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DIMENSIONALITY OF INDICATORS IN QUESTIONNAIRE FOR DIAGNOSTICS OF HAND AND FOOT PREFERENCE – ADULT POPULATION

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SUMMARY

The aim of the study was to verify the structural hypothesis whether the items of the questionnaire survey, assessing motor manifestations of upper and lower limb laterality in the adult population, consist of two separate latent variables or not. The selection of the questionnaire items was based on an expert assessment of content validity of items that were part of already created standardized foreign questionnaires. The diagnostic tool originally consisted of 10 items (of tool, skill and non-skill character). The research was carried out using 440 individuals aged 17–19 years. In order to analyze the data, structural equation modelling (SEM) was used, specifically the confirmatory approach for categorical data called item factor analysis (IFA). The results showed that the most appropriate model is a one-factor model with seven items. This model had a very high diagnostic quality, expressed by fit indices RMSEA 0.028, CFI 0.99, TLI 0.99, and signification of the model on the level of $p = 0.29$. However, the resultant one-factor model suggests that particularly answers to items of skill character in which strong factor loadings were found may be influenced by the subjective assessment of the degree of lateral preference, resulting in local dependence, i.e. the answer to a particular item is affected by the answer to the previous item.

Key words: functional asymmetry, laterality, questionnaire, structural equation modelling, item factor analysis

INTRODUCTION

Functional laterality is a manifestation of brain activity, which is also reflected in the motor activity of motor organs as a reflection of the functional asymmetry of brain hemispheres (Annett, 2002). Control of motor activity is projected differently in paired motor organs, which is expressed in different levels of motor manifestation in lower and upper limbs.

Therefore, functional laterality is viewed as the functional asymmetry manifested as the preferential use of one of paired motor organs. This organ usually works faster or better (Bryden et al., 2000; Mohr et al., 2003).

Research into functional laterality has been dealt with by a number of studies focusing on the assessment of functional laterality in the adult population in which the functional asymmetry is already stabilized (Zebrowska, 1987). These studies were primarily focused on diagnosing hand preference, which is the most transparent human functional asymmetry. Generally, hand preference is most often assessed using self-assessment questionnaires that usually contain questions of unimanual character, representing everyday motor activities (Musálek, & Štochl, 2010). The answers to these questions are then scored on a three-point or five-point Likert scale (Barut et al., 2007; Crovitz, & Zener, 1962; Oldfield, 1971). Some authors who tried to assess manifestations of functional laterality in a more complex way also included lower limb preference diagnosis in their diagnostic tools, in addition to hand preference diagnosis (Bryden, 1977; Coren, & Porac, 1978; Coren, 1993; Chapman et al., 1987). However, the dimensionality of these diagnostic tools was mostly determined using exploratory factor analysis which cannot directly express the relationship between the manifest variables (indicators) and various latent (indirectly measurable) variables or, mathematically, factors (Kline, 2011). This statistical technique neither enables to verify the structure of the issue using a structural hypothesis nor expresses a specific fit of the proposed structural model (McDonald, 1999). With regard to the assessment of motor manifestations of laterality using self-assessment questionnaires, there are not many studies that have attempted to identify specific dimensionality with quantified relationships between manifest and latent variables and the expressed fit of the proposed model. In order to assess the relationships between a latent variable and manifest variables (indicators), methods of structural equation modelling (SEM) are used. Structural modelling, which requires the formulation of a structural hypothesis, allows direct expression and verification of the theoretical concept structure (in our case, it is finding relationships within the motor manifestations of upper and lower limb laterality).

Using SEM, namely item factor analysis (IFA), the aim of this study is to verify the structural hypothesis whether questions determining hand preference together with questions determining lower limb preference within the questionnaire for the adult population form one latent variable or whether the attributes are separated.

METHODS

The research set included 440 participants (212 men and 228 women) aged 17–19 years (average age years, *SD* = 0.56 year). The participants were students of the last two years of Prague general upper secondary schools without a specific focus of instruction. Since the process of lateralization in normally developing population is generally terminated after the 12th year of life, it was not necessary, with regard to the availability of the set, to use only the results of students over 18 years of age (Gabbard, 1992; Medland et al., 2004). However, since the research set contained underage participants, the parents of these students confirmed the informed consent with the testing.

As a diagnostic tool, we used the strongest items from several most widely used questionnaires: 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, Earedness (Coren, 1993). In order to select the appropriate items from the above-mentioned diagnostic tools, we chose the method of content validity of an expert survey (Lawshe, 1975; Lynn, 1986; Mastaglia et al., 2003). The content validity of indicators was assessed using the five-point Likert scale which did not contain a neutral option and, simultaneously, displayed a fine distinction between individual degrees of the indicators' content validity with regard to the defined theoretical concept:

1. the indicator does not measure the theoretical concept at all,
2. the indicator measures the theoretical concept weakly,
3. the indicator measures the theoretical concept,
4. the indicator measures the theoretical concept strongly,
5. the indicator measures the theoretical concept very strongly.

In order to assess content validity, lists of relevant indicators were sent to six experts from different disciplines related to motor manifestations of laterality. The following disciplines were used: special education, neurology, psychiatry, anthropomotorics, kinesiology, and neurophysiology.

The lists of items were sent to the experts repeatedly, three times in total. The lists were always re-sent to the experts 14 days after returning the previous assessment. In order to determine the most appropriate content items, we used the method of agreement developed by Lawshe (1975). The calculation of agreement was carried out according to the formula:

$$CVR = \frac{\left(n_e - \frac{N}{2}\right)}{\left(\frac{N}{2}\right)}$$

(Lawshe, 1975).

Given the number of raters, based on the study by Polit and Beck, indicators displaying repeated agreement of at least 0.99 were selected (Polit, & Beck, 2006).

Finally, with regard to the data analysis, 6 indicators determining upper limb preference and 4 indicators determining lower limb preference were selected.

Selected items for the questionnaire part

– Which hand do you use to hold a pencil when drawing? **KR**
– Which hand do you use to hammer a nail into wood? **HR**[1]

[1] This item has a reverse character – the person being tested is not deliberately asked about the preferred upper limb but about the non-preferred upper limb in order to hold the attention of the people being tested, therefore the analysis contains a negative factor loading for this item.

- Which hand do you use to hold a knife while cutting? **NU**
- Which hand do you use to hold a toothbrush while brushing your teeth? **KA**
- Which hand do you use to hold a rubber when erasing? **GU**
- Which hand do you use to hold a key while unlocking the door? **OD**
- Which foot do you use to move an object? **SK**
- Which foot do you use to kick a ball? **KB**
- Which leg do you start with when walking upstairs? **SCH**
- While standing, which of your lower limbs do you place forward when you want to slide without the support of your hands? **KL**

In order to analyze the data, we used structural equation modelling (SEM), specifically confirmatory approach for categorical data of ordinal character in the M-plus statistical software (Muthén, & Muthén, 2010). This approach is also known as the Item Factor Analysis (IFA). IFA is a non-linear statistical technique for categorical data in which the limits of the general factor model are overcome by using tetrachoric and polychoric correlations. IFA thus represents an appropriate method for modelling categorical ordinal data (Mislevy, 1986). Just as confirmatory factor analysis, IFA assumes a continuous latent variable character for interval data (Yuan, & Bentler, 2007). As an estimate parameter, due to the ordinal type of categorical data, we applied the Weighted Least Square Mean Variance (WLSMV), as recommended by Muthén (1984). The asymptotic correlation matrix is used here.

In order to express the fit of the individual models tested, we used five fit indices:

- **Chi-square**: As the basic and probably the most widely used model test statistics, it expresses model discrepancy. The significance level of chi-square was set at $p > 0.05$ (Marsh et al., 2005).
- **Root Mean Square Error of Approximation** (RMSEA): This index represents standardized measurement of empirical discrepancy (Browne, & Cudeck, 1993). Values ≥ 0.10 show a poor model fit; values ranging from 0.08 to 0.10 show an average model fit; values ranging from 0.05 to 0.08 show a good model fit; and values ≤ 0.05 show a very good model fit (McDonald, & Ho, 2002; Steiger, 1990).
- **Weighted Root Mean Square Residual** (WRMR): WRMR is used to compare the difference in residual covariances. WRMR can also show values greater than 1. However, only values ≤ 1 are considered to be acceptable for this index (Muthén, & Muthén, 2010).
- **Comparative Fit Index** (CFI): CFI is an index that measures the relative improvement of the fit in the proposed model compared with the baseline model (Bentler, 1990). CFI index values are in the closed interval from 0 to 1, with values close to one indicating a good model fit. According to Hu & Bentler (1998), the recommended acceptable CFI index value is 0.95 or higher.
- **Tucker-Lewis** (TLI): TLI represents a non-standardized fit index which can also show values > 1 (Tucker, & Lewis, 1973). The recommended acceptable value of this fit index was set at 0.95 (Hu, & Bentler, 1998).

In this study, we also focused on the approximation of generic reliability. We estimated it for each construct using McDonald's ω coefficient (McDonald, 1991; McDonald, 1999), which is also the generalizability coefficient:

$$\omega = \frac{\left(\Sigma\lambda_j\right)^2}{\left[\left(\Sigma\lambda_j\right)^2 + \Sigma\psi_{j2}\right]}$$

RESULTS

First, we tested the model in which we divided upper and lower limb preference into two dimensions. Since this is categorical ordinal data, polychoric correlations were used in the model.

Table 1. SEM, Two-factor model

Model	Chi-square	P-value	df	CFI	TLI	RMSEA	WRMR
2-factors	57.51	0.0071	34	0.99	0.99	0.056	0.53

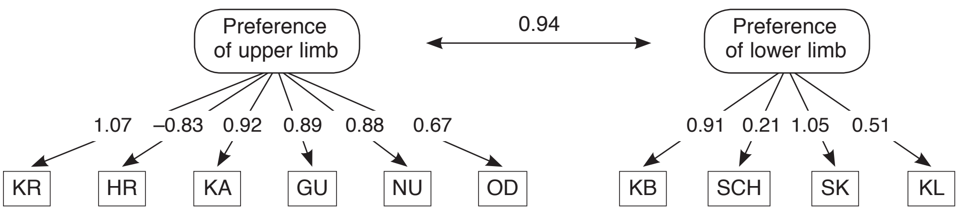

Figure 1. SEM, Two-factor model

The proposal of this two-factor structure displayed what is called a Heywood case, when the covariance matrix it is not positively defined. The KR item (drawing) for the "Preference of upper limb" factor and the SK item (object shifting) for the "Preference of lower limb" factor showed a factor loading greater than 1, which led to negative dispersion of uniqueness, and therefore this model was rejected. In addition to problems with items whose loadings exceeded the value of 1, very weak correlation of the SCH item (Which leg do you start with when walking upstairs?) to the "Preference of lower limb" factor, SCH = 0.21, was found in this model. An interesting finding was also the strong correlation between both factors, r = 0.94, which indicated that the questionnaire part assessing upper and lower limb preference may show a single factor structure.

The subsequent polychoric correlation matrix displayed the collinearity of the KR item > 0.90 with the GU item (erasing) and the NU item (cutting with a knife), therefore the KR item was removed. However, collinearity was also found in the SK item > 0.90 with the KB item (kicking the ball). Therefore, the SK item was also removed from the questionnaire.

Table 2. SEM, Two-factors model without items KR and SK

Model	Chi-square	P-value	df	CFI	TLI	RMSEA	WRMR
2-factors	26.68	0.1122	19	0.99	0.99	0.045	0.45

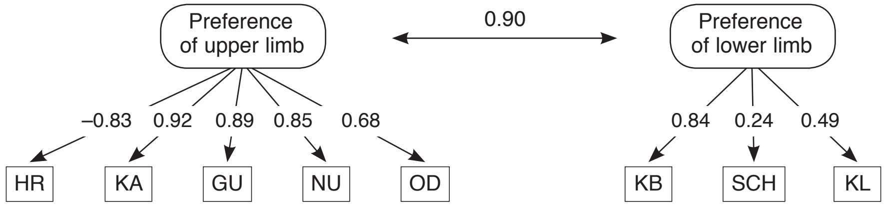

Figure 2. SEM, Two-factors model without items KR and SK

This proposed model without the KR and SK items showed a very good model fit, including an acceptable level of P-value. However, the "Preference of lower limb" factor again showed the weakest item, SCH = 0.24, which appears to measure a different attribute, not lower limb preference. In addition, despite the presence of this weak item, the correlation between both factors was still strong. It was likely that after the removal of the SCH item the correlation would increase. Therefore, this model was rejected too.

In the next proposed questionnaire structure, it was decided to remove the SCH item from the "Preference of lower limb" factor and to add the remaining items of this factor to the items determining upper limb preference. The whole factor was then called "Preference of locomotive organs".

Table 3. SEM, One-factor model without items KR, SK and SCH

Model	Chi-square	P-value	df	CFI	TLI	RMSEA	WRMR
1-factor*	16.25	0.29	14	0.99	0.99	0.028	0.38

*Accepted model

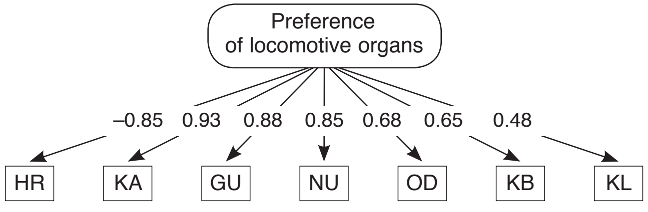

Figure 3. SEM, One-factor model without items KR, SK and SCH

Finally, this one-factor structure of the questionnaire part proved to be the most appropriate. All fit index values showed a very good model fit. The residual matrix did not contain any residual values which would be unacceptable in the model. Based on the ascertained quality of the proposed structure, the one-factor model was adopted.

Table 4. Residual correlation matrix

	HR	KA	GU	NU	OD	KB	KL
HR							
KA	–0.006						
GU	0.038	–0.004					
NU	–0.018	–0.003	0.029				
OD	0.004	–0.024	0.051	–0.048			
KB	–0.065	0.027	–0.047	–0.085	0.005		
KL	0.007	–0.009	0.039	–0.044	–0.018	0.038	

Table 5. Generic reliability

Name of factor	McDonald ω
Preference of locomotive organs	0.90

CONCLUSION AND DISCUSSION

The results of this study present the verification of the structural hypothesis whether the questionnaire items identifying motor manifestations of upper and lower limb laterality form one dimension within the questionnaire in the adult population or whether those attributes are separated. In order to verify this theory, based on the content validity procedure (expert survey), the strongest indicators and indicators measuring, according to specialists, a specific part of the attribute of motor manifestations of upper and lower limb laterality were selected from the already established foreign questionnaires. In order to analyze the data, we used structural equation modelling (SEM) and the item factor analysis (IFA), which is still not used very frequently in establishing relationships within the theoretical concept of motor manifestations of laterality. One-factor model with seven items, with items assessing the degree of upper and lower limb preference forming one dimension, proved to be the best model in this study. The dimension was called "Preference of locomotive organs". When analyzing the questionnaire, very strong factor loadings were clearly found in items of instrumental-skill character related to upper limb preferences, which could reveal possible impact on motor manifestation of laterality by imitation or social environment. The OD item (Which hand do you use to hold a key while unlocking the door?) is a spontaneous non-skill activity (not subject to the pressure of the right-sided world), which may be a reason why the responses are more variable and why its factor loadings are not so strong. The KL item (While standing, which of your lower limbs do you place forward when you want to slide without the support of your hands?)

is the weakest item in the questionnaire. The nature of this item shows the spontaneous activity that is probably also related to the rotation attribute. However, the removal of this item led to a significant deterioration of the entire model fit, including the *p*-value. A problem arose in the very choice and modelling of indicators determining lower limb preference. Since lower limbs are not functionally adapted to a wide range of motor activities that a person consciously realizes, it was difficult to ensure indicators which would have a strong relationship to the lower limb preference factor, but which would not violate collinearity, while covering the assessed attribute from multiple points of view.

The resulting one-factor model also suggests that particularly the answers to items of skill character can be affected by subjective assessment of the side preference degree, resulting in a local dependence, i.e. the answer to a particular item is affected by the answer to the previous item. The questionnaire survey concerning the diagnosis of motor manifestations of laterality remains a rough screening tool whose primary function is only to determine the side tendency. Therefore, in order to further verify the structure of the functional asymmetry of the motor organs, we recommend that (apart from the questionnaire part) the analysis should include the part of preferential motor tasks that would eliminate the influence of subjective assessment of side preference and thus also the local dependence. Modelling relationships of these two approaches in the assessment of motor manifestations of laterality by the IFA and the Latent Class Analysis could contribute to a better understanding of the core of the theoretical concept, motor manifestations of laterality. The results of this research will also contribute to the understanding of motor control within education in issues of kinesiology and anthropomotorics, which attempt to answer the question of whether the concept of "motor manifestations of laterality" form a continuous variable or a categorical latent variable.

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DIMENSIONALITA POLOŽEK V DOTAZNÍKU URČENÝCH PRO HODNOCENÍ PREFERENCE HORNÍ A DOLNÍ KONČETINY – DOSPĚLÁ POPULACE

MARTIN MUSÁLEK

SOUHRN

Cílem studie bylo ověřit strukturální hypotézu, zda položky dotazníkového šetření, hodnotící motorické projevy laterality horních a dolních končetin u dospělé populace, tvoří dvě samostatné latentní proměnné či nikoliv. Položky dotazníku byly vybrány na základě expertního šetření a posouzení obsahové validity položek, které byly součástí již vytvořených zahraničních dotazníků. Do diagnostického nástroje původně 10 položek (nástrojového, dovednostního a nedovednostního charakteru). Šetření bylo provedeno na 440 jedincích ve věku 17–19 let. Pro analýzu dat bylo použito metody strukturálního modelování (SEM), konkrétně konfirmativní přístup pro kategorická data nazývaný item factor analysis (IFA). Výsledky ukázaly, že nejvhodnějším modelem je jedno-faktorový model se sedmi položkami. Tento model měl velmi vysokou diagnostickou kvalitou vyjádřenou pomocí indexů fitu RMSEA 0.028, CFI 0.99, TLI 0.99 a signifikací modelu na hladině $p = 0.29$. Výsledný jedno-faktorový model však naznačuje, že odpovědi na položky zvláště dovednostního charakteru, u kterých byly zjištěny silné faktorové zátěže, mohou být ovlivněny subjektivním hodnocením míry stranové preference, jejímž důsledkem je lokální závislost tj., že odpověď na určitou položku je ovlivněna odpovědí na položku předcházející.

Klíčová slova: funkční asymetrie, lateralita, dotazník, strukturální modelování, kategorická konfirmatorní faktorová analýza

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