Factor structure of the Spatial ability subtest of the Learning potential test

Faktorová struktura subtestu Prostorová představivost Testu studijních předpokladů

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Abstract
The aim of the presented study was to analyze the structure of Spatial ability subtest, which is a part of admission test to Masaryk university and consists of eight items. The sample size was 1540 persons (61% women). Confirmatory factor analysis of tetrachoric correlations revealed the existence of two conceptually different dimensions that were interpreted on the basis of the existence of verbal-analytic, respective visual-analogue mental processes.

Key words
cognition, spatial ability, test

Abstrakt
Cílem prezentované studie byla analýza struktury subtestu Prostorová představivost, který je součástí Testu studijních předpokladů. Tento test je základním hodnotícím nástrojem v rámci přijímacího řízení Masarykovy univerzity. Analyzována byla data z roku 2007. Výzkumný vzorek tvořilo 1540 osob (61 % žen). Konfirmační faktorová analýza tetrachorických korelací mezi jednotlivými položkami prokázala existenci dvou konceptuálně odlišných dimenzí. Povaha těchto dimenzí byla interpretována v souladu s dvěma teoreticky předpokládanými třídami mentálních procesů, které bývají označovány jako verbálně-analytické, respektive vizuálně-analogové.

Klíčová slova
kognice, prostorová představivost, test

Introduction

Spatial ability as a part of intelligence concept enables us to solve problems or tasks which require the ability to estimate, predict, or evaluate the relations between various objects in various contexts (Eliot & Smith, 1983). Thurstone, Guilford, Zimmerman, and others involved in exploring intelligence, describe the structure of spatial ability differently. In the relevant literature we can find meta-analytic studies which incorporate existing knowledge. The most cited is the study by McGee (1979). This author suggests the existence of at least two spatial factors – spatial visualization and spatial orientation. Visualization is the ability to mentally manipulate with pictorial stimuli, i.e. rotate, turn, mirror or invert them. Orientation requires to comprehend the structural configuration of elements in visual stimuli and to remain unconfused by the changing orientations of spatial configuration. Other authors mention the existence of three main spatial factors – spatial perception, spatial visualization, and mental rotation (Linn & Petersen, 1985), or even five factors - spatial perception, spatial visualization, mental rotation, spatial relations, and spatial orientation (Maier, 1994). The problem is that the factors are partly overlapping and it is not easy to develop test items that would involve only one of the spatial factors. Generalizability of results of these authors is further complicated by the fact, that original studies were based on empirical work with very different types of items.

The above short introduction to the concept of spatial ability and its components suggest that this concept has analogue nature, and that appropriate mental activities mirror physical manipulation with objects (Embretson, 2007). However, it must be taken into consideration that items in various tests of spatial abilities can be solved not only by these visual-analogue processes but also by other solving strategies based on verbal-analytic processes. In this case the task is decomposed into a sequence of propositions (Paivio, 2009), which define individual elements of the task and their relations.

This analogue-analytic dimension can be viewed in two perspectives – perspective of the person and perspective of the task. In the person's perspective one can prefer analogue or analytic solving strategy just because he/she is talented in one way or the other. On the other hand, also certain tasks or test items can provoke to prefer one of these two strategies.

Some spatial ability tests can contain items which are solved mostly by verbal-analytic processes, because their design prevents using analogue solving or the verbal-analytic procedure provides more accurate and verifiable solution. Such items cannot be considered a valid indicator of spatial ability.

The aim of the study is to explore the structure of spatial ability subtest from university admission test.

Method

Sample

The research sample consisted of 1540 individuals (61 % women), which were administered version 02 of the Learning Potential Test as a part of admission procedure at Masaryk University in 2007. The average age was 19.6 years.

Instrument

The Learning Potential Test (LPT) is designed to ascertain the applicant's potential for successful studies at Masaryk University. In 2007 it consisted of 64 questions grouped in 8 subtests of 8 questions each; these are multiple-choice, with only one of five possible answers being correct. The correct answers are assessed by one point, the wrong or missing answers by 0 points. The LPT is a test of verbal, symbolic and numerical skills, critical thinking, analytical skills, judgmental capabilities, spatial abilities and cultural awareness. The time for administration was 90 minutes. The complete tests of all versions of the LPT are available on university's website at: http://www.muni.cz/admission/tsp. For the purpose of this study only the Spatial ability subtest from version 02/2007 was used. Item wording can be found in Appendix.

Procedure and data analysis

Due to the relatively large sample size (1540) we could use one half of the sample for proposing a model of the subtest structure and the other half for its confirmation. Therefore the original dataset was randomly split into two halves (770 persons each). After initial descriptive analysis we created two matrices of tetrachoric correlation for both halves using free software TetMat[1] by John Uebersax. The tetrachoric correlation is used when it is assumed that there are latent continuous variables underlying the observed binary variables. The tetrachoric correlation estimates the correlation between the assumed underlying continuous variables (Divgi, 1979).

On the first matrix we performed exploratory factor analysis (PCA; direct oblimin, delta = 0). On the basis of acquired matrix of factor loadings we suggested a factor analytic model which was confirmed using AMOS software on the second tetrachoric correlations matrix.

Results and discussion

The initial data file of 1540 persons was divided into two separate files of the same number (770) of cases using SPSS random select procedure. In the first step we examined both files from the perspective of item difficulties. Table 1 shows that the files are comparable and that the items are of average difficulty or slightly easier.

Table 1. **Item difficulties for randomly split data file**

Item	% of correct answers (half 1)	% of correct answers (half 2)
A	49	53
B	43	51
C	43	45

1) Available for download at http://www.john-uebersax.com/stat/tetra.htm.

Item	% of correct answers (half 1)	% of correct answers (half 2)
D	57	60
E	75	80
F	67	72
G	63	65
H	71	71

In the second step separate matrices of tetrachoric correlations were estimated for each dataset. Respective coefficients are summarized in table two. Due to the randomized procedure of splitting the file there is no surprise that the levels of coefficients for half 1 and half 2 are close enough (especially in higher levels). These matrices served as an initial input for factor analytic procedure.

Table 2. **Tetrachoric correlation matrices for both halves of the original data file**

	A	B	C	D	E	F	G
B	.10/.15						
C	.09/.15	.11/.11					
D	.12/.24	.24/.12	.12/.21				
E	.12/.03	.01/.15	.07/.16	.27/.28			
F	.07/.17	.20/.20	.13/.15	.28/.34	.38/.25		
G	.07/.06	.13/.06	.08/.15	.33/.30	.34/.27	.30/.27	
H	.21/.16	.22/.25	.09/.14	.30/.35	.30/.34	.27/.28	.33/.28

Note. Correlation coefficients are presented in half 1/half 2 order.

Matrix from the half 1 enabled us to build a proposal of the model of the subtest structure. Exploratory factor analysis departured from this matrix revealed two factors with eigenvalue bigger than 1. Coefficients in pattern matrix (table 3) shows that items A, B, C have high loadings on factor 2 and the remaining items D, E, F, G, H on factor 1.

Table 3. **Pattern matrix from exploratory factor analysis**

	Factor 1	Factor 2		Factor 1	Factor 2
E	.80	-.24	D	.54	.26
G	.72	-.06	B	.03	.70
F	.66	.04	C	-.04	.57
H	.54	.28	A	.02	.53

On the basis of the exploratory factor analysis outcome we proposed two-factorial model. One of the factors is connected to items A, B, and C, while the other factor is connected to items D, E, F, G, H. There is no cross-loading item and the factors are allowed to correlate. Such proposed model was confirmed using structural equating modeling. Structural parameters of the model are included in the depiction of the model in figure 1.

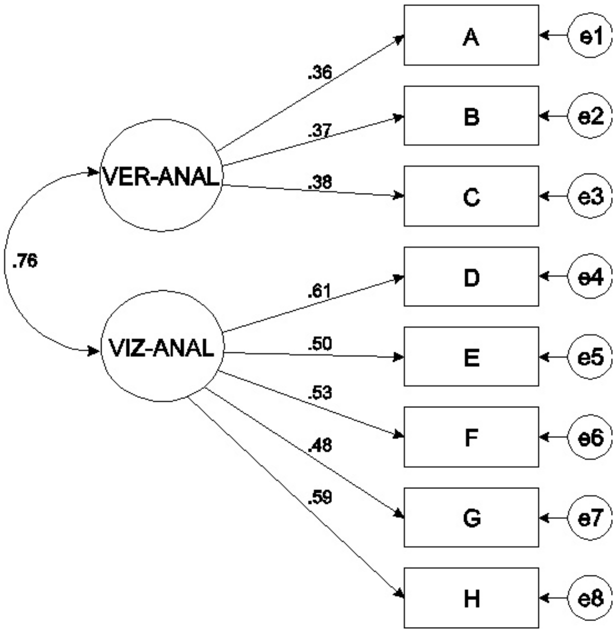

Figure 1. **Two-factorial model of the Spatial ability subtest.**

Although the level of chi-square statistic indicates the possibility of rejecting the model ($\chi^2 = 61.5$, df = 19, p <.01), regarding to the large sample size we have to take into account other indices. These indices suggest that the model provides reasonable goodness of fit ($\chi^2/df = 3.24$; RMSEA = 0.054, HONE = 453; TLI = 0.906).

As mentioned in the introductory section, those factors can be interpreted in several ways. In the relevant literature regarding the concept of spatial ability, existence of two (McGee, 1979), three (Linn & Petersen, 1985), or five (Maier, 1994) components of the concept is being mentioned. Other authors (Embretson, 2007; Tapley & Bryden, 1977, Just & Carpenter, 1985) point out that some item principles commonly used in spatial ability tests can be solved by verbal-analytic processes instead of visual-analogue processes, which are relevant for spatial ability concept.

In our data we found two factors. When considering the items wording we incline to interpret the factors according to visual-analogue / verbal-analytic dimension. We did not find any trace of spatial ability components. In our opinion, the homogeneity of visual-analogue factor can be explained by the fact that more than one component of the spatial ability are involved in solving a single item or one of the components is significantly involved in every item solution. In our case we incline to the latter explanation as the mental rotation component is clearly involved in all five items (D-H) associated in VIS-ANAL factor.

References

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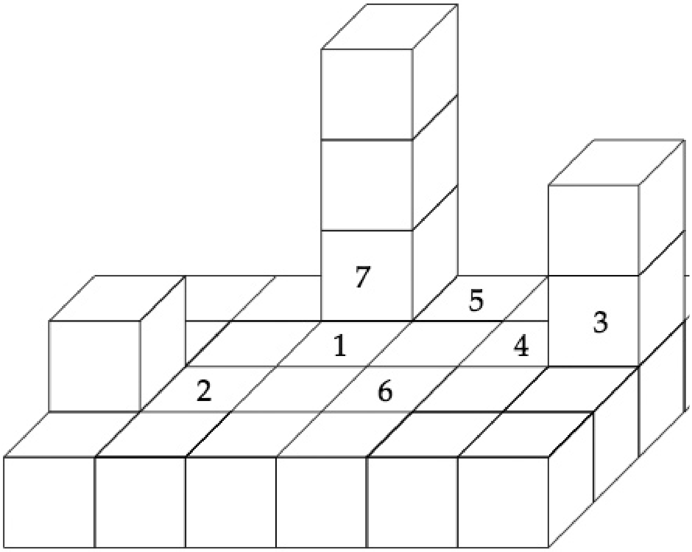
Appendix. Items in Spatial ability subtest

A

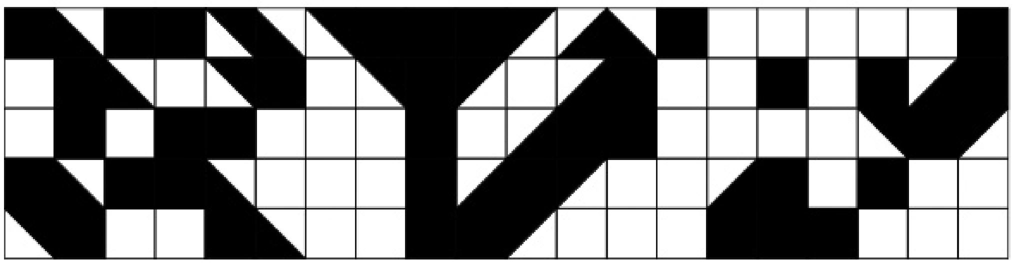
Určete, která z očíslovaných kostek se dotýká stěnou, hranou nebo aspoň vrcholem nejmenšího počtu ostatních kostek.



a) 7 b) 3 c) 6 d) 2 e) 5

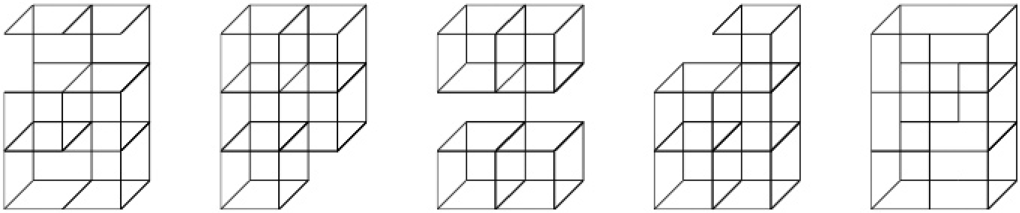
B

Určete, kolik procent čtverečkované plochy je natřeno černou barvou.



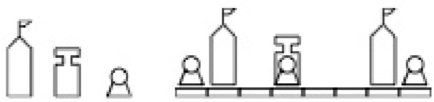
a) 44 b) 47 c) 53 d) 48 e) 49

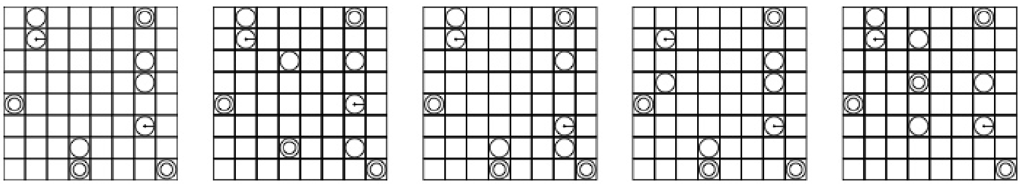
C
Na obrázcích jsou znázorněna rozestavěná lešení. Na které lešení byla použita nejmenší délka lešenářských trubek?



a) b) c) d) e)

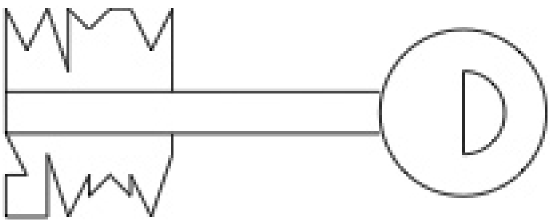
D
Na šachovnici je rozmístěna skupina figurek, kterou vidíme z bočního pohledu na šachovnici.



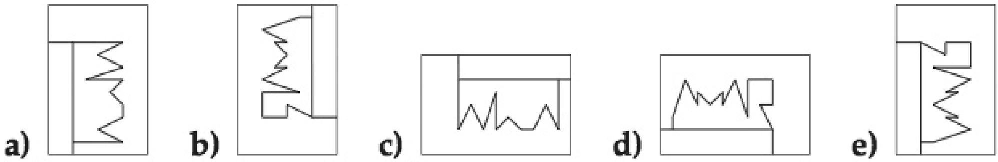


a) b) c) d) e)

E
Na obrázku je oboustranný klíč.

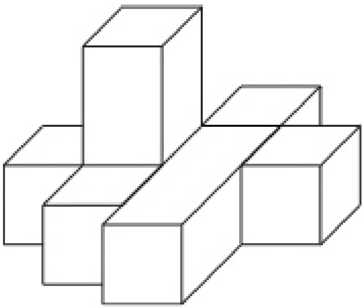


Který z níže znázorněných otisků části klíče nepatří tomuto klíči?

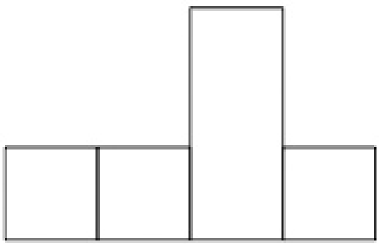


F

Na obrázku se díváme na dekorativní zahradní sestavu dřevěných krychlí a kvádrů.



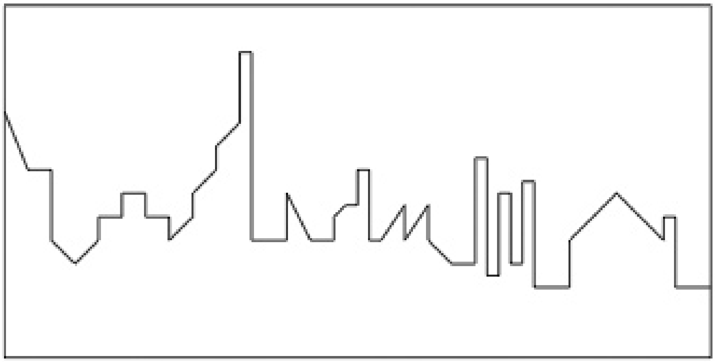
Z jakého pohledu byla vyrobena fotografie této dekorativní sestavy?



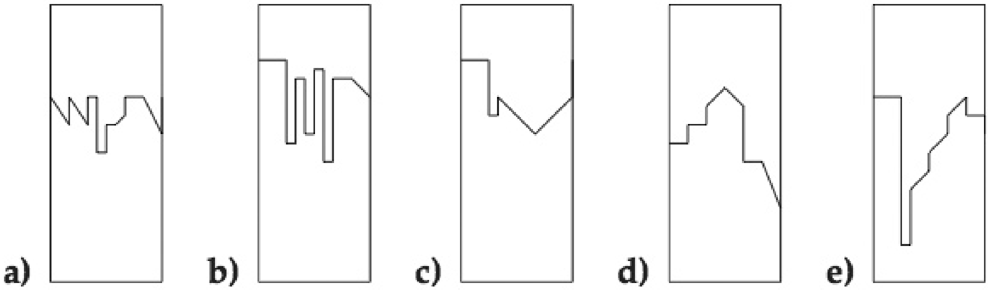
a) zprava b) shora c) zleva d) zepředu e) zezadu

G

Na obrázku je panorama města.



Který z výškově a stranově převrácených výřezu nepatří k panoramatu města?



H

Na obloze se vznáší pět stejných papírových draků. Kterého z nich vítr převrátil?