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SELECTED ASPECTS OF EYE DOMINANCE AND ITS RELATION TO MOTOR LATERALITY MANIFESTATION AT CHILDREN POPULATION

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SUMMARY

The aim of this study is to shed light on the relationship between upper limb preference and two different factors assessing ocular dominance in the population of children aged 8 to 10 years. It focuses on the sighting factor, which is manifested in the ocular preference in monocular activity, and on the binocular rivalry factor, which determines the dominant eye in spatial orientation. The upper limb preference of 204 children was determined using five motor tasks whose diagnostic quality and compliance with the "Upper Limb Preference" dimension was verified by the structural equation modelling method. Results of tetrachoric and polychoric correlation matrices showed at $p < 0.001$ a significant relationship between upper limb preference and ocular dominance, determined by the spatial orientation indicator (binocular rivalry factor). Subsequently, at $p < 0.05$, statistically significant differences in the correlation coefficients between the motor tasks assessing upper limb preference and each of the two factors determining ocular dominance were confirmed. These facts suggest that the correct positioning of the object in the given space when handling the object by the upper limb is more important than focusing on the object.

Key words: sighting factor, binocular rivalry, handedness, footedness

INTRODUCTION

Functional laterality is a manifestation of the brain activity which is reflected in motor activity of both motor and sensory organs and which is also a reflection of the functional asymmetry of cerebral hemispheres (Annett, 2002). Control of motor activity is projected onto paired motor organs differently, which is expressed by different levels of motor manifestations of the lower and upper limbs. The sensory organs (eyes, ears) display a different determination of functions.Functional laterality is a functional asymmetry that is manifested by preferred use of one of the paired organs. The preferred organ usually operates faster or better, or performs a specific function (Bryden, 2000; Mohr et al., 2003).

Functional laterality has been analyzed by many studies. They primarily focused on the assessment of functional laterality in the adult population in which functional asymmetry is already stabilized (Zebrowska, 1987). The studies mainly dealt with the diagnosis of hand preference (handedness), which is the most transparent functional asymmetry in humans. It is based on high demands on the manipulative function of the upper limb, which is also structurally adapted to this activity (spherical joint in the shoulder, opposition position of the thumb, rich innervation of fingers, etc.). The issue of handedness is often associated with the term "manual dexterity", which includes both the ability to handle objects and the fact that most people have one preferred upper limb to handle objects (Hughdal & Westernhausen, 2010). For approximately 90% of people, the right upper limb is the preferred one; for 10% of people, the left upper limb is the preferred one (McManus, 1985). Research has shown that handedness in the form of preference represents a multidimensional attribute depending on whether the activity is unimanual, bimanual, skilled or unskilled (Steenhuis & Bryden, 1989; Büsch et al., 2010).

Despite the amount of literature dealing with laterality, the issues of ocular dominance remains less clear. Based on research, it has been found that ocular dominance includes three factors:

- acuity factor, i.e., one of the eyes exhibits a greater sensitivity to recognize contrast and depth of acuity (Coren & Kaplan, 1973);
- binocular rivalry factor, first described in 1593 by John Baptist Porta, i.e., one of the eyes plays a leading role in spatial orientation (Porta, 1593; Clarke & Warren, 1938; Coren & Kaplan, 1973);
- observation (sighting) factor, i.e., preference of one of the eyes in monocular activities such as sighting down a telescope.

It is a very important fact in ocular functional laterality that the brain is also lateralized for the eyes (Mapp et al., 2003). Since the functions of the eye represent a natural manifestation of brain activity, and they are not influenced by social pressure as in handedness, some authors have considered the determination of ocular dominance as crucial in determining the motor manifestations of laterality and their disorders (Delacato, 1966; O'Connor, 1965; Bishop, 1983). However, this does not solve the problem of which of the basic factors of the eye should be considered relevant in determining ocular dominance.

Many authors have considered preference of the eye in monocular activity as a manifestation of ocular dominance, i.e., the observation (sighting) factor (Coren & Porac, 1978; Crovitz & Zener, 1962; Hull, 1936); this preference is then related to hand preference (Porac & Coren, 1976; Walls, 1951; Howard & Rogers, 2002). The literature reports that the lateral agreement (congruency) of hand preference and ocular dominance (measured by means of the sighting factor) is 80% (Bourassa et al., 1996). Studies dealing with the congruency of hand preference and ocular dominance (expressed by monocular activity) found that unstable ocular dominance (expressed by monocular activity) was displayed, for example, by dyslexic children (Stein & Fowler, 1982; Stein et al., 2000) or individuals with the Williams-Beuren syndrome (Van et al., 2005).

According to other studies, the binocular rivalry factor is decisive in determining ocular dominance, because, from a functional point of view, this role of the eye is the most important (Berens & Zerbe, 1953). According to some authors, the preferred eye does not have a specific functional role in monocular activity (Mapp et al., 2003).

At present, there is no uniform view on this issue, and there are not many studies that would carry out a more detailed examination of the relations between individual factors of ocular dominance to hand preference, particularly in the child population. Therefore, we decided to determine the relationship between hand preference and two factors of ocular dominance (binocular rivalry factor and sighting factor) in this study. In order to express the degree of relationship, we used tetrachoric and polychoric correlation matrices.

METHODS

The research sample included 204 subjects (97 boys and 107 girls) aged 8 to 10 years (average age 9.1 years) attending primary schools of the Capital City of Prague. These schools had no specific specialization (arts, technology, sports, languages).

In order to create a set of relevant indicators for assessing upper limb preference mainly items from the world's most widely used questionnaires were used: the Edinburgh Handedness Inventory (Oldfield, 1971), the Waterloo Handedness and Footedness Questionnaire (Bryden, 1977), and the Lateral Preference Inventory for Measurement of Handedness, Footedness, Eyedness, and Earedness (Coren, 1993). The questions from the questionnaire were transformed into motor tasks. Bishop's card-reaching task was added to these indicators. The objective of this task is to determine whether a child will use the preferred upper limb across the natural body axis (Connolly & Bishop, 1992; Bishop et al., 1996). The existing items were then extended by proposed motor tasks assessing upper and lower limb preference. In order to select the most appropriate items from the aforementioned diagnostic tools we used structural equation modelling (SEM), specifically the confirmatory approach for ordinal categorical data (CCFA), in the M-plus statistical software (Muthén & Muthén, 2010). CCFA is a non-linear statistical technique for categorical data which is able to overcome the limits of the general factor model (Mislevy, 1986).

Ocular dominance was assessed using two indicators:
One of them assessed ocular dominance using the sighting factor.

– Use the tube to look at the object. **LT**

The second indicator assessed ocular dominance using the binocular rivalry factor.

– Use both eyes to look at the cube that is placed approximately two metres from you. Then move your thumb to be aligned with the cube. Close one of your eyes and say if the thumb still covers the cube or not (eye – has your thumb moved?). **THE**

In order to express the relationship between hand preference motor tasks and indicators determining ocular dominance we used tetrachoric and polychoric correlation matrices.

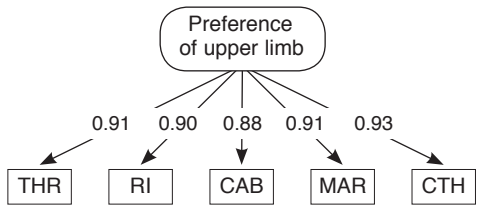
They should be used for the manifest variables that are scored dichotomously and polytomically (McDonald, 1999). The degree of the relationship was assessed using the correlation significance. The acceptable level of the correlation significance was set at $p < 0.05$.

RESULTS

The most appropriate model for assessing upper limb preference proved to be a one-factor model with five indicators.

Table 1. One-factor model with five indicators

Model	Chi-square	P-value	df	CFI	TLI	RMSEA	WRMR
1-faktor	15.08	0.10	5	0.99	0.99	0.060	0.533



Generic reliability of the specific concept of "Upper Limb Preference" was at the level of McDonald $\omega = 0.93$.

Selected motor tasks
Upper limb:

Take the ball in one hand and throw it at the target.	**THR**
Take the ring in one hand and ring it.	**RI**
According to the instructions, turn the cards of the given colours placed on the sheet of paper.*	**CAB**
Create a line in the marked space using matches.*	**MAR**
Show how many points you can roll with the dice on three attempts.	**CTH**

*This task is performed across the natural body axis of the individual.

Both indicators assessing ocular dominance were gradually correlated with these five motor tasks.

Eye:

- Use the tube to look at the object. **LT**
- Use both eyes to look at the cube that is placed approximately two metres from you. Then move your thumb to be aligned with the cube. Close one of your eyes and say if the thumb still covers the cube or not (eye – has your thumb moved?). **THE**

Table 2. Corelation matrix indicator LT (sighting factor) and motor tasks for evaluation of handedness

	THR	RI	CAB	MAR	CTH
THR					
RI	0.868				
CAB	0.796	0.859			
MAR	0.822	0.795	0.831		
CTH	0.818	0.747	0.834	0.750	
LT	**0.313***	**0.280***	**0.224**	**0.336***	**0.246**

*p < 0.05

The correlation matrix in Table 1 clearly shows that the LT indicator (Use the tube to look at the object), which assesses ocular dominance using the sighting factor, has a significant relationship to three motor tasks. The strongest relations between the LT indicator and the motor tasks for the upper limb were found in indicators emphasizing targeting. The strongest correlation, whose significance reached the level of $p < 0.01$, was displayed by the LT indicator and the motor task MAR (Create a line in the marked space using matches), $r_{LT, MAR} = 0.336$. In this task, the person being tested takes matches gradually from three different places using one hand, one of the places being always located on the other side of the body than the preferred upper limb. In this task, the quality of placing the matches (accuracy) is not assessed, and the emphasis is laid on the hand–eye operation. Likewise, the relationship between THR (Take the ball in one hand and throw it at the target) and LT, $r_{LT, THR} = 0.313$, shows that the targeting (in which monocular activity was observed) requires the hand–eye activity. However, with respect to the approximately 80% congruency reported in the literature, we expected a closer relationship, expressed by correlation. The weak correlation between the LT indicator and the motor task CAB (According to the instructions, turn the cards of the given colours placed on the sheet of paper), $r_{LT, CAB} = 0.224$, was a surprising result. By its nature, this motor task was akin to MAR (Create a line in the marked space using matches.), because when performing the CAB task, the person being tested had to perform the activity across the natural body axis.

Table 3. Corelation matrix indicator THE (binocular rivalry) and motor tasks for evaluation of handedness

	THR	RI	CAB	MAR	CTH
THR					
RI	0.868				
CAB	0.796	0.859			
MAR	0.822	0.795	0.831		
CTH	0.818	0.747	0.834	0.850	
THE	**0.666*****	**0.489*****	**0.592*****	**0.614*****	**0.600*****

***p < 0.001

The THE Indicator (eye – has your thumb moved?), which assesses ocular dominance using the binocular rivalry factor, showed a significant correlation at the level of $p < 0.001$ with all motor tasks determining upper limb preference. This suggests that when handling objects using the upper limb in the given space the spatial orientation of the eye in the form of the binocular rivalry factor is probably more important than the focusing activity of the eye in the form of the sighting factor. The strongest correlation was found between THE and the motor task THR (Take the ball in one hand and throw it at the target.), $r_{THE, THR} = 0.666$. In this task, in addition to targeting the object, the position of the object in the given space is determined. The motor tasks CAB (According to the instructions, turn the cards of the given colours placed on the sheet of paper) and MAR (Create a line in the marked space using matches), in which the person being tested had to perform the activity across the natural body axis, showed strong correlations with the THE indicator (eye – has your thumb moved?), $r_{THE, CAB} = 0.592$ and $r_{THE, MAR} = 0.614$. The weakest correlation in this correlation matrix was found between the THE indicator and the RI indicator (Take the ring in one hand and ring it), $r_{THE, RI} = 0.489$. This weaker dependence can be explained by the nature of the motor task RI. In comparison with other tasks, the performance of the motor task RI (Take the ring in one hand and ring it) did not represent a complex movement pattern which would involve both proximal and distal parts of the upper limb. The bell was placed directly in front of the subject, so there was not a significant emphasis on positioning the object in the given space.

The reported correlation coefficients from Table 2 and Table 3 were subsequently compared using Fischer's *z*-transformation to determine whether the correlation coefficients between the LT indicator and the motor tasks assessing upper limb preference, as well as correlation coefficients between the THE indicator and motor tasks assessing upper limb preference, were significantly different. The chosen statistical significance level was $p < 0.05$.

Table 4. Statistical significance of the difference of correlation coefficients from Table 2 and Table 3

Variables Correlation

$r_{LT, THR}$ $r_{THE, THR}$	0.313 0.666*
$r_{LT, RI}$ $r_{THE, RI}$	0.280 0.489*
$r_{LT, CAB}$ $r_{THE, CAB}$	0.224 0.592*
$r_{LT, MAR}$ $r_{THE, MAR}$	0.336 0.614*
$r_{LT, CTH}$ $r_{THE, CTH}$	0.246 0.600*

*statistical significance of the difference of correlation coefficients $p < 0.05$

DISCUSSION

The aim of this study was to verify the relationship between hand preference and two factors of ocular dominance (binocular rivalry factor and sighting factor) in the population of children aged 8 to 10 years. Despite the fact that in literature ocular dominance is mostly determined using the sighting factor in monocular activity, the results of the two correlation matrices (Table 2 and Table 3) show that in the child population motor tasks assessing upper limb preference have a more significant relationship with the binocular rivalry factor. These facts suggest that the correct positioning of the object in the given space when handling the object using the upper limb is more important than focusing on the object. In addition, we believe that the sighting factor that is manifested in the eye preference in monocular activity may be burdened with spherical eye defects which often affect human visual organs. Therefore, we assume that the binocular rivalry factor plays a more important role in determining ocular dominance than the sighting factor, and it should not be omitted in the diagnosis of motor manifestations of laterality.

CONCLUSION

The results of this research have shown a significant relationship between upper limb preference and ocular dominance determined by the spatial orientation indicator (binocular rivalry factor). The resultant correlation coefficients between the motor tasks assessing upper limb preference and each of the two factors determining ocular dominance showed a statistically significant difference at the level of $p < 0.05$. Therefore, it is possible that the binocular rivalry factor plays a major role in determining ocular dominance, which is a very important aspect in the assessment of motor manifestations of laterality. We are aware that the research sample of 204 individuals is not sufficient for the generalization of these assumptions, and, therefore, we recommend conducting further research that would confirm the correlation of the most transparent human asymmetry (handedness) and ocular dominance. Last but not least, the results of this research will help to deepen the scientific theory, and they will also be used in instruction in the field of anthropomotorics and motor control.

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VYBRANÉ ASPEKTY OČNÍ DOMINANCE A JEJICH VZTAH K MOTORICKÝM PROJEVŮM LATERALITY U DĚTSKÉ POPULACE

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SOUHRN

Cílem studie bylo u populace dětí ve věku 8–10 let osvětlit vztah preference horní končetiny se dvěma různými faktory hodnotícími oční dominanci. Jednalo se o sighting factor, který se projevuje preferencí oka v monokulární činnosti a o faktor binocular rivalry, kterým je určeno dominantní oko v prostorové orientaci. Preference horní končetiny byla u 204 dětí zjišťována prostřednictvím pěti motorických úkolů, jejichž diagnostická kvalita i příslušnost k dimenzi „Preference horní končetina“ byla ověřena prostřednictvím metody strukturálního modelování. Výsledky tetrachordických a polychorických korelačních matic byl prokázán na hladině $p < 0.001$ signifikantní vztah mezi preferenci horní končetiny a oční dominancí určenou prostřednictvím indikátoru prostorové orientace, (faktor binocular rivalry). Následně byly na hladině $p < 0.05$ potvrzeny statisticky významné rozdílnosti korelačních koeficientů mezi motorickými úkoly hodnotícími preferenci horní končetiny a každým ze dvou faktorů určujícím oční dominanci. Tyto skutečnosti naznačují, že správné určení polohy předmětu v prostoru při manipulaci s předmětem horní končetinou je zřejmě důležitější než zaměření se na předmět.

Klíčová slova: bystřící faktor, binokulární rivalita, ruková preference, preference dolní končetiny

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