Connections between Spatial Ability and Visual Imagery Preferences

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Abstract: The aim of the current study is to reveal the types of connections between spatial ability and visual imagery preferences. Participants in the study were 114 students from five Universities in Hungary. Two measurement tools were administered: (1) The OSIQ questionnaire (30 items, 15 items on object imagery, and 15 on spatial imagery), and (2) A spatial ability test. The score achieved on spatial imagery items of the OSIQ test has a significant correlation with performance on the spatial ability test ($r = 0.46$; $p < 0.001$), while score on the object imagery items has a neutral correlation with spatial ability ($r = -0.07$; $p = 0.46$). This tendency in the strengths of correlations was independent of the type of study (engineering students and visual art pre-service teachers) and of gender. Results have relevance for designer training, skills identification and talent identification.

Keywords: spatial ability; visual imagery; OSIQ; visual skills development

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Development of spatial abilities is crucial in training, for a wide range of professions. Research on factors influencing developmental levels may improve training programs, by means of providing data for more targeted, skills enhancements. Our study aims to reveal connections between spatial ability and visual imagery preferences and experiences, in two tertiary student populations: engineering students and pre-service teachers of art, with a background in design. Whereas possessing an appropriate level of spatial ability is crucially important in several fields of tertiary education, the role of visual imagery preferences and their connections with spatial ability is an issue for critical discussion. The phenomenon of visual imagery preferences in itself deserves further clarifications, since there are at least two main types of imagery towards which preferences can be defined and measured. Object imagery and spatial imagery are the two broad categories; the first referring to colorful, vivid images, while spatial imagery refers to schematic drawings.

1 Introduction

1.1 Spatial Ability and its Importance in Tertiary Education

Spatial ability has long been recognized as an important intelligence factor, a field of talent recognition and development, and a set of skills necessary for academic expertise indifferent fields of tertiary education.

Research on spatial ability has a long tradition, under different paradigms, including the Piagetian tradition and the factor-analytical studies of intelligence. Piaget presumes that man organizes reality into coherent and stable patterns at certain points of cognitive development which are structurally different from those at other points – an idea of developmental stages influencing research on visual language of children and youth for decades [27, 17]. Piaget identified sensorimotor, preoperational, concrete and formal operational stages in the perception of and manipulation with space as well [16].

In factor-analytic studies of human intelligence, a wide variety of tests were used to measure a broad range of abilities labeled under the umbrella of spatial ability (see [26, 11, 6, 9] for overviews). The common base for the divergent definitions of spatial ability can be identified in the ability to manipulate images mentally. In Carroll's overview [11], spatial ability consists of several different first-order intelligence factors such as visualization and other, speed-related factors. More recent findings on the structure of intelligence challenged the traditional division of fluid and crystallized factors, and [18] suggest that image rotation – considered as the core part of spatial ability – also deserves a separate intelligence factor, besides the verbal and perceptual components.

In spite of the widely recognized importance of spatial ability as a distinct intelligence factor, school curricula and talent recognition instruments often fail to involve spatial ability as befitting its importance [21]. As [14] emphasized, the assessment of spatial intelligence (one important branch of intelligence in Gardner's multiple intelligences paradigm) should take the form of manipulative tasks, as opposed to linguistic ones. Measures of academic potential (like the Scholastic Aptitude Test) do not assess spatial ability, despite its crucial role in STEM (science, technology, engineering and mathematics) subjects [1]. This may be a reason why many university students in STEM subjects, start their studies with a deficient spatial ability. As a consequence, they face problems in acquiring visual representations required by art and geometry and fail to decode spatial visualizations in science textbooks. There have been weaknesses reported in spatial ability even among first year engineering students [15].

The importance of an appropriate level of spatial ability in engineering studies is emphasized by [34] and it is highlighted in the European Space for Higher Education documents [10]. In a study on the relation of spatial skills and areas of study, engineering students tend to provide better performance in different spatial ability tests than students of visual arts and humanities [38]. Another population of special interest with regard to the role of spatial ability in tertiary education is the pre-service teacher population, especially in the fields of mathematics and visual arts and design. Pre-service and in-service mathematics teachers' performance on 3D visualization tasks was hindered by their frequently observed misconceptions when trying to transform 3D situations to two dimensional problems [13].

Diagnosing deficiencies of spatial performance inspired researchers to address the issue of skills development in higher education and beyond. It is still an unresolved problem if and to what extent spatial ability can be improved in adulthood by means of adequate instructional strategies and tasks. In an experiment, computer-based real-world tasks were applied to improve spatial ability, but no significant between-group differences were found [25]. In other skill enhancement experiments, there were some promising findings published on the potentials of improving spatial ability among engineering students [29, 36]. At the same time, these efforts emphasize the importance of spatial ability development in adulthood. Nevertheless, it has been revealed that enriching activities are needed over a long period of time in order to gain long-term development effects [31].

1.2 Visual Imagery Preferences

According to the MIT Encyclopedia of the Cognitive Sciences [22], mental imageries are mental processes that can be connected to either generating, transforming or inspecting images (what we see with our inner eyes). The measurement of imagery rely on people's subjective statements considered to be true for themselves, thus an established means of measuring imagery preferences and experiences is the self-report questionnaire methodology. For instance, adults and even teenagers may give unbiased judgments on their own skills and abilities, and who else would better know what an individual prefers (i.e., choosing between a work of architecture and painting) than the individuals themselves. There were six items used among young children (from grades 3 to 12) on their 'spatial experience' [12]. In that study, spatial experience did not prove to be a significant predictor of spatial ability.

One of the widely used self-report questionnaires on visual imagery is the Object-Spatial Imagery Questionnaire [4] which contains 30 statements on the individual's visual imagery preferences and experiences. Obviously, measuring preferences and experiences in a cognitive domain by definition accomplishes the measurement of cognitive and learning styles, too. An extended version of the OSIQ questionnaire, OSIQV [3] covers three cognitive style factors: two visual and one verbal factor.

The taxonomy of cognitive styles must be briefly mentioned here as it is closely related to OSIQ, the questionnaire that we also used in our study. This taxonomy would certainly involve a discussion on the verbalizer-visualizer dichotomy, and there are two types of visualizers revealed [24]. Some people rely on vivid, colorful images in their thinking, while others prefer to use schematic drawings. This division of visualizers was incorporated in the OSIQ theoretical framework where the object imagery scale refers to the first, while the spatial imagery scale to the second type of visualization. A comprehensive, new model of cognitive styles with three pillars were introduced [5]: object imagery, spatial imagery, and verbal style. Why is it preferential to study cognitive styles in a tertiary education context? Blazhenkova and Kozhevnikov provide a detailed analysis of different aspects from which cognitive styles can be discussed: e.g., from the aspect of the brain areas involved in cognitive processing, different cognitive styles have their brain region correlates. Other aspects from which cognitive styles can be distinguished and defined are the psychological representations involved and the sequential nature of the related psychological processing.

In their study of visual artists, scholars of humanities and scientists, differences in object and spatial imagery scores were found [4]. As expected, visual artists obtained much higher object imagery scores, while scientists scored much better in spatial imagery tasks. As for the connection between object or spatial imagery scores and spatial ability, significant correlations (above .3) were found for spatial imagery scores, and non-significant correlations for object imagery [7].

The relevance of studies on connections between mental imagery scores and spatial ability can be justified from at least two aspects. First, the instructional strategies and tasks that are used in tertiary education may effectively foster students' spatial ability. At least in a diagnostic assessment setting, some expected correlations between OSIQ scores and different task genres were found [37]. Another, even broader aspect of relevance is the possible predictive value of either the mental imagery scores or the level of spatial ability. Mental imagery scores may well predict an individual's ability level and dispositions necessary to be successful a profession requiring the production and/or processing of different types of visualizations or to qualify for such university degree programs at all. Moreover, the level of spatial ability (that correlates with spatial imagery) has also some important correlations with personality traits, for example, with the openness personality factor [39].

1.3 Research Questions

Based on the literature review, and in accordance with the main aim of the current investigation (revealing correlations between training types and developmental level of spatial abilities), the following research topics have been formulated.

First, are spatial ability and visual imagery preferences of tertiary student interdependent? Provided that both psychological constructs can be reliably measured, we aim to investigate their relationships with two background variables: type of study and gender.

Second, in accordance with the main motive and title of the current research, we suggest that the nature or magnitude of the connections between spatial ability and visual imagery preferences are influenced by the background variables.

In line with these research topics, we hypothesized that:

- Both spatial ability and visual imagery preference can be reliably measured among engineering and arts and design pre-service teachers. Besides the two main factors of OSIQ, we presumed to identify other clusters of items (e.g., items related to color perception and preference).
- Engineering students will tend to have higher scores on the spatial imagery than on the object imagery subscale, while art and design pre-service teachers will have results in the opposite direction.
- Engineering students are expected to have better performance on the spatial ability test.
- Spatial ability is likely to have stronger correlation with the spatial imagery than with the object imagery subscale.
- The strength of correlations is thought to be the same regardless of the type of study.
- Males are expected to have better performance on the spatial ability test, while the results on the OSIQ scales would show mixed findings in relations to gender.
- Since there are more male engineering students, the study-type-effect and the gender effect are supposed not to interact with each other, i.e., both factors were supposed to have their own independent effect on both the OSIQ scores and on spatial ability performance.

These hypotheses derived from the two main research topics have driven our data analysis and the presentation of the results.

2 Methods

2.1 Sample

The students involved were recruited from five tertiary institutions of Hungary. The main characteristics of the sample composition are presented in Table 1.

Table 1
Characteristics of the sample

Institution and field of study	N	Male + female participants
Nyíregyháza College of Education	8	4 + 4
Óbuda University	46	41 + 5
Kecskemét College	28	1 + 27
Moholy-Nagy University of Art and Design	11	0 + 11
University of Pécs	21	13 + 8
Σ	114	59 + 55

The training program, infrastructure and student population of the universities and colleges selected are not fully representative of Hungarian institutions with similar training programs. While the University of Pécs has an accredited engineering program similar to others in Hungary, the Moholy-Nagy University of Art and Design is a unique and worldwide recognized institution that trains designers and teachers of art and design, who all possess an M.A. degree in an area of design, before entering the teacher training course. Students, however, are representative of the three university-level art and design teacher training institutions of Hungary.[1] The other two training sites are representative of college level art teacher education in Hungary. The Kecskemét and Nyíregyháza Teacher Training Colleges accepts students with a B. A. in Education (a primary teacher's degree) into their M. A. degree course in Art Education through a less competitive examination procedure.

Students tested were randomly selected from among those in the same degree course at each institution. However, the number of students attending each course is different and so are the chances of having been selected for the sample. At the University of Pécs, the sample was selected from 240 engineering students. At the Kecskemét and Nyíregyháza Teacher Training Colleges, students represent a cohort of 30 art education teacher trainees. At Moholy-Nagy University of Art and Design, all but four second-year Art and Design Education M. A. students were included in the sample.

[1] Besides Moholy-Nagy University of Art and Design, Budapest, the Hungarian University of Fine Arts, Budapest and the Faculty of Arts at the University of Pécs offer M. A. degree courses on Art and Design Education for M. A. degree holders in Art or Design.

2.2 Measures

Two tests were used in this investigation. A spatial ability test developed by Séra, Kárpáti and Gulyás [35], for an English description, see [28], and a questionnaire on visual imagery preferences [4].

2.2.1 Spatial Ability Test

The test measured two large skills clusters: spatial manipulation and perception. The subgroups evaluated were visualization, imagination, psychomotor components and visual memory. Item types were as follows

*A) Perception of space (*recognition and interpretation of 2D images representing spatial relations*)*

- Perception of spatial relations (e. g. location, direction, positioning, relative size)
- Interpretation of the structure and composition of spatial objects (e. g. positive and negative relations, juxtaposition, rules of illusionary representation of space)
- Reconstruction of spatial objects (e. g.: depiction of a geometric shape based on its floor plan, estimating size based on plans and sections, reading reduced images: silhouettes, maps, technical drawings, explanatory charts, representations of processes)

In all three item groups, the aspect of time was also present in tasks challenging spatial memory, mental rotation and manipulation, imagination of movement in space etc.)

B) Creation of 2D spatial images: representation, transformation, manipulation

- Rotation, alteration, mirroring and construction of images representing spatial relations. Two tasks are shown on Figure 1 to illustrate item types.

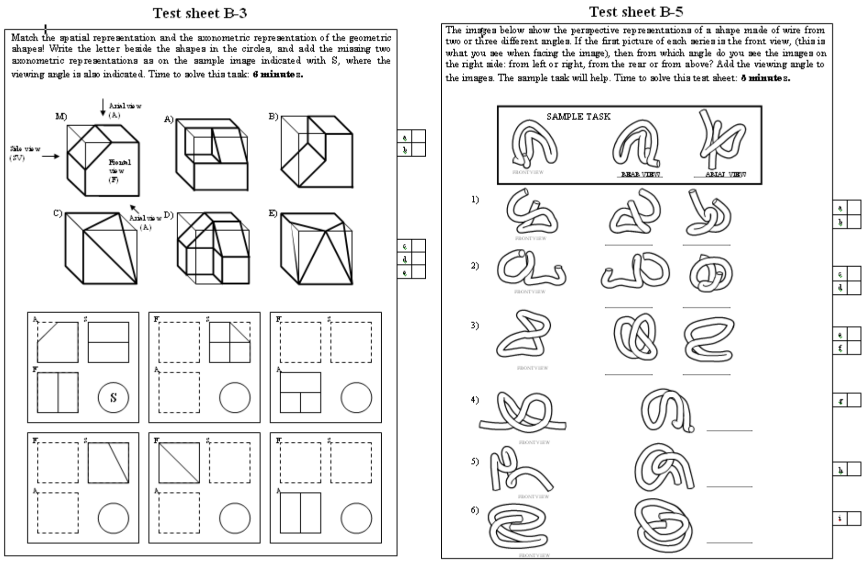

Figure 1(a) and 1(b)
Two tasks of the Spatial Ability Test by [30, p. 67]

The Spatial Ability Test proved to be a reliable measure: Version A (56 items) and Version B (47 items) had Cronbach's α coefficients .81 and .93, respectively. The mean score on Version A was 52.19%, while on Version B 50.79%. Items of the test have been successfully used in the Visual Culture subtests of the Hungarian Competence-Based Assessment of Student Skills [39].

2.2.2 OSIQ

Object-Spatial Imagery Questionnaire (OSIQ) measures individual differences in representing and processing visual imagery. It consists of an *object imagery scale* that reveals preferences for representing and processing colorful, pictorial visualizations of objects individual objects and a *spatial imagery scale* that shows the degree of preferences for schematic images, spatial relations amongst objects, and spatial transformations. The developmental process of the OSIQ questionnaire on visual imagery preferences is detailed in Blajenkova, Kozhevnikov and Motes (2006).

The reliability of OSIQ proved to be appropriate for the purposes of the current study. For the whole questionnaire (30 items), Cronbach's α coefficients was .77, while for the two subscales reliability was .86 (object imagery) and .80 (spatial imagery).

2.3 Procedure

The tests were administered within a one-week period to volunteering university and college students. In all institutions, OSIQ was administered first, followed by the Spatial Abilities Test.

3 Results

The results are presented in three consecutive sections. Section 3.1 discusses the results on the spatial ability test and the connections between spatial ability and background variables. Then results of the OISQ questionnaire are addressed in 3.2. In Section 3.3 the connections between the two psychological construct, and how these are influenced by background factors will be presented.

3.1 Spatial Ability Level

The level of spatial ability, i.e. the total score performed on the Spatial Ability Test is presented in Table 2 according to the type of study, and in Table 3, according to gender.

Table 2
Results on the Spatial Ability Test according to the type of study

Type of study	N	M	SD
Engineering students	66	57.71	19.73
Visual art and design pre-service teachers	47	43.03	23.71
Total	113	51.61	22.58

Our results suggest that engineering students outperformed visual art and design pre-service teachers in their spatial ability level. The difference is significant ($t = 3.59$; $p = 0.001$).

Table 3
Results on the Spatial Ability Test according to gender

Gender	N	M	SD
Male	58	56.53	19.76
Female	55	46.42	24.32
Total	113	51.61	22.58

Gender differences proved to be also significant with male students' advantage ($t = 2.43$; $p = 0.02$).

3.2 Visual Imagery Preferences

Table 4 and Table 5 present the results on visual imagery preferences for both subscales and for study type (Table 4) and gender (Table 5). Please note that for 15 items with five-level Likert-scale, the minimum total score is 15, and maximum is 75.

Table 4
Results on OSIQ according to the type of study

		Object imagery		Spatial imagery	
Type of study	N	M	SD	M	SD
Engineering students	67	50.55	9.13	51.69	7.00
Visual art and design pre-service teachers	47	55.74	8.83	42.64	8.80
Total	114	52.69	9.33	47.96	8.95

Independent-samples t-test showed significant differences in both scales of the questionnaire: $t = 3.03$; $p = 0.001$ for object imagery, and $t = 6.11$, $p < 0.001$ for spatial imagery.

Table 5
Results on OSIQ according to gender

		Object imagery		Spatial imagery	
Gender	N	M	SD	M	SD
Male	59	49.25	9.06	51.32	7.79
Female	55	56.38	8.18	44.35	8.77
Total	114	52.69	9.33	47.96	8.95

Gender differences proved to be significant in both subscales: $t = 4.40$; $p < 0.001$ for object imagery, and $t = 4.50$; $p < 0.001$ for spatial imagery. Since there is connection between the type of study and gender in the current sample, the relative weight of these two factors will be analyzed separately in section 3.4.

3.3 Item Clusters in OSIQ

Cluster analysis is a multivariate technique of analysis that groups variables into similarity clusters. The aim of using this method rather than confirmatory factor analysis is that cluster analysis relies on manifest variables only. Manifest variables are actually the students' answer scores, and the tendency in similarities and dissimilarities in their answers are shown in the dendrogram. Figure 3 shows the results of cluster analysis using the furthest neighbor method based on Pearson correlations.

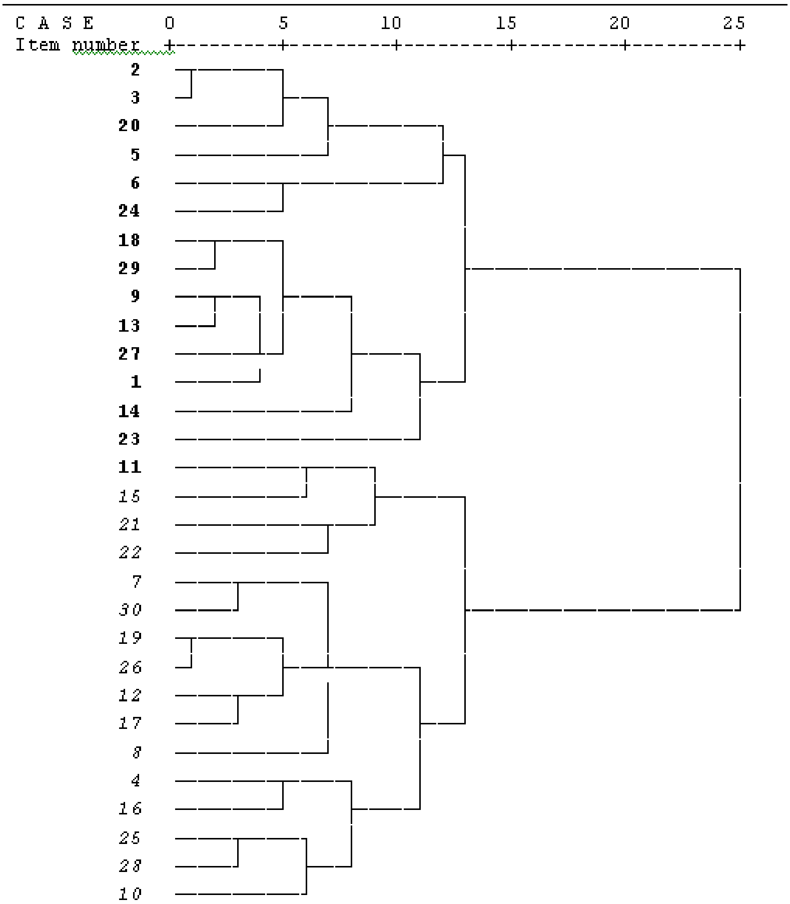

Figure 2

Dendrogram of the OSIQ items based on Pearson-correlation using the furthest neighbor method

Note: spatial imagery item numbers are in bold, and object imagery item numbers are in italic

The immediate visualization in Figure 2 reveals two distinct clusters: one containing spatial imagery items (with the exception of Item 11), and another cluster with object imagery items only. This immediate visualization is further approved by the analysis of significant correlations, since the last seven vertical lines represent non-significant connections. Consequently, Item 11 forms a separate cluster together with the Item 15, and this two-component cluster has no significant connections to other similarity groups. Item 11 is a rather long sentence claiming that ‘I [the respondent] normally do not experience many spontaneous vivid images; I use my mental imagery mostly when attempting to solve some problems like the ones in mathematics.’ Item 15 expresses preference for architecture as opposed to genres of visual arts. The peculiar place of Item 11 in this dendrogram may point to a didactical problem of making students aware of the role of mental imagery in problem solving in art and design as well as geometry. This division of items according to content proves the validity or the questionnaire and also supports our previous results.

Figure 2 shows other similarity groups, i.e., clusters where the vertical line is at most on scale level 6. For instance, Items 19 and 26 belong to such a similarity group, and both items contain the terms ‘remember’ with the words visual or visually. Similarly, Items 12 and 17 refer to vivid and clear mental images. Similarly, among the spatial imagery items, Items 2 and 3 refer to professions closely associated with spatial imagery, and Items 18 and 29 concern graphic abilities.

3.4 Connections between Spatial Ability and Visual Imagery Preferences

As revealed in previous studies and hypothesized in the current research, there may be significant correlations between the level of spatial ability and visual imagery preferences. Since both measures provide interval scale level scores, Pearson-correlation coefficients were computed and shown in Table 6.

Table 6

Correlation coefficients between spatial ability and visual imagery in the whole sample and in two subsamples

Whole sample	**Object imagery**	**Spatial imagery**
Spatial ability	-0.07	0.46
Object imagery		-0.13
Engineering students	Object imagery	Spatial imagery
Spatial ability	0.11	0.27
Object imagery		0.01
Pre-service teachers	Object imagery	Spatial imagery
Spatial ability	-0.09	0.45
Object imagery		0.02

Note: Correlation coefficients highlighted in bold are significant, other coefficients are non-significant at p = 0.05 level

Table 6 suggests that independently of the type of study the students pursue, there is a significant correlation between their spatial ability and spatial imagery. There is no significant correlation either between spatial ability and object imagery or between object and spatial imagery. The latter non-significant coefficients indicate the independence of the two OSIQ subscales, and therefore, validate the correlation between spatial imagery and spatial ability.

With respect to gender, similar patterns were revealed. It means that for both male and female students, the correlation between spatial ability and spatial imagery was significant, while the other two types of correlations were non-significant.

Consequently, the connection revealed for the whole sample by a massive .46 correlation coefficient is stable independently of either study type or gender.

To examine the cumulative role of the type of study and gender, a two-way analysis of variance has been conducted. This type of analysis reveals effects (if any) of two background variables, and examines whether the effects occur independently of each other. According to two-way ANOVA, interestingly, neither the type of study nor gender has a significant effect on *spatial ability* in itself (due to the small intersectional subsamples). However, the interaction of the two background factors proved to be significant with eta-squared coefficient = 7.2%. (Eta-squared coefficients are estimates of the explained variances on spatial ability). In itself, the magnitude of explained variance in this case can be considered medium sized. On the contrary, having examined the cumulative role of study type and gender, significant gender effect was found on *object imagery* (eta-squared = 3.7%), and the type of study had also a significant effect on spatial imagery (eta squared = 9.1%). In neither case the interaction of the two factors was significant.

This result, however, needs further research as several other spatial ability studies report gender-related performance differences. Gender played a significant role when computer-based real-world tasks were applied to improve spatial ability [25]. In a recent study of the same age group [9], a group of 202 female and male university undergraduates were administered three performance tests and three imagery questionnaires. Men obtained higher scores than women on the performance tests while no significant gender differences were observed on the imagery questionnaires. Women obtained higher scores than men on the Object scale of the Object-Spatial Imagery and Verbal Questionnaire. Gender differences were also observed between the correlations obtained for the performance test, with higher correlations for men. Other studies, comparing spatial imagery with a performance test also found significant gender differences [6].

4 Discussion

In this section, we review our research questions and hypotheses in light of the results of the current survey.

Engineering students had significantly better scores on the spatial ability test. Their good spatial ability level may be due to their training program involving more exercises in mental imaging. Training in spatial creation of art teachers generally lacks mental manipulation in space and focuses on realistic representation only. Therefore, their performance on this test is inferior to those of engineering students in mental manipulation tasks. This type of Pre-service training is later reflected in the teaching practice of art teachers: instead of developing a balanced curriculum of mental and creative spatial tasks, thus preparing students for vocations and everyday life situations requiring mental operations in space, they focus on representing space in a realistic manner.

This type of representation, however, is less and less required both in the world of work and in leisure time activities while mental operations gain importance in jobs like engineering and Information Technology as well as in free time activities like finding our way during a web search or in a city, reading a map. Spatial orientation tasks requiring mental rotation, completion and transformation range from reading and producing technical drawings to learning through simulations and playing computer games.

Our findings are in line with [4] who claim that 'compared to visual artists and humanities professionals, scientists, reported higher spatial imagery ratings; however, compared to scientists and humanities professionals, visual artists reported higher object imagery ratings' (p. 239).

Spatial ability was hypothesized to have stronger correlation with the spatial imagery than with the object imagery subscale. This hypothesis is supported by our results. Engineering students scored higher on the spatial imagery than on the object imagery subscale, and pre-service art and design teachers scored better in object imagery. Engineering students were also more successful in the Spatial Ability Test. This supports the predictive, discriminant, and ecological validity of both of our measures.

Connections between the two tests employed were strong. Good performance in our Spatial Ability Test predicted preference for spatial imagery as identified by the OSIQ questionnaire. This result does not mean that both measures may be used for the detection of the level of spatial abilities – for the screening of mental and psychomotor abilities needed for the study of engineering or art education, discipline-specific measures should be used. (The Spatial Ability Test has repeatedly been employed for identifying students in need of special training in an area of spatial perception or manipulation at the University of Technology in Budapest).

Strong connection between results in the test and the self-report questionnaire indicates a preference for a certain mode of visualization. If a group of pre- or in-service art educators have a strong preference for object imagery, it may indicate that they are likely to favor expressive and representational tasks versus analytical, design-oriented ones. Art teachers in secondary education should not have such a preference as their students need a balanced education in both technical and expressive skills. Therefore, pre- and in-service trainers should emphasize planning and design tasks to reveal their creative potentials and thus motivate for their inclusion in the curriculum.

The strength of correlations between the OSIQ scales and spatial ability was the same regardless of the type of study. Consequently, different types of studies may not have a specified effect on the connections between visual imagery preferences and spatial ability.

In line with previous research, males were expected to have better performance on the spatial ability test. In the OSIQ scales, we expected mixed findings in relations to gender, but the preference of engineering students for spatial imagery and the art education students for object imagery was significant. There is a significant correlation between their spatial ability and spatial imagery. There is no significant correlation either between spatial ability and object imagery or between object and spatial imagery. The latter non-significant coefficients indicate the independence of the two OSIQ subscales, and therefore, validate the correlation between spatial imagery and spatial ability. With respect to gender, similar patterns were revealed. It means that for both male and female students, the correlation between spatial ability and spatial imagery was significant, while the other two types of correlations were non-significant.

The connection between OSIQ scores and spatial ability results revealed for the whole sample by a massive .46 correlation coefficient is stable independently of either study type or gender. The type of study had also a significant effect on spatial imagery. Since there are many more male engineering students, the study-type-effect and the gender effect were thought not to interact with each other, i.e., both factors were supposed to have their own independent effect on both the OSIQ scores and on spatial ability performance. Gender differences, however, proved to be significant in both subscales.

4.1 Theoretical and Practical Relevance

Theoretical relevance of this research involves the establishment of connections between spatial ability and visual imagery preferences – a result that may be relevant for empirical aesthetics studies of personality traits and environmental effects affecting the development of taste. The level of perception of and creation in space is apparently connected to preferring certain visualizations. We have shown that spatial manipulations and visual preferences are connected in the mind, and the strength of connection depends on the type of training. Practical relevance of our research includes methodological aspects, the possibility of using a self-reported paper-and-pencil questionnaire to diagnose visual imagery preferences (and henceforth some aspects of spatial ability), and to provide an easy to administer measure for profession counselors. The Spatial Ability Test proved to be a reliable measure to identify outstanding spatial ability among engineering student, and the OSIQ showed interrelations with preferences of spatial imagery. Current research emphasizes the importance of spatial skills in STEM education [26, 28]. The joint use of these instruments promotes talent identification that may result in more efficient development.

The development of spatial ability can and should be supported by educational practices that are not oriented toward searching for gifted persons, but are oriented toward different gifted behaviors [8]. Spatial ability as supported by Gardner's multiple intelligence paradigm, is one of the important fields where gifted behavior can be observed and recognized. Identification of outstanding (or deficient) spatial ability is especially important for future and in-service art and design educators, who are supposed to develop spatial skills and abilities of their students, thus preparing them for a range of technological vocations and professions. When identified as lacking adequate spatial abilities, students may enter remedial courses that are likely to improve their spatial skills considerably [30]. Our results may help in early talent recognition and identification of spatial ability.

4.2 Limitations

The limitations of this research come from at least two sources. First, the sample is not representative of all types of engineering instruction offered by Hungarian universities and colleges. Architecture students were not involved – a cohort that may have more balanced skill structure, integrating both object and spatial imagery. Second, the indirect nature of any self-report questionnaire must be taken into account when interpreting the results of our study.

Although our Spatial Ability Test has repeatedly proven to be a reliable instrument, assessing spatial skills with two-dimensional, paper-and-pencil tasks has some ecological validity issues. For example, gender differences may be different, if tasks are to be performed in real space with authentic instruments. In such a situation, females were superior at static object-location memory tasks [32]. We also improved ecological validity through the introduction of three-dimensional, movable images produced by the open-source, internationally used GeoGebra software and launched studies on age-related and gender differences in a virtual environment resembling real-life situations in terms of changeability of viewpoints. (See [19], for a description of interactive, mobile, three-dimensional testing instruments.)

4.3 Implications for Future Research

Until the advent of neuroscience research, educators of artists and engineers had been convinced that individual differences in mental imagery, as well as the investigations of individual preferences for processing visual versus verbal information, were based on imagery as an undifferentiated, unitary construct and therefore individuals could simply be classified as good or bad imagers [33]. However, neuroscience research has proven the existence of distinct imagery subsystems [23]. In the current study, the nature and strength of connections between two types of measures have also been revealed.

Training programs have to consider such differences and, if necessary, ensure that the less developed mode of representation and encoding is enhanced through discipline-relevant developmental tasks [2]. This is especially true for art teacher education, where object imagery seems to be in the focus, while in art education programs focusing on ‘real world’ needs, spatial imagery of students has to be developed as well. Therefore, future art teachers have to be taught to develop curricula that support the encoding and processing of visual information in different ways.

In order to train students with high level spatial imagery skills, art educators have to develop their own spatial ability as well. Their spatial imagery will support the representations of the spatial relations amongst objects and their parts, locations and movements in space and other complex spatial transformations. These may of course be easily created in a computer assisted design environment – but only if the person at the keyboard has a clear mental vision about the desirable image. Additionally, a new factor, i.e. possible dynamic changes in the relationship between spatial ability and visual imagery preferences should also be addressed. It may be done by means of either longitudinal studies or design experiments. Both possibilities are available and feasible already from lower secondary school grades.

On the other hand, engineering students seem to need more training in visual creativity to develop their object imagery capacity. Object imagery supports the representations of objects in terms of their form, size, shape, color and brightness as they are perceived. For future architects and industrial designers or engineers, this capacity helps create convincing for their prospective customers visualizations of inventions or novel technical solutions.

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References

[1] Andersen, L.: Visual-spatial ability: important in STEM, ignored in gifted education. Roeper Review, 36, pp. 114-121, 2014

[2] Babály, B. and Kárpáti, A.: The Impact of Creative Construction Tasks on Visuospatial Information Processing and Problem Solving. Acta

Polytechnica Hungarica, (13)7, pp. 159-180, 2016, http://uni-obuda.hu/journal/Babaly_Karpati_71.pdf

[3] Blajenkova, O., Becker, M. and Kozhevnikov, M.: Object-spatial imagery and verbal cognitive styles in children and adolescents: Developmental trajectories in relation to ability. Learning and Individual Differences, 21, pp. 281-287 (2011)

[4] Blajenkova, O., Kozhevnikov, M. and Motes, M. A.: Object-spatial imagery: A new self-report imagery questionnaire. Applied Cognitive Psychology, 20, pp. 239-263, 2006

[5] Blazhenkova, O. and Kozhevnikov, M.: The new object-spatial-verbal cognitive style model: theory and measurement. Applied Cognitive Psychology, 23, pp. 638-663, 2009

[6] Blazhenkova, O. and Kozhevnikov, M.: Visual-object ability: A new dimension of non-verbal intelligence. Cognition, 117, pp. 276-301, 2010

[7] Borst, G. and Kosslyn, S. M.: Individual differences in spatial mental imagery. The Quarterly Journal of Experimental Psychology, 63, pp. 2031-2050, 2010

[8] Brown, S. W., Renzulli, J. S., Gubbins, E. J., Siegle, D., Zhang, W. and Chen, C.-H.: Assumptions underlying the identification of gifted and talented students. Gifted Children Quarterly, 49, pp. 68-79, 2005

[9] Campos, A.: Gender differences in imagery. Personality and Individual Differences, 59, pp. 107-111, 2014

[10] Carrera, C. C., Saorín Pérez, J. J., de la Torre Cantero, J. and Marrero González, A. M.: Engineers' spatial orientation ability development at the European Space for Higher Education. European Journal of Engineering Education, 36, pp. 505-512, 2011

[11] Carroll, J. B.: Human cognitive abilities: A survey of factor-analytic studies. Cambridge: Cambridge University Press, 1993

[12] Chan, D. W.: Gender differences in spatial ability: Relationship to spatial experience among Chinese gifted students in Hong Kong. Roeper Review, 29, pp. 277-282, 2007

[13] D. Moore-Russo, J. M., Viglietti, M., Chiu, M. and Bateman, S. M.: Teachers' spatial literacy as visualization, reasoning, and communication. Teaching and Teacher Education, 29, pp. 97-109, 2013

[14] Gardner, H. and Hatch, T.: Multiple intelligences go to school: educational implications of the theory of multiple intelligences. Educational Researcher, 18, pp. 4-10, 1989

[15] Garmendia, M., Guisasola, J. and Sierra, E.: First-year engineering students' difficulties in visualization and drawing tasks. European Journal of Engineering Education, 32, pp. 315-323, 2007

[16] Hardiman, G. and Zernich, T.: Some considerations of Piaget's cognitive-structuralist theory and children's artistic development. Studies in Art Education, 21, pp. 12-19, 1980

[17] Hurwitz, A. and Day, M.: Children and Their Art. New York: Harcourt, Brace and Jovanovich, 1994

[18] Johnson, W. and Bouchard, T. J. Jr.: The Structure of Human Intelligence: It is verbal, perceptual, and image rotation (VPR), not fluid and crystallized. Intelligence, 33, pp. 393-416, 2005

[19] Kárpáti, A., Babály, B. and Budai, L.: Authentic assessment of spatial abilities through interactive, online 2D and virtual 3D tasks. International Journal of Arts Education, 13, pp. 94-124, 2014

[20] Kárpáti, A.: Child Art of the Z Generation - A Multimedia Model of Visual Skills Development. In: Benedek, A. and Nyíri, K. (Eds.): How to Do Things With Pictures. Skill, Practice, Performance. Frankfurt/M.: Peter Lang Verlag, pp. 57-74, 2013

[21] Kell, H. J. and Lubinski, D.: Spatial ability: a neglected talent in educational and occupational settings. Roeper Review, 35, pp. 219-230, 2013

[22] Kosslyn, S. M. and Rabin, C. S.: Imagery. In Wilson, R. A. and Keil, F. C. (Eds.): The MIT Encyclopedia of the Cognitive Sciences, Boston: MIT Press. pp. 387-389, 1999

[23] Kosslyn, S. M.: Image and brain: The resolution of the imagery debate. Cambridge, MA: MIT Press, 1994

[24] Kozhevnikov, M., Hegarty, M. and Mayer, R. E.: Revising the visualizer-verbalizer dimension: evidence for two types of visualizers. Cognition and Instruction, 20, pp. 47-77, 2002

[25] Lajoie, S. P.: Individual differences in spatial ability: Developing technologies to increase strategy awareness and skills. Educational Psychologist, 38, pp. 115-125, 2003

[26] Lohman, D. F.: Spatial abilities as traits, processes and knowledge, In R. J. Sternberg (Ed.), Advances in the psychology of human intelligence. Hillsdale, NJ: Erlbaum, pp. 181-248, 1981

[27] Lowenfeld, V.: Creative and Mental Growth. New York: Macmillan Co, 1947

[28] Lubinsky, D.: Spatial ability and STEM: A sleeping giant for talent identification and development. Personality and Individual Differences, 49, pp. 344-351, 2010

[29] Martín-Gutiérrez, J., Luís Saorín, J., Contero, M., Alcañiz, M., Pérez-López, D. C. and Ortega, M.: Design and validation of an augmented book

for spatial abilities development in engineering students. Computers & Graphics, 34, pp. 77-91, 2010

[30] Menenghetti, C., De Beni, R., Gyselinck, V. and Pazzaglia, F.: The joint role of spatial ability and imagery strategy in sustaining the learning of spatial descriptions under spatial interference. Learning and Individual Differences, 24, pp. 32-41, 2013

[31] Miller, D. I. and Halpern, D. F.: Can spatial training improve long-term outcomes for gifted STEM undergraduates? Learning and Individual Differences, 26, pp. 141-152, 2013

[32] Montello, D. R., Lovelace, K. L., Golledge, R. G. and Self, C. M.: Sex-Related Differences and Similarities in Geographic and Environmental Spatial Abilities. In: Annals of the Association of American Geographers. 89, pp. 515-534, 1999

[33] Paivio, A.: The empirical case for dual coding. In: J. C. Yuille (Ed.): Imagery, memory and cognition. Hillsdale, NJ: Lawrence Erlbaum Associates, pp. 307-332, 1983

[34] Potter, C. and van der Merwe, E.: Perception, imagery, visualization and engineering graphics. European Journal of Engineering Education, 28, pp. 117-133, 2003

[35] Séra, L., Kárpáti, A. and Gulyás, J.: A térszemlélet [Spatial ability] Pécs: Comenius Bt., 2006

[36] Sorby, S., Casey, B., Veurink, N. and Dulaney, A.: The role of spatial training in improving spatial and calculus performance engineering students. Learning and Individual Differences, 26, pp. 20-29, 2013

[37] Thomas, P. R. and McKay, J. B.: Cognitive styles and instructional design in university learning. Learning and Individual Differences, 20, pp. 197-202, 2011

[38] Williams, C. B. Gero, J., Lee, Y. S. and Paretti, M.: Exploring spatial reasoning ability and design cognition in undergraduate engineering students. In: Proceedings of the ASME 2010 International Design Engineering Technical Conferences & Computers and Information in Engineering Conference. Montreal: American Society of Mechanical Engineers, pp. 669-676, 2010

[39] Woodfield, R., Jessop, D. and McMillan, L.: Gender differences in undergraduate attendance rates. Studies in Higher Education, 31, pp. 1-22, 2006