are being organized with left hemisphere dominance and some others with right hemisphere dominance, thus exclusive dominance of either hemisphere being ruled out.

The establishment and maturation of one *versus* other extremity dominance develop gradually and in dependence of the maturity of cerebral lateralization. This process of dominant extremity maturity in the area of manipulation has been associated with age 5–11 years (Gabbard et al., 1995; Segalowitz and Molfese, 1988; Hill and Khanem, 2009)[1–3], when gradual maturation of between-hemisphere connections occurs. In the phylogenic development, lateralization is formed in concordance with the development of fine motor coordination, i.e. complex manipulative activities such as catching small objects, graphomotor expression, use of tools, etc.

Human population are divided into dextral (D), sinistral (S) and ambidextral (D/S) persons, the leading hand being inadequately differentiated in the latter. Interpretation of the hand preference distribution in the general population depends on the investigators and instruments employed. The Annett's model (1985)[4] proposes that handedness is distributed continuously, whereas McManus's model (1985)[5] proposes it to be distributed dichotomously. Dragović et al. (2008)[6] conclude that the distribution of hand preferences in humans is discrete and not continuous. In addition to congenital disposition (Annett, 1964)[7], structural asymmetries of brain hemispheres (Subirana, 1964)[8], pathologic mechanisms acting during the central nervous system (CNS) maturation, in daily activities the development of upper extremity laterality is also influenced by immediate environment.

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Monitoring the usage and gesture laterality implies dual observation as a synchronous and unsynchronous phenomenon. The former assumes it to follow a harmonious, synchronous phylogenic development during which all structures and functions have developed and supplemented each other, eventually resulting in concordant ontogenetic development that will manifest as dextrality in both usability and gesture laterality. In the latter, the phylogenic development is supposed to be followed by forced extremity utilization against dominance, under the influence of the social environment.

The congenital basis of hand laterality is termed gesture laterality and is determined by cortical dominance of the brain hemispheres. This laterality is clinically manifested by movements that are spontaneous, without any specific meaning or aim (Povše-Ivkić and Govedarica, 2000; Bojanin, 1986; Lurija, 1983; Mohr et al., 2006)[9–12]. Some of these movements are: cross your hands on top of your head, cross your hands on the chest, point two fingers one over the other, etc.

Dominant laterality of upper extremities indicates the leading extremity on performing complex psychomotor activities (Bojanin, 1986)[10]. Children learn these movements at home and at school, and refer to the activities such as writing, using cutlery, cutting with scissors, combing, etc. The leading usable hand in manipulative activities is formed under the influence of social environment.

Harmonious psychomotor organization implies clear lateralization of either dextral or sinistral type. Usability and gesture laterality need not always be ipsilateral. Bojanin (1986)[10] found 23% of children with harmonious psychomotor organization to have different usability and gesture laterality. In fact, ambivalence leading to inadequate psychomotoricity and causing difficulties on identifying the leading extremity on performing some motor activity poses a problem for harmonious psychomotor organization. It is usually referred to as dyslaterality or ambidexterity in persons showing ambivalence in either usability or gesture laterality. However, it should be noted that the lack of harmony between usability and gesture laterality also represents dyslaterality leading to inadequate psychomotoricity. This form of dyslaterality is more common in children with dysgraphism, dyspraxia and dyslexia than in those with harmonious psychomotor organization (Bojanin, 1986)[10]. According to the level of manifestation, it is categorized into strong, moderate and mild extremity laterality or cerebral hemisphere dominance. Numerous studies have compared motor test performance, motor skills and abilities between the dominant and subdominant hand, frequently with quite contradictory results, mostly due to the lack of uniform methodological approach. Studies generally report on the children with harmonious laterality to show better performance than those with dyslaterality. This also refers to motor coordination and motor precision (Tan, 1985)[13]. Significant differences in favor of right-handed children have been described, pointing to their higher precision, accuracy and stability (Mori et al., 2007)[14]. These authors note that bimanual coordination and precision in children are influenced by the dominant hand and are associated with the development of intra-hemispheric communication. In contrast, Keane (2008)[15] considers bimanual tasks to be regulated by the general motor movement programming rather than being dependent on the dominant hand. The problems of dyslaterality and hand coordination are more common in clumsy children lacking motor coordination (Nikolić and Ilić-Stošović, 2009)[16].

In contrast to most other authors, Mori et al. (2004)[17] found no significant difference in motor abilities between children with harmonious laterality and dyslaterality of upper and lower extremities. Functional difference between the left and right extremities was more pronounced on performing the tasks requiring precise control, such as throwing, aiming and pricking, usually associated with dominant extremity. On spontaneous movements, right-handed persons will use left hand more frequently than left-handed persons using their right hand (Annett, 2009)[18].

The aim of the present study was to analyze relations between laterality and motor abilities used to assess motor factor of movement structuring, and factor of functional synergy and tonus regulation. To the best of our knowledge, there are no studies of motor space based on a great number of variables to determine a cybernetic and hierarchical model of motor abilities in children. Therefore, defining the motor factors mentioned above was based on the results of studies carried out in adolescents (Kurelić et al., 1975)[19]. According to these findings, the factor of movement structuring could be defined as a regulatory and integrating system allowing for fast formation of efficient motor programs and their controlled performance based on the information received *via* numerous perceptive canals. Within this factor, the ability of performing complex motor structures by whole body transfer in space is of special interest in children, especially if the motor problem requires reorganization of the movement stereotype, i.e. the basic movement already mastered to be performed in a different way (e.g., belly crawling – back crawling, walking on all four forward – walking on all four backward, climbing up and down the stairs facing forward – backward, etc.). The factor of synergistic regulation and tonus regulation could be defined as the ability of regulation and integration, i.e. control of simultaneous sequence, extent and intensity of inclusion and exclusion of the motor units of agonist and antagonist muscle groups, and of the magnitude of force thus generated. This factor control the ability of rapid performance of simple or alternating movements, mostly hand movements, as well as the precision of aiming and shooting.

Materials and Methods

Subjects

The study included 202 children aged 5.00–7.50 decimal years, M=6.01±0.90; subgroup of 131 male children, M=6.08±0.87 and subgroup of 71 female children, M=

5.89±0.95, from Novi Sad preschool facilities. Sex difference in decimal years was not statistically significant and study subjects were matched for intellectual abilities and socioeconomic status. Parental consent was obtained for their children's inclusion in the study as part of the research project entitled Integral Development, Physical Activity and Aberrant Behavior of Preschool Children, financed by the Ministry of Science and Technology, Republic of Serbia.

Measures and tests

Laterality was assessed by a test battery (Povše-Ivkić and Govedarica, 2000)[9]. The dominant usability laterality of upper extremities is assessed by movements daily performed for actions learned in social environment. There are a total of 12 tasks and the child is asked to indicate the hand used to perform these movements, the hand indicated by the child is recorded, and the child is evaluated as being right-handed, left-handed or ambidextrous based on the number of movements performed. The following indicators are used to assess usability laterality of upper extremities: taking a spoon, rotating a screw, lighting a match, combing, hammering, pulling out a nail, threading a ribbon, teeth brushing, cutting bread, dealing cards, eating with a fork, and ringing.

Gesture laterality of upper extremities denotes the side used by the child on performing spontaneous, unlearned movements, which predispose the inborn choice of either side. There are 6 tasks the child has to perform. The lifted arm is recorded and the child is evaluated as being right-handed, left-handed or ambidextrous on the basis of the number of movements performed. The following indicators are used to assess gesture laterality of upper extremities: index finger crossing, extended arm crossing, fist clapping, putting hands on top of the head, fist against fist, and rotating around oneself.

The children showing concordant, i.e. ipsilateral usability and gesture laterality, are evaluated as having harmonious laterality, whereas those where there is discrepancy between usability and gesture laterality are considered as having dyslaterality.

The following test battery was used to assess motor abilities in the field of the general factor of central movement regulation:

- to assess the factor of movement structuring:
  - movement stereotype reorganization: 1) obstacle course backwards (0.1s)
- to assess the factor of functional synergy and tonus regulation:
  - frequency rate: 2) arm plate tapping (frequency)
  - precision: 3) darts (points)

The motor tests employed are briefly described below.

Obstacle course backwards. The child has to walk backwards on all fours and cover the distance of 10 m, climb the top of Swedish bench and go through the frame of the bench. The task is measured in tenths of a second.

Arm plate tapping. For fifteen seconds, the child has to tap alternately two plates on the tapping board with his dominant hand, while holding the other hand in-between the two plates. The result is the number of alternate double hits.

Darts. The subject is standing on the shooting line, 150 cm of the target on a board with eight concentric circles; each concentric field value increases successively from 1 to 10. The target is hung on the wall with its upper edge at 150 cm of the floor. The subject is asked to shoot the target 6 times with either hand and rhythm. The total number of hits is evaluated.

Data analysis

Relations between usability and gesture laterality according to sex were analyzed first, followed by relations between the two laterality categories in the study sample as a whole, thus obviating the possible sex effects on the lateralization. The laterality variables and sex were cross-tabulated, and the significance of relations was determined by Pearson χ^2-test. Motor variables were quantitatively and qualitatively analyzed according to sex, first by multivariate analysis of variance (MANOVA), then by factorization of the matrix of motor variable inter-correlation (Hotelling method of main component), to define the general motor factor of the motor variables applied. The same analyses were employed to assess differences and similarities in motor variables according to groups of harmonious laterality and dyslaterality.

Results

As the left hemisphere, among others associated with speech dominance, has already been considered dominant in females and right hemisphere in males, we wanted to see whether the manifestation of usability and gesture laterality differed between male and female children (Tables 1 and 2). In our study sample, there were 91.6% of right-handed children, 5.9% of left-handed children, and 2.5% of mixed-handed children. These figures are consistent with those reported by Zverev (2004)[20] in Malawian schoolchildren aged 6–17. The frequency of spontaneous (gesture) upper extremity right, left and ambidextrous laterality was 50.5%, 28.2% and 21.3%, respectively. According to χ^2-test there was no statistically significant sex difference in either usability or gesture laterality.

The χ^2-test yielded statistically significant differences in relations between usability and gesture laterality of upper extremities (Table 3). Spontaneous left-handed and mixed-handed laterality was by far more commonly recorded in association with usable left hand dominance as compared with spontaneous right-handed laterality that was not accompanied by the respective usability laterality.

As stated above, harmonious laterality implies ipsilateral manifestation of spontaneous (gesture) and usability laterality, whereas inharmonious laterality refers

TABLE 1
RELATION BETWEEN UPPER EXTREMITY USABILITY DOMINANT LATERALITY AND SEX

			Sex		Total
			Male	Female	
Usability laterality	Right	Count	119	66	185
		% of total	58.9%	32.7%	91.6%
	Left	Count	9	3	12
		% of total	4.5%	1.5%	5.9%
	Mixed	Count	3	2	5
		% of total	1.5%	1.0%	2.5%
Total		Count	131	71	202
		% of total	64.9%	35.1%	100.0%
		Pearson χ^2=0.62		p=0.73	

TABLE 2
RELATION BETWEEN UPPER EXTREMITY GESTURE LATERALITY AND SEX

			Sex		Total
			Male	Female	
Spontaneous laterality	Right	Count	67	35	102
		% of total	33.2%	17.3%	50.5%
	Left	Count	39	18	57
		% of total	19.3%	8.9%	28.2%
	Mixed	Count	25	18	43
		% of total	12.4%	8.9%	21.3%
Total		Count	131	71	202
		% of total	64.9%	35.1%	100.0%
		Pearson χ^2=1.20		p=0.55	

TABLE 3
RELATION BETWEEN UPPER EXTREMITY USABILITY AND GESTURE LATERALITY

			Usability laterality			Total
			Right	Left	Mixed	
Spontaneous laterality	Right	Count	99	2	1	102
		% of total	49.0%	1.0%	0.5%	50.5%
	Left	Count	47	8	2	57
		% of total	23.3%	4.0%	1.0%	28.2%
	Mixed	Count	39	2	2	43
		% of total	19.3%	1.0%	1.0%	21.3%
Total		Count	185	12	5	202
		% of total	91.6%	5.9%	2.5%	100.0%
		Pearson χ^2=11.97		p=0.02		

to dominant extremity on one side and spontaneous laterality on the other side of the body. The results obtained showed that there was no statistically significant sex difference in the distribution of harmonious laterality and dyslaterality (Table 4).

Previous studies have demonstrated some motor abilities to be superior in male than in female children (Katić et al., 2004; Vlahović et al., 2007; Katić et al., 2008; Bala et al., 2009)[21–24]. Our results were consistent with these reports only in the Obstacle course backwards and Darts variables, whereas no statistically significant sex differences were found for the Arm plate tapping variable (Table 5). Yet, the structure of the set of motor variables, i.e. the general factor of this set of variables, was quite similar in both male and female children (H1 girls and H1 boys), thus general factor was calculated for the study

TABLE 4
SEX DISTRIBUTION OF HARMONIOUS LATERALITY AND DYSLATERALITY VARIABLES

		Sex		Total
		Male	Female	
Harmonious laterality	Count	72	35	107
	% of total	35.6%	17.3%	53.0%
Dyslaterality	Count	59	36	95
	% of total	29.2%	17.8%	47.0%
Total	Count	131	71	202
	% of total	64.9%	35.1%	100.0%

TABLE 5
DESCRIPTIVE STATISTICS OF MOTOR VARIABLES IN MALE AND FEMALE CHILDREN

Variable	Sex	Mean	SD	f	p
Obstacle course backwards (0.1 s)	Male	229.82	94.44	7.06	0.01
	Female	267.88	94.53		
Darts (points)	Male	12.56	8.65	8.08	0.00
	Female	9.09	6.83		
Arm plate tapping (frequency)	Male	16.90	3.53	0.08	0.78
	Female	16.75	4.11		
	F=4.60		p=0.00		

TABLE 6
STRUCTURE OF GENERAL MOTOR FACTOR IN MALE AND FEMALE CHILDREN

Variable	Sex		H1 Total
	H1 Male	H1 Female	
Obstacle course backwards	–0.83	–0.87	–0.85
Darts	0.74	0.72	0.73
Arm plate tapping	0.79	0.82	0.81
% of variance	62.22	65.07	63.27

sample as a whole (H1 total) (Table 6). Accordingly, general factor in the space of the motor variables in male children was similar to the general factor in female children; however, there were significant differences in the quantitative manifestation of this general motor ability (Katić, 2003; Katić et al., 2004; Katić et al., 2005)[25–27].

As there was no statistically significant sex difference according to harmonious laterality and dyslaterality, statistical significance of differences in manifesting whole body motor coordination, speed of alternate simple hand movements and shooting precision between children with harmonious laterality and children with dyslaterality was tested by multivariate analysis of variance. This analysis showed no statistically significant difference between the two groups of children in performing these tasks, while descriptive statistics indicated their achievements to be quite comparable (Table 7).

Besides these quantitative similarities in performing the motor tests analyzed, a qualitative similarity in the general motor factor structure was also recorded between the children with harmonious laterality and dyslaterality (Table 8). Qualitative similarity was also observed between laterality and sex (Tables 6 and 8).

TABLE 7
DESCRIPTIVE STATISTICS AND DIFFERENCES IN MOTOR VARIABLES IN HARMONIOUS LATERALITY AND DYSLATERALITY

Variable	Laterality	Mean	SD	F	p
Obstacle course backwards (0.1 s)	Harmonious	241.21	101.35	0.02	0.90
	Dyslaterality	245.47	89.78		
Darts (points)	Harmonious	12.10	8.78	1.44	0.23
	Dyslaterality	10.47	7.44		
Arm plate tapping (freq.)	Harmonious	16.88	3.47	0.01	0.90
	Dyslaterality	16.81	4.03		
	F=0.539		p=0.656		

TABLE 8
GENERAL MOTOR FACTOR STRUCTURE IN HARMONIOUS LATERALITY AND DYSLATERALITY

Variable	Laterality	
	H1 Harmonious	H1 Dyslaterality
Obstacle course backwards	–0.83	–0.87
Darts	0.74	0.72
Arm plate tapping	0.79	0.82
% of variance	62.22	65.07

Discussion

The primary aim of the study was to assess the relations between laterality and motor test performance requiring whole body coordination, speed of alternate hand movement frequency and hand precision. We assessed the presence of sex differences in manifesting usability and gesture laterality, considering data reported from neuropsychological studies suggest the left hemisphere to be dominant in female and right hemisphere in male individuals, Gaddes' referring to Lannenberg hypothesis (1994)[28] that describes developmental process as the child's brain being initially bilateral for speech, followed by abrupt expansion in the development of the left to the account of the right hemisphere, and studies that have, among others, found the choice of right hand to occur earlier in female children (Carlson and Harris, 1985; Humphrey and Humphrey, 1984)[29,30]. This study found no sex differences; however, it could be attributed to the small number of study subjects, whereas studies investigating sex differences generally include larger study population.

Considering the usability and gesture laterality as a synchronous phenomenon, where a harmonious development is expected, and thus harmonious manifestation of right-handedness and left-handedness in both usability and gesture laterality, study results indicated laterality to exist at an equal rate as a synchronous and asynchronous phenomenon. Although right side prevailed in usability dominance, spontaneous right-sided laterality was less frequently recorded. In contrast, spontaneous left--sided or ambidextrous laterality was more commonly observed, pointing to the impact of social environment on the choice of dominant extremity. An increased number of usability right-handed persons are recruited from this group of spontaneous ambidextrous and spontaneous left-handed individuals influenced by the factors of social environment and teaching.

Considering the distribution of harmonious laterality and dyslaterality recorded in about half of our study subjects, and the results of previous studies (Gabbard et al., 1995; Iteya, 1998)[1,31] reporting on the children with more pronounced laterality to be superior in motor task performance and less variable in hemispheric specialization (Bishop, 1990)[32], we used motor tests of arm tapping and darts that require use of dominant hand, while the test of obstacle course backwards requires the ability of fast and coordinated space planning and organization on appropriate movement. The children with harmonious laterality were expected to be superior in performing the tasks of arm tapping and darts because these activities are performed by dominant hand which is in harmony with spontaneous laterality. The children with pronounced one side dominance and harmonized laterality types were expected to perform the obstacle course backwards better because their laterality is both directed and fixed and the child should have no problems with either self perception or spatial perception of his/her body. However, there was no statistically significant difference in the performance of motor tests between the children with harmonious laterality and those with dyslaterality. The absence of significant difference in motor task performance may be explained by the children's age because the children aged 4–5 have poorly pronounced hand dominance in comparison with older children (Hill and Khanem, 2009)[3] and the choice of dominant hand is being established during the childhood. Thus, a greater number of study subjects of different ages would definitely yield more conclusive results.

Conclusion

The analysis of relations between laterality and motor abilities in preschool children produced no statistically significant differences either in sex distribution of laterality or in laterality harmonization. There was no statistically significant difference in motor test performance between children with harmonious laterality and those with inharmonious laterality. These findings suggest the ability of movement structuring in children, which is defined as nervous regulation and integration allowing for rapid formation of efficient motor programs and their controlled performance, to be comparable in children with harmonious laterality and those with inharmonious laterality. The same applies to the ability of synergic regulation and tonus regulation, defined as the ability of regulation and integration, i.e. control of simultaneous sequence, extent and intensity of inclusion and exclusion of motor units of the agonist and antagonist muscle groups, and the magnitude of power thus generated.

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R. Katić

Faculty of Kinesiology, University of Split, Teslina 6, 21000 Split, Croatia
e-mail: ratko.katic@gmail.com

ODNOSI IZMEĐU LATERALIZACIJE GORNJIH EKSTREMITETA I MOTORIČKIH SPOSOBNOSTI KOD PREDŠKOLSKE DJECE

SAŽETAK

U radu se analiziraju odnosi između lateralizacije i motoričkih sposobnosti kod djece predškolske dobi. Uzorak ispitanika u ovoj studiji činilo je 202 djece u dobi od 5 do 7,5 decimalnih godina. Nizom testova procijenjena je upotrebna i gestualna lateralizacija gornjih ekstremiteta, na osnovi čega su potom djeca ocijenjena kao usklađeno odnosno neusklađeno lateralizirana. U odnosu na to procjenjivala se uspješnost u izvršavanju motoričkih zadataka koji zahtijevaju koordinaciju čitavog tijela, brzinu frekvencije naizmjeničnih pokreta rukom, te preciznost gađanja rukom. Nisu nađene statistički značajne razlike među spolovima u raspodjeli lateralizacije, kao ni razlike u odnosu na usklađenost lateralizacije. Nije bilo statistički značajne razlike u izvođenju motoričkih testova između djece s usklađenom i djece s neusklađenom lateralizacijom.