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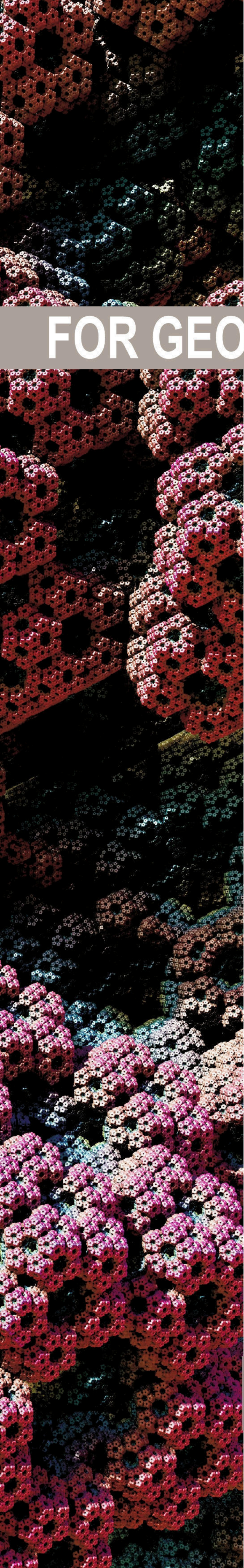

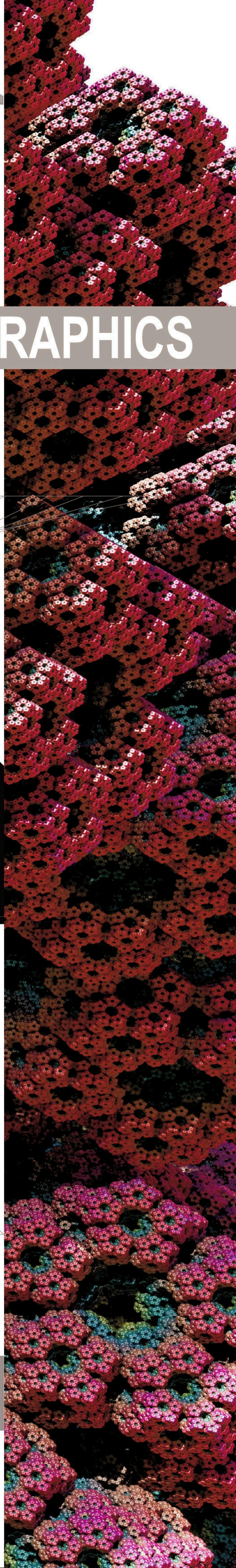

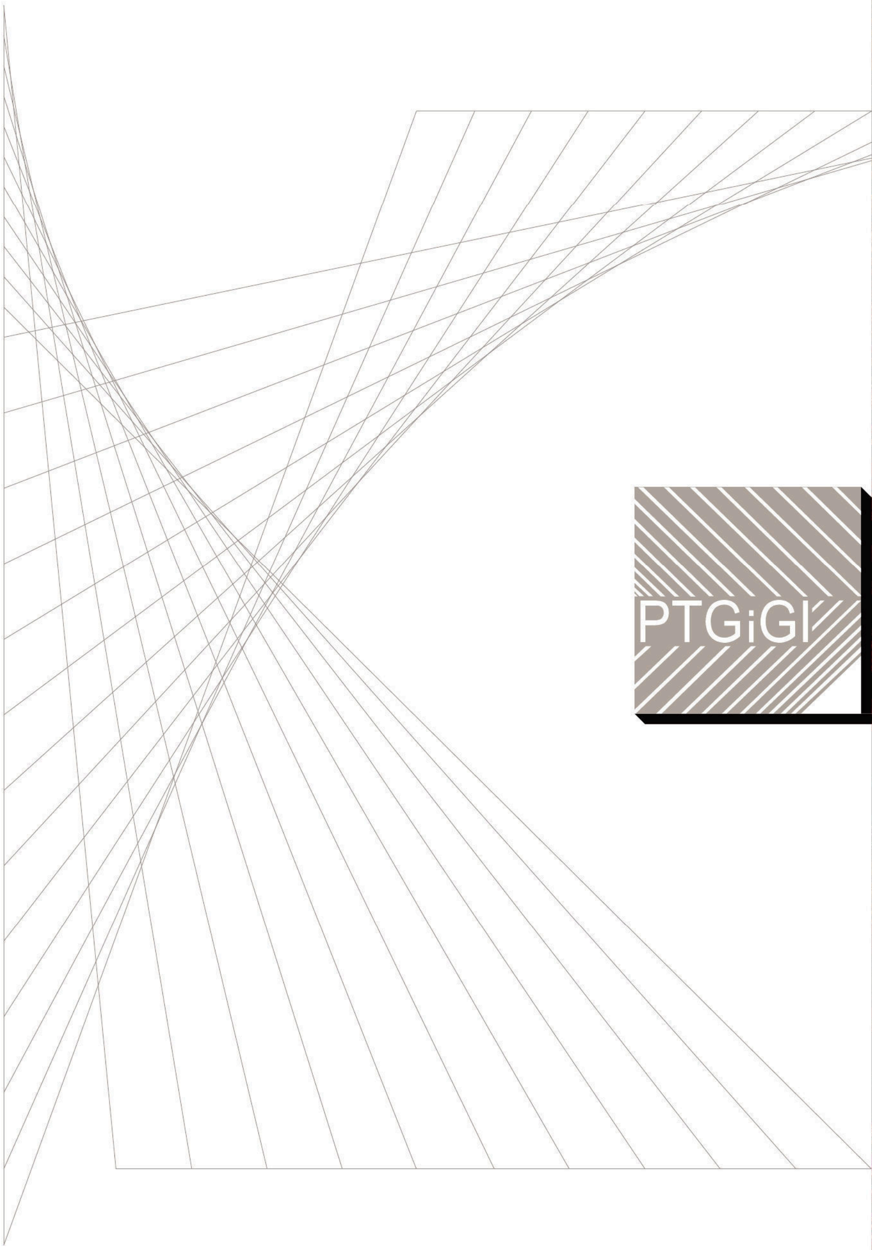

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ANALYSIS AND COMPARISON OF THE THREE SPATIAL TESTS: MRT, MCT AND HSAT

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Abstract. Visual-spatial skills are present in the everyday activities of engineers and architects. During tertiary education, it is extremely important to develop the ability to interpret three-dimensional objects and their connections. The paper deals with spatial abilities of first year civil engineer and architect students from Szent István University, Ybl Miklós Faculty of Architecture and Civil Engineering, in the light of three consecutive tests: Mental Cutting Test, Mental Rotation Test and the Spatial Ability Test created by Séra and his colleagues. All the surveys proved development in spatial skills during the first year studies, which we discuss from different aspects. We introduce the concept of saturation index, as a refinement of measuring development. Beside the statistical analysis and comparison of results, the paper also deals with the critics of the tests.

Keywords: MCT, MRT, Hungarian Spatial Ability Test, engineering education, visual-spatial skills.

1 Introduction – assessment tools and conditions of the surveys

Spatial visualization is a component of human spatial intelligence. With the linguistic, mathematical, locomotor, natural, musical and personal intelligence, it contributes to all human abilities.

The study of spatial visualization approximately started in 1880 with Sir Francis Galten, who reported about some experimental findings in the field of mental visualization [7]. It was important to observe that spatial visualization may exist separately from general intelligence, as evidenced by psychometric research. This was later confirmed by the existence of several components of visuospatial thinking. Parallel to the research on spatial visualization skills, measurement tools have been developed. Probably one of the oldest ones is the standard Mental Cutting Test (MCT) which was originally developed in the US as an entrance examination aptitude test and dates back to 1939 [8]. The test was rediscovered by Suzuki has been used in many research projects from Japan to Germany, Austria, Poland [6], Croatia, Slovenia and Slovakia, just to mention a few. The classic MCT contains 25 problems. In each case parallel perspective drawing of a solid body is given which is cut by a plane. The subjects are asked to choose only one shape of the plane sections from the suggested five alternatives. MCT measures the spatial visualization factor of spatial intelligence: the ability of visualizing the relations between the parts of a solid. Time solution is set to 25 minutes. As the second test we used MRT (Mental Rotations Test), which was created by Vandenberg and Kuse (1978) [9] using block diagrams based on Shepard and Metzler's work [10]. The Mental Rotations Test consists of 20 items. Each item contains a criterion figure, two correct alternatives and two false ones. The criterion figure for each item is a cube aggregate. The correct alternatives are same in structure but presented in various rotation positions. The incorrect alternatives are partly rotated mirror images (10

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elements) or rotated images of other structures (10 elements). MRT measures the mental rotation factor of spatial intelligence: the ability of rotation of three dimensional solids mentally. Time solution for each part of 10 items is assumed to be 4 minutes. As third assessment tool the Hungarian Spatial Ability Test by Kárpáti & Gulyás (2002) [1] has been used. This test was successfully employed in large scale assessment projects both in secondary and in tertiary education. The two versions of the tool can be used for pre- and post-testing purposes (Version A, with 56 items and Version B with 47 items have a Cronbach's alpha 0.81 and 0.93, respectively). In addition to solving problems by selecting from alternatives that use mental operations, it also includes drawing tasks that can be used to measure "thinking by drawing".

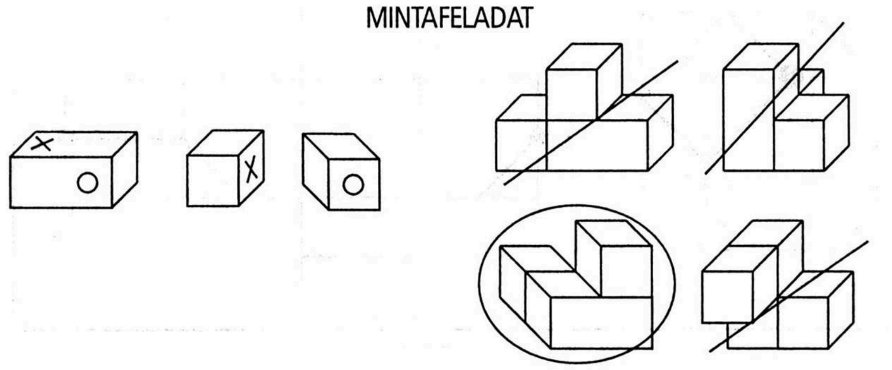

Figure 1: Sample problem from HSAT

This test measures two large skills' clusters: basic mental operations: mental analysis (observation of hidden spatial structures), mental synthesis (compositions); and complex mental operations: mental rotation and transformation and construction of mental spatial images.

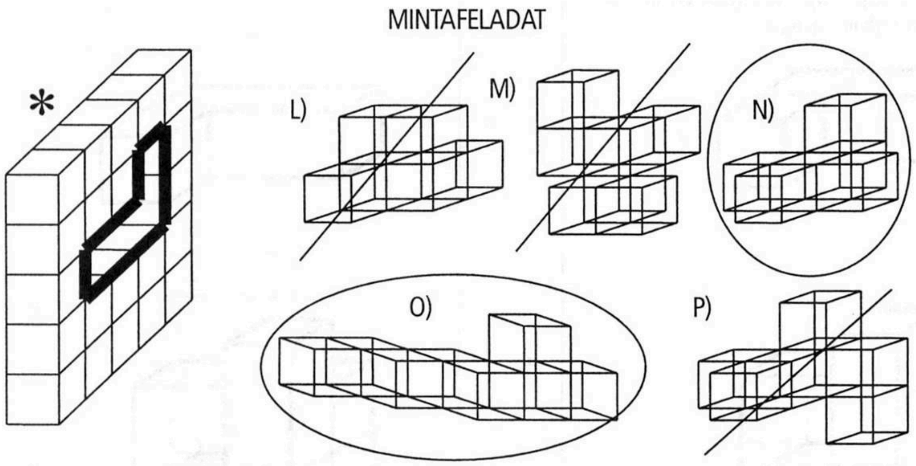

Figure 2: Another sample problem from HSAT

The research described here has been conducted at Ybl Miklós Faculty of Architecture and Civil Engineering, Szent István University, Budapest.

The MCT survey started in the first semester in the academic year 2010/11 [2, 5]. The subjects of the survey were architecture and civil engineering students in the first grade. The students were required to complete the test twice in the semester, on the beginning of the course, i.e. at the first class-meeting and at the end of the semester, i.e. during the last class-meeting. Altogether 223 students participated in the survey, completing both the pre- and post-tests.

In the academic year 2011/12 the MRT for measuring spatial skills has been applied. Again, subjects of the survey were architecture and civil engineering students in the first grade. 120 students participated in the survey, completing both pre- and post-tests on the first and on the last class-meetings.

The data of Hungarian Spatial Ability Test (HSAT) test were recorded in the academic year 2014/15 [4]. The number of architecture and civil engineering students participating in the survey was 178.

2 Results

2.1 Improvement, saturation and normality

Pre-test and post-test averages show improvement in each cases. For MCT we detected 49,34% which increased to 56,37%. The mean of MRT goes from 49,52% to 57,89%, whilst HSAT produces improvement to 68,63% from 62,15%. Interestingly enough, the improvement is about the same in each cases (7,03; 8,37 and 6,48%, respectively). It seems so, that some of the task groups of HSAT were easy for the subjects, this would explain the relatively high starting score. The effect of university training (Descriptive Geometry, Freehand Drawing, Technical Representation and for architects: Architecture Design) appears among the components of visuospatial thinking in mental rotation the best.

A new aspect of comparison can be the measurement of improvements by introducing relative numbers of distribution. The hypothesis is that subjects may produce different test results related to their individual psychological and/or psychical condition at the moment of the research. Considering the scoring systems and the effect of small changes, our convention will be to detect improvement or decline at least 5% difference between pre- and post-test results. Fig.3 summarizes the results in improvement: the three groups of columns refer to those who improved/decreased their results or stayed constant.

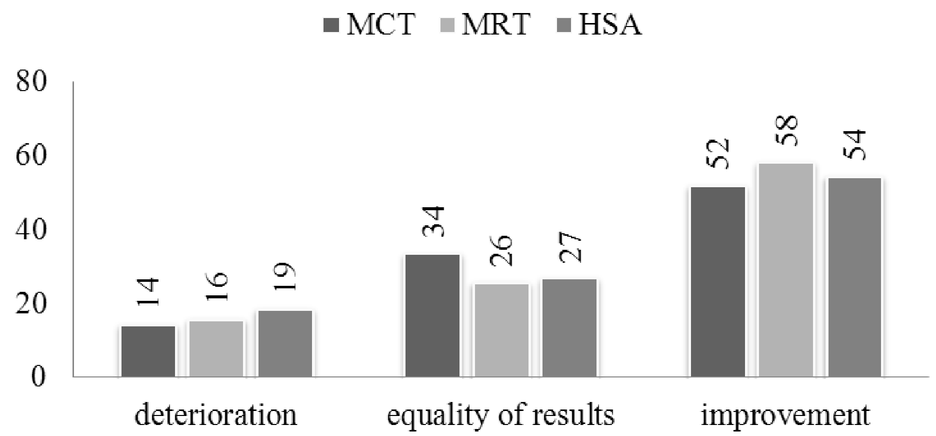

Figure 3: Improvement diagram of the tests

These results just confirm that university training has positive effect to the majority of students. The improvement rates of different tests show consistence, just like those of deterioration. It can be noticed that the number of students whose result stayed on the same level in both tests (pre- and post-) is the highest on the MCT. We will try to give an explanation to this occurrence in the critical part of this paper.

Improving scores is a more complicated problem, as the limit of available scores is maximized. That means, it is difficult to get more points above a certain level of knowledge. For example, a student who scored at the first test 20% and at the second 30% has the same improvement as the other getting 90% first and 100% next. In order to make difference between the two achievements we introduce the so-called saturation index s:

$$s = \frac{h}{m} \tag{1}$$

where h denotes the change in percentage and m denotes the percentage still achievable by the subject. Considering the previous example, for the first subject 1080=0,125 and for the second one .

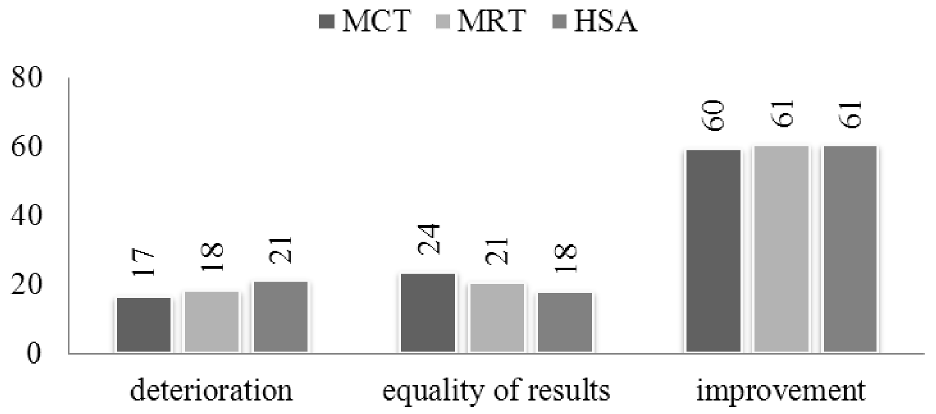

Figure 4: Improvement diagram by saturation

In this case our subjective convention is to consider a student's achievement to be constant if he/she produces within ±15% difference between pre- and post-test results. It is remarkable that the improvement rate is the same in each case. Otherwise the diagram shows the same tendencies, but with less stagnation and more improvement.

Results of the pre- and post-tests show normal distribution, because all the values below are in the interval [-1;1].

Table 1: Kurtosis and skewness of test results

	MCT pre	MCT post	MRT pre	MRT post	HSAT pre	HSAT post
kurtosis	-0,486	-0,722	-0,938	-0,649	0,027	0,843
skewness	0,364	0,117	-0,090	-0,211	-0,358	-0,855

In the case of MRT we can observe extremely low value of kurtosis. This can be explained by the lack of average test results (Fig.5) which is probably the consequence of the scoring system [3] and structure of the test, discussed later on.

The big negative skewness of HSAT results can be explained by some items the students are already familiar with: namely the university entrance examination test contains a similar type question (Fig.5).

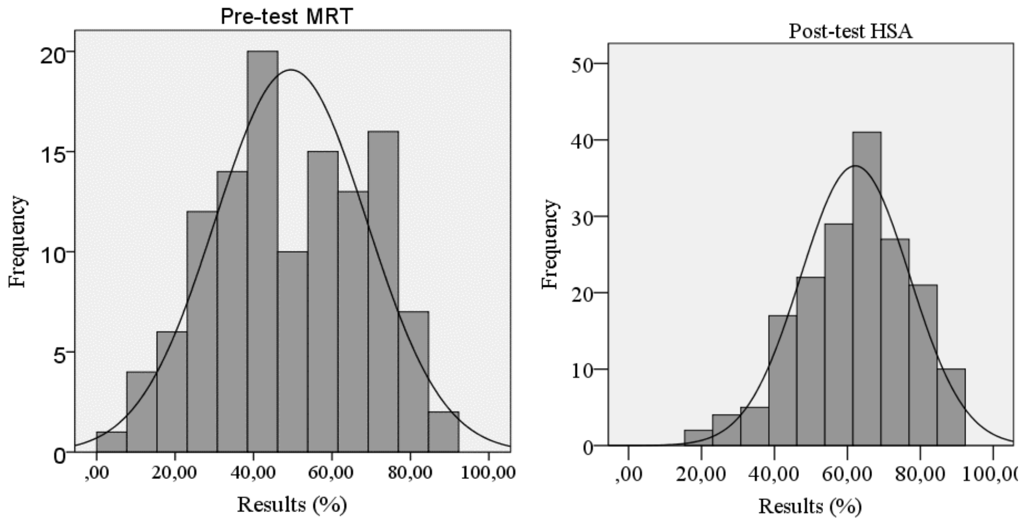

Figure 5: Pre-test results of Mental Rotations Test and Post-test results of Hungarian Spatial Ability Test

2.2 Hypothesis testing

In our study we selected those problems from HSAT which develop the same spatial skill components as MCT and MRT, respectively. Table 2 contains the test results we recorded.

Table 2: Comparison of MCT, MRT and parts of HSAT

	MCT	mental transformation in HSAT	MRT	mental rotation in HSAT
deterioration	14%	36%	16%	37%
equality of results	34%	10%	26%	20%
improvement	52%	54%	58%	43%

The relative big differences could be explained partly by the different scoring systems. In HSAT it is easier to step through the 5% limit and change category. On the other hand HSAT contains similar, but not the same type problems comparing to MCT or MRT. In addition to that, as we shall see in Chapter 2.3 both MCT and MRT have structural problems.

Table 3 presents students' performance and comparison using t-tests.

Table 3: Comparison by paired sample tests

tests	Pre-test %		Post-test %		
	mean	standard deviation	mean	standard deviation	Paired-samples t-test
MCT	49,34	19,72	56,37	20,18	t= -7,17; p<0,001
mental tr. in HSAT	46,79	18,36	54,49	35,93	t= -3,18; p<0,002
Independent-samples t-test	t[401]= -1,33; p< 0,182 not significant		t[401]= -0,62; p< 0,532 not significant		
MRT	49,52	19,30	57,89	19,89	t= -5,72; p<0,001
mental rot. in HSAT	66,29	18,36	67,79	22,34	t= -,91; p<0,366 not significant
Independent-samples t-test	t[298]= 7,504; p< 0,001		t[298]= 4,005; p< 0,001		

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For mental cutting/mental transformation the results are coherent. Both for MCT and HAS the development is significant during the semester, but the two test results are not significantly different. In mental rotation skills, however, we see strange anomalies. In Hungarian Spatial Ability test the results are higher (although not significantly), but there is no significant improvement in these questions, nevertheless the whole HSAT shows significant development. It seems so that MRT was more challenging and overall more difficult than HSAT.

2.3 Critics of the tests

We think that most of the above mentioned deviations can be explained by the weaknesses of the tests.

Mental Cutting Test has been used since 1939 but it reflects the scientific level and knowledge of that time. The focus is very narrow, it measures just a partial skill of spatial intelligence. Its main problem is that the interpretation of the cutting tasks is not unique. The perspective view of the object and the plane cannot determine their mutual positions correctly; you need some intuition to find out what the teacher's intention is. On the top of that the shape of some bodies cannot be decoded in a unique way. All together cause that MCT doesn't indicate the development in visuospatial thinking in some cases.

Mental Rotations Test is much more developed but has also weaknesses. The problems you have to solve are of the same type, therefore the subjects getting tired and bored while dealing with them. One can observe that the number of unsolved questions is more at the end of the worksheet. If the subjects had had more time, probably they would have scored more. The other problem is the unfair scoring system (for details see [3]). As we pointed out in [3] an other scoring system would fit better to the subjects' achievements.

The Hungarian Spatial Ability test is the most complex from these three ones and measures a wide range of spatial skills. However, it contains some relatively easy tasks compared to MRT or MCT. The mental transformation problem are different from those of MCT, therefore the comparison is difficult.

3 Conclusions

In the paper the authors compare some spatial ability test results conducted in the last few years at the Ybl Miklós Faculty of SzIU in Budapest. The main observations of the investigation can be formulated as follows:

- University education has great positive impact to the factors of spatial ability measured by MCT, Mental Rotations Test and HSAT. We proved this statement by presenting the increasing mean, the increasing ratio of improving students and by paired samples t-tests.
- We offer the saturation index as a new tool of investigations. With it a more adequate development index can be computed.
- Although all the tests we presented have disadvantages all of them are useful to measure one or more components of spatial skills. In the future we offer to use the more complex Hungarian Spatial Ability test for research purposes.

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ANALIZA I PORÓWNANIE WYBRANYCH TESTÓW DO BADANIA WYOBRAŹNI PRZESTRZENNEJ

Umiejętności wizualno-przestrzenne są istotne w codziennej pracy zawodowej inżynierów i architektów. W czasie studiów wyższych niezwykle ważne jest rozwijanie umiejętności interpretowania obiektów trójwymiarowych i ich powiązań. Praca dotyczy badania wyobraźni przestrzennej studentów I roku Inżynierii Lądowej i Architektury z Uniwersytetu Szent István oraz Wydziału Architektury i Inżynierii Lądowej Uniwersytetu Ybl Miklós, w świetle trzech następujących testów: Mental Cutting Test (MCT), Mental Rotation Test (MRT) i test wyobraźni przestrzennej stworzony przez Séra i jego szkołę (HSA). Wszystkie badania dowiodły rozwoju wyobraźni przestrzennej podczas pierwszego roku studiów, który omawiamy w różnych aspektach. Wprowadzamy pojęcie wskaźnika nasycenia, jako udoskonalenie pomiaru rozwoju. Poza analizą statystyczną i porównaniem wyników, w artykule dokonano również analizy krytycznej testów.