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TURNING AROUND A VERTICAL AXIS AS A MANIFESTATION OF HUMAN ROTATION AND ITS RELATION TO CONCEPTS OF UPPER AND LOWER LIMB PREFERENCE, DIFFERENCES IN RELATION TO GENDER IN ADOLESCENT POPULATION*

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SUMMARY

The current study was conducted in order to examine the structure and relation between rotation, item (turning around a vertical axis) and validated preference tasks for the evaluation of the concepts of handedness and footedness in the adolescent population. A total of 220 individuals from Prague high schools (males = 104, females = 116) in the 17–19 age range (mean age 18.1 years) participated. Structural equation modelling, specifically MIMIC models, showed that turning behaviour has a significant regression relation to the concept of "lower limb preference" $p < 0.001$. Participants with a right foot preference had a tendency to do rotation on the left side, whereas participants who showed a left foot preference in the tasks tested had a tendency to rotate on the right side. Moreover, in further processing of data by multigroup modelling it was found that the female population showed a slightly more stable preference of both locomotive organs than males, but a poor tendency in rotating. By contrast, the male population showed a significantly ($p < 0.01$) strong relation of lower limb preference and rotating around a vertical axis, in the sense of rotating on the opposite side than the preferred lower limb. The limitations of the study and further suggestions are discussed.

Keywords: laterality, turning behavior, asymmetry, preference, structural equation modeling, MIMIC models

INTRODUCTION

Human motor laterality manifestation is a multidimensional trait that is mostly perceived as a preference or higher performance in the use of one locomotive or sensor organ

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(Bryden, Steenhuis, 1991; Reiss, 1999; Rigal, 1992). An infinite number of experimental works has been conducted to examine human handedness and footedness; however, few of these studies were focused on the link between motor laterality manifestation and the attribute of rotation. This attribute involves rotation direction preference (turning around a vertical axis, circling when walking, etc.) (Patla, Prentice, Robinson, Neufeld, 1991) but its correct place in the structure of functional laterality in humans is still not fully understood. Current research suggests that the problem of turning behaviour and rotation is in humans related to the dopaminergic system, which some authors consider to be linked with handedness (Bracha, Livingston, Clothier, Linington, 1993). This hypothesis was established on the basis of results from animal models, when animals like rodents, rats and cats turn preferentially on the side of the motoric dominance hemisphere with a higher level of neurotransmiter dopamine (Glick, Ross, 1981; Pycock, 1983). The key role of dopamine was suggested in studies focused on turning bias in populations with dopamine-related diseases (Bracha, Shults, Glick, Kleinman, 1987). Later, some studies proved that right-handers from the general child population, as well as from the adult population, prefer left-side turning (Day, Day, 1997; Mohr, Landis, Bracha, Brugger, 2003). However, research that tried to support this hypothesis by repeating measures of turning in daily routine processes, aimed at confirming its stability, did not find any significant relation to either handedness or footedness (Mohr, Lievesley, 2007). The majority of previous researchers were focused only on the expression of a direct relation between preferred side of rotation and indicators evaluating handedness and footedness. Štochl and Croudace (2013) proved a deeper view of the relation of rotation attribute and other concepts of motor laterality manifestation. These authors modelled, by means of the structural equation modelling method, several rotation items divided into specific concepts of local rotation (circular hand movement) and global rotation (turning of a whole body) with aspects of handedness as well as footedness. This research suggested that handedness and footedness are significant predictors of rotation (Stochl, Croudace, 2013). Nevertheless, this study, as well as most previous studies, used a questionnaire inventory to determine motor laterality manifestation. This meant that the attribute of rotation was not modelled with observable preference motor tasks for assessing the concepts of handedness and footedness.

The importance of evaluating rotation direction and its relation to motor laterality manifestation is evident in movement behaviour and in the field of sport, particularly in the process of talented children selection, space orientation (figure skating, gymnastics) and for solving key situations in team sports.

Therefore, the purpose of this study was to examine relation of rotation item (turning around vertical axis) with preference tasks to evaluate the concepts of handedness and footedness in the adolescent population. These tasks were taken from a recently developed test battery (Musálek, 2012). To determine the role of rotation in the structure of motor laterality manifestation, we used the structural equation modelling (SEM) method, a concrete confirmatory factor analysis approach with covariates (MIMIC) and categorical ordered indicators.

METHODS

Participants

A total of 220 individuals from Prague high schools (males = 104, females = 116) in the 17–19 age range (mean age 18.1 years) participated.

In order to support the selection, we used a complete list of high schools from Prague. With respect to the complexity of a randomized selection of probands from Prague schools and an accurate definition of the area of the City of Prague, we decided to obtain a research sample based on the method of purposive sampling which met the following conditions. In co-operation with the Institute of Educational and Psychological Counselling, high schools from each district of the city were selected. The probands representing the adolescent category were students of Prague general high schools without a specific specialization (art, technology, sports, languages). As we set the number of tested individuals at one school to 20, only those schools attended by at least 30 individuals of the given age were selected. Out of these schools, a list was created from which one high school was randomly selected from each district of Prague.

Indicators

A total number of 8 tasks include rotation item were used. Four indicators in upper limb preference part and three indicators in lower limb preference part. All chosen tasks were validated in study Musálek (2012). Its validity to individual concepts is in range r = 0.48−0.96. Reliability of both concepts expressed by coefficient McDonald ω:

Upper limb preference McDonald ω = 0.89
Lower limb preference McDonald ω = 0.85.

Used items:
Upper limb:
Throw the ball at the target. **THR (three repeating attempts)**
Erase the lines. **ER**
Use the pointer to point at the following objects. **POC (three repeating attempts)**, (participant have to show objects which are opossite to preferred upper limb)
Clap your hands. **CL**

Lower limb:
Demonstrate how you would write the letter T on the floor using one of your feet. **WT**
Kick the ball at the target. **KB (repeating attempts)**
Perform jumps forward using one leg. **HOP**

Rotation task:
Make a 360-degree turn. **TU**

Indicators: throw the ball at the target, use the pointer to point at the following objective, and kick the ball at the target are scored polytomously; other tasks are scored dichotomously.

Analysis

Since the study is focused on the modelling of relations between manifest and latent continuous variables, we decided to use the method of structural equation modelling. Specifically, we used confirmatory factor analysis with covariates (MIMIC) with categorical ordered indicators and multiply group confirmatory factor analysis with covariates (MIMIC) with categorical ordered indicators. These approaches provide appropriate techniques to evaluate structures in which reflective as well as formative relations of manifest variables are defined (Kaplan, 2009). In these techniques tetrachoric correlations for categorical binary data and polychoric correlations for categorical ordered data (polytomous) are used. Thus MIMIC for categorical data represents a suitable method for modelling ordinal categorical data, even if the data have a multidimensional character (Forero, Maydeu-Olivares, 2009). For parameter estimation we used, on the recommendation of Muthén and Asparouhov (2002), a robust weighted least square estimator. In order to determine the quality of a model, we also used several model fit indices: chi-square, model discrepancy (badness of fit) (Marsh, Hau, Grayson, 2005), and root mean square error of approximation (RMSEA) value lower than 0.06 indicate good fit of model (Browne, Cudeck, 1993). Furthermore we used comparative fit index (CFI) value higher than 0.95 indicates acceptable fit of model (Bentler, 1990) and weighted root mean square residual (WRMR) value lower than 1 indicate acceptable fit of model (Muthén, Muthén, 2010). Data were analysed in M-plus software version 6 (Muthén, Muthén, 2010).

RESULTS

We first tested one factor model upper limb and lower limb preference together with formative relation of rotation task on this factor called "preference of locomotive organs". We decided to evaluate how well a human global rotation attribute can be predicted by means of the concept of locomotive organs preference.

Table 1. Fit of the 1-factor model preference tasks with formative relation of item turning on "preference of locomotive organs" factor

Model	Chi-square	P-value	df	CFI	RMSEA	WRMR
1-factor	32.11	0.042	20	0.96	0.068	0.773

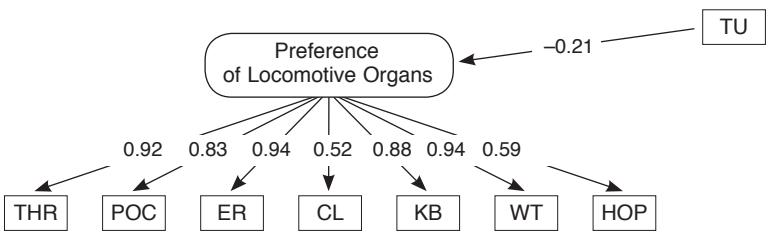


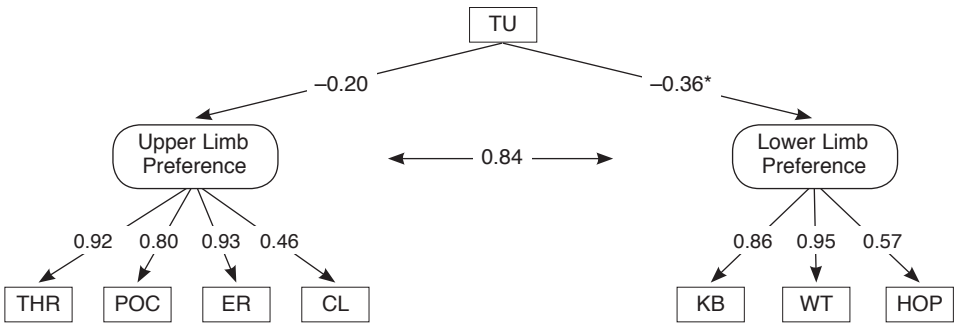
Figure 1. Path diagram of the 1-factor model preference tasks with formative relation of item turning (TU) to the factor "preference of locomotive organs"

The proposed model with a formative relation of TU item (make a 360-degree turn) on the "preference of locomotive organs" factor showed only average values of fit of the model, particularly indices RMSEA = 0.069 and WRMR = 0.976. Also P-value represented significance of model was under rule of thumb value 0.05. Further, from Fig. 1 it is evident that manifest variable TU, which represents the global rotation attribute, has a poor non-significant regression coefficient TU = −0.21 on "preference of locomotive organs" factor. Negative value means an inverse proportion between manifest variable TU and the "preference of locomotive organs" factor.

In next step we tested two factor models with separate dimensions of upper limb and lower limb preference and formative relation of rotation task on both factors.

Table 2. Fit of the 2-factor model preference tasks with formative relation of item turning to both limb preference factors

Model	Chi-square	P-value	df	CFI	RMSEA	WRMR
2-factors	12.11	0.417	18	0.99	0.012	0.238



* signigicant regression on level p < 0.05

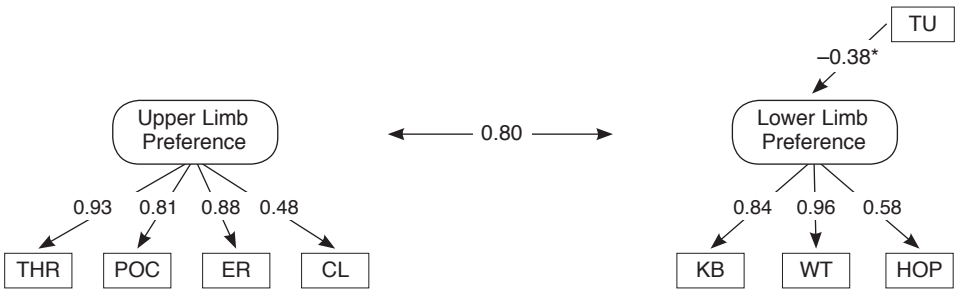
Figure 2. Path diagram of the 2-factor model preference tasks with formative relation of item turning (TU) on both factors

The proposed model with a formative relation of TU item (make a 360-degree turn) to the both factor showed above average values of fit of the model, particularly P-value = 0.417 and indices RMSEA = 0.012 and WRMR = 0.238. Further, from Fig. 1 it is evident that manifest variable TU, has significant regression on p < 0.05 to "lower limb preference" factor TU = −0.36. Generally a quite strong correlation between both factors was confirmed r = 0.84. Despite this strong relation, the entire structure could not be determined as a single factor because the fit of the model immediately deteriorated (compare Tab. 1 and Tab. 2). This finding supports results from the study Musálek (2012). The strong correlation is obviously due to the basic character of the factors. Both represent an assessment of the motor preference of paired locomotive organs; however, their uniqueness function (upper limb for manipulation and lower limbs for posture and walking) precluded modelling them together.

In subsequent modelling item TU left and modelled on the "lower limb preference" factor due to significance regression on this factor.

Table 3. Fit of the 2-factor model preference tasks with formative relation of item turning on lower limb preference factor

Model	Chi-square	P-value	df	CFI	RMSEA	WRMR
2-factors	15.64	0.386	20	0.99	0.023	0.434



* signigicant regression on level $p < 0.05$

Figure 3 Path diagram of the 2-factor model preference tasks with formative relation of item turning (TU) on "Lower limb preference" factor

After modelling the item TU to the "lower limb preference factor", the model fit was not significantly deteriorate and all indices expressed still above-average values. Moreover from Fig. 2, it is apparent that formative relation of item TU = −0.38 on "lower limb preference" factor remain significant on level $p < 0.05$. In addition, this relation means that right-footed people have a tendency to rotate on the left side and left-footed people on the right side. This means that footedness can in some way predict the rotation of a person. We assume that this result may be due to uniqueness function of lower limbs, posture, balance and locomotion (walking) where the rotation attribute probably plays an important role.

In further modelling we suggested that item TU expressing preference of rotation around the vertical axis could possibly have a different power of relation in the male and female population. Therefore we tested a so-called multigroup MIMIC model. This multigroup MIMIC models content overall chi-square value with the possibility to see definite chi-square for each sub-population. In tables it is seen as a value in brackets. The question was if items' factor loadings and the regression coefficient of the rotation item inside the structure in each analysed sub-population was also the same. The female subpopulation was tested first.

Table 4. Fit of the 2-factor model preference tasks with formative relation of item turning on lower limb preference factor – female sub-population

Model	Chi-square	P-value	df	CFI	RMSEA	WRMR
2-factors	43.53 (16.21)	0.099	41	0.98	0.066	0.786

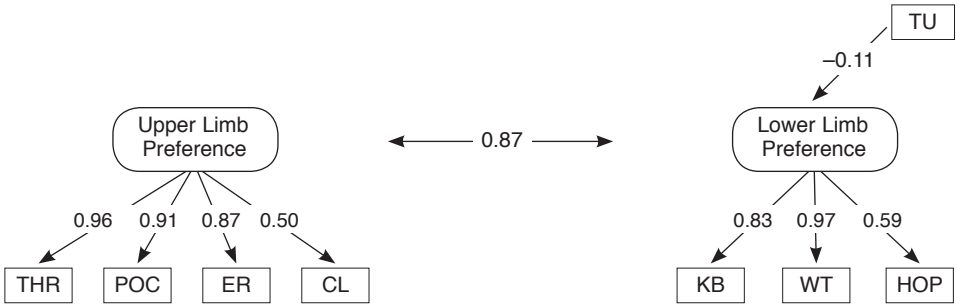


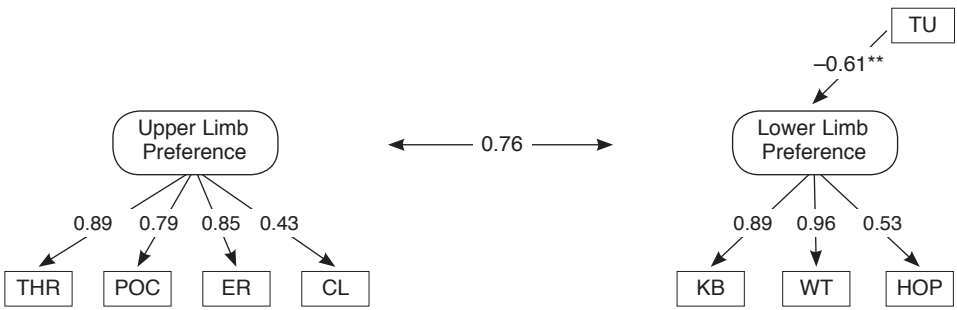
Figure 4. Path diagram of the 2-factor model preference tasks with formative relation of item turning (TU) on "Lower limb preference" factor – female population

Results from the female sub-population showed that items evaluating hand and foot preference have a slightly stronger relation to both concepts. However, item TU has with its value TU = −0.11 a non-significant formative relation on the "lower limb preference" factor. This finding can be explained in that females are probably more stable in hand and foot preference, but do not have a significant tendency in turning. Moreover, the correlation of factors was stronger in the female sub-population than in modelling with both genders together.

Based on these result we assume that the male sub-population will have significant formative relation of TU item to the "lower limb preference" factor.

Table 5. Fit of the 2-factor model preference tasks with formative relation of item turning on lower limb preference factor – male sub-population

Model	Chi-square	P-value	df	CFI	RMSEA	WRMR
2-factors	43.53 (27.32)	0.099	45	0.98	0.066	0.786



** signigicant regression on level p < 0.01

Figure 5. Path diagram of the 2-factor model preference tasks with formative relation of item turning (TU) on "Lower limb preference" factor – male population

By contrast with the female model, the male sub-population showed slightly weaker factor loadings of indicators assessing the preference of both locomotive organs. This result is also seen in the correlation between both factors, which is lower than in female model. However, from Fig. 4 is evident that the regression coefficient of TU indicator on "lower limb preference" factor was significantly increased compared to the female model. The difference between both regression coefficients was statistically significant at the level of $p < 0.01$. This outcome suggests that our male population is more stable in relation of lower limb preference and the rotation attribute. The negative value of the regression coefficient indicates again that there is an inverse relation between lower limb preference and rotation around a vertical axis.

DISCUSSION

The aim of this study was to examine the relation between preference tasks focusing on evaluating the concepts of handedness and footedness and the item expressing global rotation TU (turning around vertical axis) in adolescent population n = 220. The diagnostic quality and structure of the used indicator preference tasks, except for TU, was known from the study Musálek (2012). Since we evaluated the formative relation of item TU on the latent variables "upper limb preference" and "lower limb preference", we used the method of structural equation modelling concrete MIMIC models. First our results supported hypothesis that concepts preference of upper and lower limb measured by observed tasks is appropriate modelled rather as two factors structure. In addition structural hypothesis about the formative relation of item TU on both factors was defined. This modelling showed above-average values of fit P- value = 0.417 and fit indices RMSEA = 0.012 and WRMR = 0.238, however poor non-significant regression TU = −0.20 on "upper limb factor" was found. This result is not in absolutely conformity with the current suggestion of a Stochl and Croudace study (2013), where even handedness was a significant predictor of rotation attribute. These authors, who used a questionnaire approach for assessing motor laterality manifestation, modelled hand and foot preference factors together due to collinearity. A possible explanation of this difference could be in approach to assessing motor laterality, when we used directly observable preference tasks. The second model which contains the relation TU on the "lower limb preference" factor showed a non-significant deterioration fit and all fit indices values, regression coefficient of TU in this model TU = −0.38. This result suggests that the concept of lower limb preference can be in some way a predictor of rotation, with the conclusion that right-footed persons tend to rotate on the left side and left-footed person on the right side. This result supported the assumption of Mohr et al. (2003) about a link between opposite turning behaviour and side preference. To get more information about the rotation attribute in the adolescent population we modelled item TU in each gender. The results of multigroup MIMIC models showed that females have a slightly more stable preference in both preference concepts. This is obvious from different factor loadings in both models. This result is in conformity with the study Tan (1988). Item POC (Use the pointer to point at the following objective), when a tested person worked across natural axis of preference part of body from "upper limb preference" factor in particular proved this difference (see Fig. 3

and Fig. 4). In addition, it was found that relation of rotation attribute evaluated by item TU to "lower limb preference" factor modelled on both populations was significantly different $p < 0.01$. Relation of female TU to "lower limb preference" factor TU = −0.11, male TU to "lower limb preference" factor TU = −0.61. This outcome suggests that our male population is more stable with regard to lower limb preference and rotating around a vertical axis.

LIMITATIONS

The current study examined a large sample of individuals with respect to rotation and preference. However, there was one major limitation. It was not feasible to administer all aspects of rotation to the entire sample, and hence the item that expresses only the global aspect of rotation was chosen. Therefore, our results can be generalised only with regard to the relation between hand preference and foot preference and the item "turning around a vertical axis".

CONCLUSION

In summary, the current study assessed the relation of turning behaviour (turning around a vertical axis) (TU) as a manifestation of global rotation attribute to factors of hand and foot preference. The method of structural equation modelling, specifically MIMIC models, was used to express the relation. It was found that turning behaviour has significant regression relation to the concept of "lower limb preference" $p < 0.05$. Participants with a right foot preference had a tendency to do rotation on the left side, whereas participants who showed a left foot preference in the tasks tested had a tendency to rotate on the right side. In a further process, we assessed this model by means of a multigoup approach, separately in the male and female sub-populations. This modelling produced two basic results. First that the female population showed a slightly more stable preference of both locomotive organs. Especially in the "upper limb preference" factor in item POC (Use the pointer to point at the following objective) when the tested person could also work across the natural axis of preference part of body a statistical significant difference was found between values for males $r = 0.79$ and females population $r = 0.91$ at a level of $p < 0.01$. Second that the male population showed a significantly closer relation between TU and "lower limb preference" factor $p < 0.01$. This outcome suggests that our male population is more stable in relation of lower limb preference and rotating around a vertical axis in the sense of rotating on the opposite side than is the preferred lower limb. This finding could play an important role in the field of sport with regard to the development of rotation habit and its stabilization (track and field, ice hockey, handball). On the other hand, we realize that the multigroup modelling had a pilot character, due to insufficient sample size. Therefore, we suggest the verification of our pilot finding about the different relations of rotation (turning around a vertical axis) in the male and female population. Moreover, it would be beneficial if future research were to use more items relating to the rotation attribute and modelled this relation at child population.

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OTÁČENÍ KOLEM VERTIKÁLNÍ OSY JAKO PROJEV LIDSKÉ ROTACE A JEHO VZTAH KE KONCEPTŮM PREFERENCE HORNÍ A DOLNÍ KONČETINY, ROZDÍLY V ZÁVISLOSTI NA POHLAVÍ U POPULACE ADOLESCENTŮ

MARTIN MUSÁLEK & ŠÁRKA HONSOVÁ

SOUHRN

Cílem studie bylo modelovat manifestní proměnnou preferenci rotace (otáčení kolem vertikální osy) a zjistit její vztah ke specifickým konceptům hodnotících preferenci horní a dolní končetiny u populace adolescentů. Studie se zúčastnilo 220 studentů pražských gymnázií (muži = 104, ženy = 116) ve věkovém rozpětí 17–19 let (průměrný věk 18,1 roku). Preference horní i dolní končetiny byla zjišťována prostřednictvím validizovaných testů. Použitá metoda strukturálního modelování konkrétně MIMIC modely ukázala, že indikátor otáčení kolem vertikální osy má na hladině $p < 0,05$ signifikantní regresní vztah ke konceptu hodnotícího preferenci dolní končetiny. Testované osoby, s pravostrannou preferencí dolní končetiny měli tendenci provádět otočení kolem vertikální osy doleva. Toto zjištění bylo dále modelováno pro každé pohlaví zvlášť. Z výsledků tohoto modelování vyplývá, ženská subpopulace má stabilnější preferenci lokomočních orgánů ovšem ne signifikantně regresní vztah mezi preferencí dolní končetiny a otočením kolem vertikální osy. Mužská subpopulace vykázala signifikantní regresní inverzní vztah mezi konceptem preference dolní končetiny a otočením se kolem vertikální osy $p < 0,01$. Ve studii jsou diskutována omezení tohoto výzkumu i další doporučení zkoumání fenoménu rotace ve vztahu k motorickým projevům laterality.

Klíčová slova: lateralita, rotace, asymetrie, preference, strukturální modelování, MIMIC modely

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