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THE PERSONAL NEED FOR STRUCTURE AS A FACTOR AFFECTING THE UNDERSTANDING AND PROJECTING OF COMPLEX SPACIAL STRUCTURES

POTRZEBA STRUKTURY JAKO CZYNNIK WPŁYWAJĄCY NA ROZUMIENIE I PROJEKTOWANIE ZŁOŻONYCH STRUKTUR PRZESTRZENNYCH

A b s t r a c t

Creativity and understanding of complex spatial structures are required from architects. Thereat, avoiding the uncertainty and the necessity of simplifying complex structures may, in consequence, lead to an inadequacy of the effect of their work. Employing the scales of Personal Need for Structure (PNS) and PNS-Geometry served to determine if the individuals with strong intensity of these qualities will have problems with understanding construction of complex spatial structures and correct solving of geometrical problems. The results of the preliminary research appear to validate the thesis.

Keywords: Personal need for structure, architecture, geometry

S t r e s z c z e n i e

Od architektów wymaga się kreatywności oraz zdolności rozumienia konstrukcji struktur przestrzennych. Z tego powodu unikanie niepewności i konieczność upraszczania złożonych struktur mogą powodować, że efekt pracy architektów nie będzie odpowiedni. Wykorzystując skale Indywidualnej Potrzeby Struktury (PNS) i PNS-Geometria, starano się określić, czy rzeczywiście osoby, u których natężenie tych cech jest wysokie, będą miały problem z rozumieniem konstrukcji złożonej struktury przestrzennej i prawidłowym rozwiązywaniem zadań geometrycznych. Wyniki pilotażowego badania wydają się potwierdzać tę tezę.

Słowa kluczowe: potrzeba struktury, architektura, projektowanie, geometria

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1. Introduction

Every individual has to deal with the complexity of the environment that he/she lives in. No matter whether we examine the biological or the social environment, the amount of analysed data is enormous, whereas our cognitive resources are limited [9]. Therefore, it has become necessary to find ways to reduce the information load. Two types of strategies used for this can be distinguished [10].

First of all, there is the avoidance strategies, which limits the amount of information to which individuals are exposed. Included here are all of the behaviours creating the barriers between an individual and the environment e.g., putting on earphones and listening to music while using public transportation, or building high fences around houses, gardens or housing developments [10]. These strategies can also be observed in the case of people who intentionally ignore social stimuli e.g., by avoiding eye contact.

The other way of reducing the cognitive load are the strategies allowing to organize the world into a simplified, more manageable structure. Cognitive structuring refers to creating and using abstract mental representations, like schemas, scripts, attitudes, and stereotypes, which are simplified generalizations of previous experiences [15, 1, 8].

The need to simplify the structure will also manifest through difficulties in integrating multiple pieces of information at the same time, which might explain why integrating mathematical data or dealing with constructional geometrical tasks may be more difficult for some people.

Even in case of planar geometrical constructions, which we execute in the image plane and which are graphical representations of complex three-dimensional structures, require the designer to have the ability to correctly understand spatial relations existing between the spatial objects. Being one of the primary elements of spatial orientation, the perception of shape depends heavily on the integration of sensory information in cortical centres [7]. Despite the fact that the image on the retina is two-dimensional, the reality is perceived as three-dimensional, and the spatial relations between objects are precisely determined [16][17]. However, while performing constructional geometrical tasks, we do not rely on experience; instead we need to read the projections of spatial elements correctly. The ability to analyse the information related to the objects, which are mathematical structures, is essential. One has to visualise the principles of projecting separate elements, which do not emerge from the intuitive, automatic processing of the visual stimuli. Individuals who avoid complexity in social situations and who impose an incorrect, simplified structure on these experiences may also have a tendency to oversimplify mathematical (and also geometrical) complexity, which will lead to inappropriate integration of information and drawing false conclusions [13]. Neuberg and Newsom performed a study pertaining the ability to categorise (based on abstracting) with reference to a non-social environment overstimulating with information [10]. The Participants were presented with various images, which they were to group at their own discretion. The individuals with a stronger need for simple structure created larger, less complex categories, simultaneously demonstrating lower flexibility and associating each of the elements only with one category, as opposed to the individuals with a lower need for simple structure. This might suggest that the ability to analyse the qualities of objects, in the case of individuals with a strong need for simple structure, is constrained by the inability to deal with too many stimuli, and by the necessity to reduce cognitive overload.

Architects need to have a theoretical background in architectural design, construction and building. On the other hand, the final effect of their work is an individual architectural composition, which should express their emotions, experiences, which has to be open for the mutual understanding with the recipient, and which should have a personality [11]. The need for a simple structure and reluctance to go beyond clichés might prevent projecting on this level of proficiency, which will cause the design to reflect neither the individualism of the architect nor the personality of the client. It is explained by the fact that creativity requires some doze of tolerance for ambiguity, which the subjects with a high need for structure lack [3, 4]. Neuberg and Newsom [10] suggest that the Personal Need for Structure is related to the lower level of Openness to Experience – a trait strongly associated with creativity [6]. In Rietzschel's, Slijkhuis' and Van Yperen's studies [12], the negative correlation between creativity and the need for simple structure was observed, especially in case of tasks without a detailed, step-by-step instruction.

The aim of the research presented here was to determine whether high level of Personal Need for Structure is related to the lower performance on tasks in terms of understanding the construction of complex spatial structures. The secondary goal was to answer the question, if high level of Personal Need for Structure reduces the level of creativity in the architectural design process.

2. Method

2.1. Participants

The participants comprised of forty undergraduate students of the first year at the Faculty of Architecture of Cracow University of Technology (30 women and 10 men).

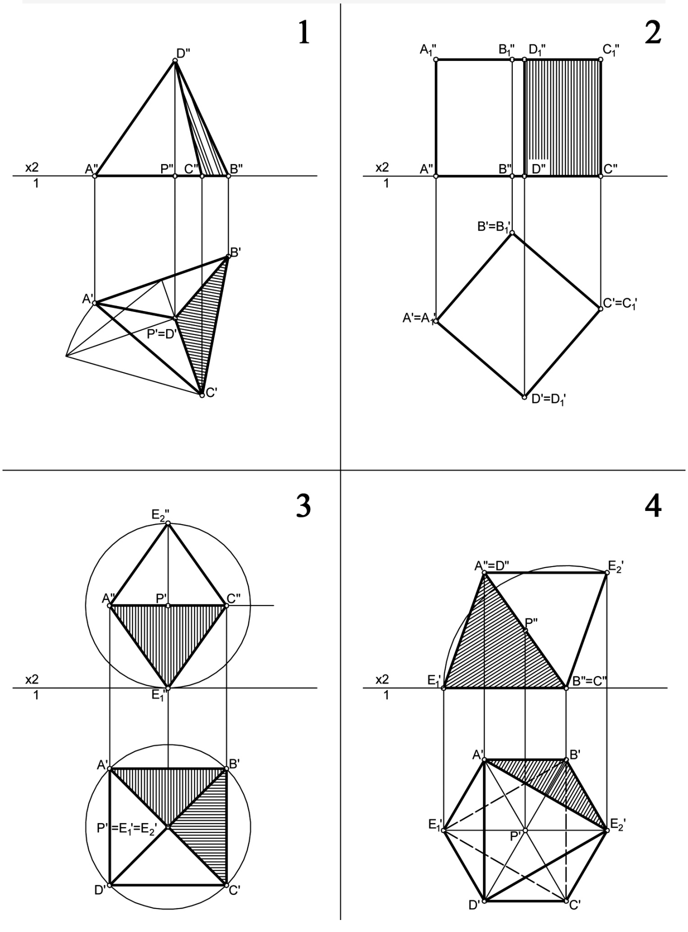
2.2. Research tools

The Polish version of Personal Need for Structure scale (PNS) [14, 15] was used. The scale consists of 12 statements (e.g.: "I become uncomfortable when the rules in a situation are not clear", "I don't like situations that are uncertain" – full scale in Neuberg and Newsom [10]), to which participants ascribe numbers from 1 ("strongly disagree") to 6 ("strongly agree"). The higher the score, the higher the motivation to create simple structures. Beside the general result, the scale allows to describe two qualities: the need for structure in everyday life (PNS Desire for structure – items: 3, 4, 6 and 10) and the way of reacting to the lack of structure (PNS Response to lack of structure – items: 1, 2, 5, 7, 8, 9, 11, 12). Due to its weaker connection with other statements, item no. 5 was not included in the general result, nor in any of the sub-scales [10]. The scale allows to determine the extent to which an individual prefers structuralization and organizing experiences, without referring to social or political issues.

For the purpose of the study, an additional tool was devised: the Personal Need for Structure – Geometry (PNS-Geometry). It was based on the English version of PNS scale, which was adapted for the purpose of measuring the need for structure with a reference to mathematical data [13]. In the primary version, the scale had 12 items, to which participants were to answer using a six-item scale, analogical to the original PNS scale. However, during the statistical analyses it was decided that only 11 items would be used.

2.3. Geometrical tasks

The study has used the construction of three Platonic solids (Mongean projection method): a tetrahedron, a cube and an octahedron in two possible orientation positions in relation to the projection plane (with one position to choose from two options). The participants were to draw two views (a front view and a top view) of each of the Platonic solid, with one of the solid's faces lying in the horizontal picture plane. In the case of a tetrahedron, the task boiled down to constructing its height in the top view, which in sequence allowed to draw the front view of the tetrahedron. During the construction of a cube, it was necessary to take into account the fact that its edge length equals the length of the square's side. In the case of an octahedron being placed in the position in which one of its faces belongs to the horizontal picture plane, it was required to construct the distance between its two opposite faces in the top view and then to draw the front view. In the second position, in which one of the apexes



Ill. 1. The Mongean projection (rectangular) of three Platonic solids: a tetrahedron (1), a cube (2) and an octahedron in two possible orientation positions in relation to the projection plane (3, 4)

of the octahedron is lying in the horizontal picture plane while simultaneously one of its diagonal planes, which is a square, is parallel to the horizontal picture plane and its other diagonal square is parallel to the frontal picture plane, it was required to consider the fact that the distance between the opposite apexes is equal to the diagonal of the square. All used geometrical tasks are presented in the Illustration 1.

In the evaluation process two factors were taken into consideration: the understanding of the solid's construction and the ability to correctly label visible (with a continuous line) and hidden edges (with a dashed line) of each of them.

With the consent of the participants, the analyses also included the results of the mid-term test and the final exam grades taken in the "Descriptive geometry" course as well as the final grade from the course of "The introduction to the theory of architectural and urban design". In the last course, students were graded for doing individual design projects of the business premises to which the assumption was that the space was built-up by using a few solids. This piece of work was entitled: "the inside, the light and the shade".

2.4. Procedure

The participants attended a lecture on Platonic solids, after which, and based on which (not being allowed to look into the notes), they were asked to solve geometrical problems and fill in the PNS-Geometry scale. After a week, the subjects were asked to do the Personal Need for Structure scale. Since the research was conducted during regular classes, not all of the participants were present in both parts of this research.

2.5. Statistical analyses

The analyses were conducted with the use of statistical analysis software STATISTICA 10. In the analysis of the structure of PNS-Geometry scale, the exploratory factor analysis and the reliability analysis of the obtained factor structure were made. Moreover, the correlation analyses and t-tests were conducted. The level of the statistical significance was assumed as $\alpha = .05$. Considering preliminary character of the research and a rather small group of samples, the results in which the statistical significance level alpha is less than one ($\alpha < .1$) have also been presented.

3. Results

3.1. The analysis of the PNS-Geometry structure

Bartlett's test ($\chi^2(66) = 112.20$; $p < 0.001$) and the KMO = 0.55 factor showed heterogeneity of the factor matrix, which justifies the usage of factor analysis [5]. As the criteria for determining the amount of the factors, the Kaiser's criterion (eigenvalue larger than one) and the Cattell's criterion (based upon the factor scree plot) were used [5]. After taking them into account, the structure with three and four factors was chosen. The Varimax rotation showed, that a three-factor structure is better adjusted to the analysed factors (Table 1).

Table 1

Varimax rotation – loads >.55 are presented

Item	Factor 1	Factor 2	Factor 3
It upsets me when I encounter a geometrical problem unlike any problems I have encountered in the past.			0.59
When solving a geometrical task, I am not bothered when I hit a dead end and have to adopt a new strategy.			–0.68
When approaching geometrical constructions, I enjoy having a clear and structured set of instructions.	0.81		
I feel better about geometry when I am able organize geometrical rules and concepts into simple, overarching structures.	0.82		
I am fascinated by geometrical tasks that can be approached in multiple ways.		0.68	
I find that doing geometrical tasks with a series of clear and simple steps to their solution feels boring.		–0.67	
I don't like working on geometrical tasks when I am uncertain about whether I can get the correct answers.	0.71		
I hate it when I have to change my approach to solving a particular geometrical task.		–0.69	
I hate it when geometry professors are unpredictable.			0.60
I find that having a consistent approach to geometry enables me to enjoy working geometrical tasks more.		0.55	
I enjoy the exhilaration of being presented with geometrical constructions unlike any I've ever seen before.			0.63
eigenvalues	**2.58**	**1.57**	**1.54**

The analysis showed that the full scale reached the average level of reliability (Cronbach's $\alpha = 0.61$), and a similar result was obtained for each factor (factor 1: Cronbach's $\alpha = 0.60$; factor 2: Cronbach's $\alpha = 0.56$; factor 3: Cronbach's $\alpha = 0.55$). Factor no. 1 refers to the desire for structure during the process of solving geometrical problems (e.g.: "When approaching geometrical constructions, I enjoy having a clear and structured set of instructions"). Factor no. 2 is related with the participants' reaction to the lack of structure in solving this type of problems (exemplary item: "It upsets me when I encounter a geometrical problem unlike any problems I have encountered in the past"). Factor no. 3 was described as avoiding unpredictability in geometry (exemplary item: "I don't like working on geometrical tasks when I am uncertain about whether I can get the correct answers"). To determine the relation between PNS-Geometry and the construct of Personal Need for Structure, the analysis of Pearson's correlation was conducted. The relation between the general result of PNS-Geometry and the Avoiding of Unpredictability in Geometry with general score in Personal Need for Structure was found (Table 2).

Table 2

Correlations between PNS-Geometry with Personal Need for Structure

		PNS-Geometry	**PNS-Geometry *Desire for structure***	**PNS-Geometry *Response to lack of structure***	**PNS-Geometry *Avoiding unpredictability***
PNS	***r***	0.46	0.20	0.31	0.42
	p	0.005	0.260	0.069	0.012

3.2. Comparisons of PNS and PNS-Geometry with abilities to solve geometrical problems and projecting

Due to a low number of participants, the level of significance was not reached, however, the conducted analysis of Spearman's correlation showed that the participants had the tendency to achieve lower scores in geometrical problems solved directly after the lecture, with the higher general need for structure in geometry ($rho_{N=40} = -0.34$; $p = 0.065$). The participants also performed better in geometry exams, with hig her scores in the Avoiding of Unpredictability in Geometry scale ($rho_{N=40} = 0.29$; $p = 0.073$). This effect was observed not only for a summary result, but also for the ability to allow for the fact that the solids be visible ($rho_{N=40} = 0.28$; $p = 0.080$) and the ability to provide a correct solution for construction problem ($rho_{N=40} = 0.27$; $p = 0.096$).Furthermore, it was observed that the general personal need for structure ($rho_{N=28} = -0.34$; $p = 0.080$) and the difficulty in dealing with the lack of structure ($rho_{N=28} = -0.34$; $p = 0.081$) were negatively correlated with participants' ability to correctly solve the constructional part of geometrical tasks.

The more detailed analyses within each constructional problems showed that subjects who provided correct solutions for the tetrahedron task had lower levels of Personal Need for Structure (on the edge of statistical significance, also for both PNS sub-scales), and scored lower on Avoiding of Unpredictability in Geometry scale, than the subjects who did not solve the problem correctly (Table 3).

Interestingly, PNS was not significantly related to any of the abilities measured during the examination and the test from the "Descriptive geometry" course.

Table 3

The differences in level of PNS-Geometry and PNS for correct and incorrect solutions of tetrahedron task

	M_0	M_1	t	df	p	N_0	N_1	SD_0	SD_1
PNS-Geometry	50.83	47.00	1.62	28	0.117	12	18	5.52	6.83
PNS-Geometry *Desire for structure*	15.33	14.72	0.70	28	0.488	12	18	1.97	2.54
PNS-Geometry *Response to lack of structure*	18.25	18.06	0.16	28	0.878	12	18	2.96	3.61
PNS-Geometry *Avoiding of unpredictability*	17.25	14.22	2.38	28	0.024	12	18	3.41	3.41
PNS	47.73	40.71	2.22	26	0.035	11	17	8.13	8.19
PNS *Desire for structure*	17.27	14.47	1.98	26	0.058	11	17	4.34	3.14
PNS *Response to lack of structure*	30.45	26.24	2.00	26	0.056	11	17	4.68	5.90

0 – group with incorrect solution of tetrahedron task.
1 – group with correct solution of tetrahedron task.

3.3. Comparisons between particular abilities developed during the classes on “Descriptive geometry” and “The introduction to the theory of architectonic-urban projecting”, and the performance in solving geometrical problems

Relationships between the results of the test, the examination in the “Descriptive geometry”, grades in projecting, and the results in geometrical problems solved directly after the lecture were also analysed. The results in solving the geometrical problems were associated exclusively with the test scores. It was observed that, along with the increase in the performance in solving problems in the constructional part, the level of performance in the test also increased (visibility criterion: $rho_{N=40} = 0.45$; $p = 0.012$; construction criterion: $rho_{N=40} = 0.48$; $p=0.008$; general score of the test: $rho_{N=40} = 0.46$; $p = 0.010$). Moreover, the higher the general result in solving the geometrical problem, the higher was the performance in the constructional part of the task during the test ($rho_{N=40} = 0.37$; $p = 0.042$).

What is more, the results of the examination and the evaluation of architectural projects were not significantly related to the level of solving geometrical problems.

It was also observed that the grades in architectural projects were positively correlated with the results of the test ($rho_{N=40} = 0.36$; $p = 0.022$) and the results of geometry exam ($rho_{N=40} = 0.47$; $p = 0.002$).

4. Discussion

The obtained results show specific relationships between the personal need for structure, the personal need for structure in geometry, and the ability to correctly analyse and integrate information about construction of complex spatial structures. The discovered tendencies seem to show that, with the increase in the need for simple structure and for Avoiding of Unpredictability, the numbers of mistakes in the complex geometrical understanding grow, which in consequence leads to errors in the constructional solutions. This regularity was observed only in the case of formerly unlearnt abilities. However, when subjects were able to learn and prepare themselves in advance – even without understanding how to solve specific constructional problems – the tendency was opposite. This implies that subjects with a stronger need for simple geometrical structure were dealing better in this case, since their ability to avoid unpredictability in geometry could have resulted in paying more attention to mastering the required material. Consequently, the participants with low levels of this trait have relayed more on their general abilities – not skills – which, in a situation as stressful as examination, might have led to making mistakes.

The lack of significant correlations between grades in the projection design and the results from the examination in geometry with the ability to understand complex spatial structures, and the openness to ambiguity and novelties, might signalize that, during the process of architectural education, and for the final evaluation, the abilities connected with reproducing of the already-known structures are more important than innovative designing of space, which is of secondary importance. Or that the tasks involving the creativity are very structured, which significantly facilitates the functioning of individuals with high levels of PNS [12]. Those conclusions are consistent with findings stating that the individuals with the need for structure – understood as the need for any sort of answer in an unclear situation to avoid uncertainty – are less creative than those with lower intensity of this trait [4], but when task is highly structured, they could be as much creative [12]. One should bear in mind that, although the architecture is a conscious process of shaping the space in a way that would correspond with intended function – in specific construction and form [2] – relying only on known and verified schemes leads to architectural monotony and mediocrity. As a consequence, artistry – the perception of architecture as a form of art – will disappear.

The presented research obviously has a preliminary character, and hence, the formulating of final conclusions should be taken with caution. It is necessary to conduct further research in this area, perhaps taking into account other indicators of creativity in a design practice, and certainly conducting research on a larger sample of subjects.

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