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SPATIAL REASONING SKILLS LEVELS OF JUNIOR HIGH SCHOOL STUDENTS

Ortaokul Öğrencilerinin Mekânsal Akıl Yürütme Becerisi Düzeyleri

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Öz

Bu çalışma ortaokul öğrencilerinin mekânsal akıl yürütme becerisi düzeylerini ve mekânsal akıl yürütme becerileri üzerindeki çeşitli değişkenlerin etkisini incelemeyi amaçlamaktadır. Çalışmada tarama araştırması deseni kullanılmıştır. Araştırmanın katılımcılarını 2021-2022 eğitim öğretim yılında Aydın il sınırları içerisinde ortaokulda okumakta olan 486 öğrenci oluşturmuştur. Çalışmanın verileri Mekânsal Akıl Yürütme Testi ile toplanmıştır. Veriler analiz edilirken yüzde, frekans, bağımsız gruplar-testi, tek yönlü varyans analizi, etki büyüklüğü ve korelasyon testleri kullanılmıştır. Verilerin analizi sonucunda, ortaokul öğrencilerinin mekânsal akıl yürütme becerilerinin orta düzeyde olduğu saptanmıştır. Öğrencilerin mekânsal akıl yürütme becerileri puanları üzerinde cinsiyet değişkeninin bir farklılık yaratmadığı gözlenirken; yaş, sınıf, anne eğitim düzeyi, baba eğitim düzeyi, anne mesleği, baba mesleği değişkenlerinin farklılık yarattığı saptanmıştır. Ayrıca mekânsal akıl yürütme testi bileşenleri arasında orta, pozitif yönlü anlamlı bir ilişki olduğu gözlenmiştir.

Anahtar Kelimeler: Mekânsal akıl yürütme; mekânsal görselleştirme; zihinsel döndürme; mekânsal oryantasyon; ortaokul öğrencileri

Abstract

The present study aims to investigate the spatial reasoning levels of junior high school students and the impact of various variables on spatial reasoning. The study was designed with survey methodology. The study participants included 486 junior high students in Aydın province, Turkey, during the 2021-2022 academic year. The study data were collected with the "Spatial Reasoning Test. While analyzing the data, percentage, frequency, independent groups-test, one-way analysis of variance, effect size and correlation tests were used. Data analysis revealed that the spatial reasoning levels of the junior high school students were moderate. Furthermore, it was observed that there was no difference between the spatial reasoning scores of the students based on the gender variable, while there were differences based on age, grade, maternal education level, paternal education level, mother's occupation, and father's occupation variables. It was also observed that there was a moderate, positive and significant correlation between the spatial reasoning test components.

Keywords: Spatial reasoning; spatial visualization; mental rotation; spatial orientation; junior high school

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INTRODUCTION

Humans try to understand and make sense of the space place they live in to recognize the environment better and to improve quality of life. Thus, it could be suggested that space plays a key role in our lives. Because individuals conduct all activities in spaces. It is sometimes even synonymous with the term environment. However, the meaning of the space is broader since it includes the entire three-dimensional human environment on the ground, below the ground and in the space above us (Özgüç and Tümertekin, 1997). Therefore, space is everywhere (Liben, 2002). Thus, it could be beneficial to discuss how human beings perceive space.

The human brain includes extraordinary and complex structures to store, retrieve, and analyze material, spatial and temporal data. In recent years, neuroscientists observed relatively small cerebral regions to determine the reasoning processes conducted in these regions. With the introduction of novel cerebral scanning methods, scholars concluded that certain cerebral regions are devoted to certain types of thought. Certain regions conduct certain thinking activities associated with location and spatial relations (Gersmehl and Gersmehl, 2008). Thus, it could be suggested that spatial reasoning has a biological dimension. However, spatial skills are not only associated with genetic factors but also education. Several educational branches aim the acquisition of these skills by the students. The studies conducted in mathematics education, science, computer and instructional technologies (information technologies and software), pre-school education, education of gifted students, social studies, music and painting (visual arts) aimed to improve spatial skills (Adak Özdemir, 2011; Akbay, 2015; Aykan, 2013; Başaran Şimşek, 2012; Batdal Karaduman, 2012; Bayrak, 2008; Çilingir Altıner, 2018; Demirkaya, 2017; Dursun, 2010; Emül, 2013; Ertekin, 2017; Gök Çolak, 2021; Göktepe, 2013; Gün, 2014; Göktepe Yıldız, 2019; Gökçe, 2022; Harput, 2019; Hetland, 2000; Işık, 2008; İnce, 2012; Kalay, 2015; Karaaslan, 2013; Korkmaz, 2017; Kök , 2012; Kösa, 2011; Mercan, 2019; Olgun, 2016; Orion, Ben – Chaim, & Kali, 1997; Öcal, 2007; Özkayıhan, 2016; Rauscher, Shaw Levine, Wright, Dennis, & Newcomb, 1997; Sarı, 2012 ; Sezgin, 2020; Taşcan, 2019; Tekin, 2007; Turğut, 2007; Turğut, 2010; Uçar Kaplan, 2016; Uygan, 2011; Ünal, 2017; Yetkin Atacan, 2021; Yolcu, 2008; Yurt ve Sünbül, 2012; Yurt and Tünkler, 2016; Yüksel, 2013). Thus, it could be argued that spatial skills are interdisciplinary. It could be beneficial to discuss what the spatial skills on which several educational fields focus.

Spatial skills have been described in several studies. Lohman (1993) described spatial skills as the ability to produce, store, retrieve and transform well-structured visual images, while Turğut (2007) associated the concept with the ability to animate or recreate the objects in three-dimensional space and their components. Linn and Petersen (1985) reported that spatial skills entail the ability to represent, transform, create and recall symbolic and non-linguistic data. Various descriptions of spatial skills were also reflected in the classification of the components of these skills, and the literature is quite diverse in that aspect (Yüksel, 2013). Although studies have been conducted on spatial skills since the 1940s, these studies were unable to clearly determine the factors of spatial skills (Yılmaz, 2009), and the number of spatial skills reported in these studies varied between two and ten (D'Oliveira, 2004). However, it could be suggested that certain elements form the basis of spatial skills. Lohman (1993) argued that several spatial skills emphasize different aspects of the creation, storage, retrieval and transformation of images. In the current study, the spatial reasoning skills of the junior high school students were scrutinized based on mental rotation, spatial orientation and spatial visualization dimensions Because it can be said that these three factors are mostly accepted in the field (Ramful, Lowrie ve Logan 2017). The sub-components could briefly be described as follows: Spatial visualization is the skill associated with the imagination of changing configurations of objects by mentally rotating or folding these objects in two or three dimensions (Mayer and Sims, 1994). In other words, spatial visualization is the skill to mentally rotate, manipulate and bend two – or three-dimensional objects (McGee, 1979). Mental rotation is the skill that entails the rotation of mental representations of two – and three-dimensional objects (Addepalli, 2005). Spatial orientation is the knowledge of one's location and how to navigate the world. In other words, it entails the knowledge and efforts about the relationships between different coordinates in space, especially with reference to one's location (Clements, 1998).

These skills, discussed based on various dimensions, are convenient for the students with respect to various achievements. For example, these skills support academic achievements, while improving the quality of their daily lives. Because the perception of one's location, and the locations of other living beings and inanimate objects is convenient. Thus, spatial skills are required for achievements in several fields (Kösa, 2011). Furthermore, spatial reasoning is required for the acquisition of scientific thinking skills by the students (Clements & Battista, 1992). It could be suggested that it is important for students to acquire spatial skills, which would provide these conveniences. Thus, it was considered beneficial to investigate the spatial reasoning skills of the students. The present study aimed to determine the spatial reasoning levels of the junior high school students and the effects of various variables on their spatial reasoning levels, and the following research problems were determined:

1. What are the spatial reasoning skills levels of junior high school students?
2. Is there a difference between the spatial reasoning skills levels of junior high school students based on gender?
3. Is there a difference between the spatial reasoning skills levels of junior high school students based on age?
4. Is there a difference between the spatial reasoning skills levels of junior high school students based on grade?
5. Is there a difference between the spatial reasoning skills levels of junior high school students based on maternal education level?
6. Is there a difference between the spatial reasoning skills levels of junior high school students based on paternal education level?
7. Is there a difference between the spatial reasoning skills levels of junior high school students based on maternal occupation?
8. Is there a difference between the spatial reasoning skills levels of junior high school students based on paternal occupation?
9. Is there a correlation between the spatial reasoning skills components based on the student responses?

METHOD

The Research Design

The current study was conducted with the survey method. The studies that aim to collect data to determine certain properties of a group are called survey research (Büyüköztürk, Kılıç Çakmak, Akgün, Karadeniz, Demirel, 2020). In these studies, the researcher does not control or interfere with natural and social phenomena. The phenomenon is allowed to continue its course independent of the study (Sönmez and Alacapınar, 2019).

The Study Sample

It was reported that a sample size of 384 is adequate to study a population of 1,000,000 (N) with a 5% margin of error (Cohen, Manion, Morrison, 2000). The present study was conducted in Aydın province, Turkey, and 486 junior high school students participated in the study. Thus, it could be suggested that the sample size was adequate. The study participants were assigned with the convenience sampling method. The convenience sampling method entails the collection of data from an easy to access sample (Büyüköztürk et al., 2020). Furthermore, the study was conducted with only volunteering participants. Certain students refused to answer the test questions. In that case, the study data were collected from students who voluntarily answered the survey questions. Also, since the test was developed for the 11-13 age group, data were not collected from 8th grade students who were older than 13. Data were collected with Google forms. In addition, ethical permission was obtained for this study with the decision no. VII of the Aydın Adnan Menderes University Educational Research Ethics Committee at the meeting dated 29.04.2022 and numbered 2022/07.

Data Collection Instrument

The study data were collected with the "Spatial Reasoning Test" developed by Ramful, Lowrie and Logan (2017) for 11-13 years old junior high school students and adapted to Turkish language by Akkaya Yılmaz, Arıkan and Çetin (2022). The original test included 30 items, and after the Turkish language validity and reliability of the scale was determined, the final scale included 24 itens. The scale includes 3 sub-dimensions: "Mental rotation", "spatial orientation", and "spatial visualization." Mental rotation sub-dimension includes 10 items, spatial orientation sub-dimension includes 9 items, and spatial visualization sub-dimension includes 5 items. One question has 2 options and other questions have 4 options.

Data Analysis

Initially, the normal distribution of the study data set was analyzed with the skewness and kurtosis tests. According to Tabachnick and Fidell, when the skewness and kurtosis are between +1.5 and – 1.5, the data distribution is normal (Cited by Yüner and Özdemir, 2020). The skewness of the data set was calculated as .377 and the kurtosis was calculated as – .632. Thus, it was determined that the data exhibited normal distribution. Furthermore, the sub-dimension data were also distributed normally. Thus, the data analysis was conducted with parametric tests. Frequencies, percentages, and arithmetic means were determined, and eta-square, independent groups t-test, one-way ANOVA and simple correlation tests were employed in data analysis.

FINDINGS

The First Research Problem

Table 1. Spatial reasoning levels of junior high school students

		Low	Moderate	High	$\bar{X}$	Ss
Spatial reasoning levels	Range	0-8	9-16	17-24	11.73	4.76
	F	142	257	87		
	%	29.21	52.88	17.90		

As seen in Table 1, in the spatial reasoning test, a score between 0 and 8 is low, 9 and 16 is moderate, and 17 and 24 is high. Thus, %29.21 (142) of junior high school students exhibited low, %52.88 (257) exhibited moderate, and %17.90 (87) exhibited high spatial reasoning skills. The mean student score was 11.73. Thus, it was observed that the spatial reasoning levels of junior high school students were moderate.

The Second Research Problem

Table 2. The difference between the spatial reasoning levels of junior high school students based on gender

Gender	N	$\bar{X}$	Ss	t	p
Male	276	11.62	4.86	-.59	.557
Female	210	11.88	4.63		

Based on the t-test results presented in Table 2, there was no significant difference between the spatial reasoning scores of male and female participants [t(484)= – .588; p>05]. The mean score of the male participants was 11.62, and the mean score of the female participants was 11.88. Thus, it was concluded that spatial reasoning scores of both genders were similar.

The Third Research Problem

Table 3a. Descriptive age findings

Age	N	X̄	Ss
11	163	10.75	4.58
12	183	11.57	4.46
13	140	13.07	5.07
Total	486	11.73	4.76

Table 3b. One-way ANOVA results on the variation of reasoning skills based on age variable

Source of the variance	KT	sd	KO	F	p	Tamhane difference	η2
Inter-group	411.465	2	205.733	9.385	.000	11-13 age; 12-13 age	.037
Intra-group	10588.224	483	21.922				
Total	10999.689	485					

There was a significant difference between the spatial reasoning test scores of the students based on the age variable [F(2-483)= 9,385; p<0.05]. Tamhane comparison test was conducted to determine the age groups between which there was a significant difference. The results of the Tamhane comparison test revealed that the spatial reasoning mean score of the 13-year-old students (X̄=13.07) was higher than that of the 11-year-olds (X̄=10.75) and 12-year-olds (X̄=11.57). The effect size of the age variable was calculated as .037.

The Fourth Research Problem

Table 4a. Descriptive grade findings

Grade	N	X̄	Ss
5th	106	10.13	4.68
6th	189	11.33	4.12
7th	109	12.70	5.23
8th	82	13.44	4.86
Total	486	11.73	4.76

Table 4b. One-way ANOVA results on the variation of reasoning scores of the students based on grade variable

Source of the variance	KT	SD	KO	F	p	Tamhane Difference	η2
Inter-group	642.673	3	214.224	9.970	.000	5-7 and 8; 6-8	.058
Intra-group	10357.017	482	21.488				
Total	10999.689	485					

There was a significant difference between the spatial reasoning scores of the students based on the grade variable [F(3-482)= 9.970; p<0.05]. Tamhane comparison test was conducted to determine the grades between which there was a significant difference. Tamhane comparison test findings demonstrated that 8th grade students (X̄=13.44) were more successful than the 6th grade (X̄=11.33) and 5th grade (X̄=10.13); and 7th grade students (X̄ =12.70) were more successful than 5th grade students (X̄ =10.13.). The effect size of the grade variable was.058.

The Fifth Research Problem

Table 5a. Descriptive maternal education level findings

Education level	N	X̄	Ss
Primary school	160	9.97	4.55
Junior high school	75	10.55	3.14
High school	126	12.12	4.65
College	116	14.29	4.79
Graduate	9	15.67	4.61
Total	486	11.73	4.76

Table 5b. One-way ANOVA results on the variation of reasoning scores of the students based on maternal education level

Source of the variance	KT	sd	KO	F	p	Tamhane Difference	η2
Inter-group	1466.605	4	366.651	18.500	.000	College-primary, junior high and high; junior high-high	.133
Intra-group	9533.084	481	19.819				
Total	10999.689	485					

There was a significant difference between the spatial reasoning scores of the students based on the maternal education level variable [F(4-481)= 18,500; p< 0.05]. Tamhane comparison test was conducted to determine the education levels between which there was a significant difference. Tamhane comparison test findings revealed that the spatial reasoning mean score of the children whose mothers were college graduates (X̄=14.29) was higher than those of the children whose mothers were primary school (X̄ =9.97), secondary school (X̄ =10.55) and high school (X̄=12.12) graduates. The effect size of the maternal education level variable was .133.

The Sixth Research Problem

Table 6a. Descriptive paternal education level findings

Education level	N	X̄	Ss
Primary school	138	10.00	4.07
Junior high school	84	10.24	4.53
High school	102	11.54	4.41
College	143	13.85	4.66
Graduate	19	15.95	4.71
Total	486	11.73	4.76

Table 6b. One-way ANOVA results on the variation of reasoning scores of the students based on paternal education level

Source of the variance	KT	sd	KO	F	p	Scheffe difference	η2
Inter-group	1578.553	4	394.638	20.148	.000	College-primary, junior high and high school; graduate-primary, junior high and high school	.144
Intra-group	9421.137	481	19.587				
Total	10999.689	485					

There was a significant difference between the spatial reasoning scores of the students based on the paternal education level variable [F(4-481)=20.148; p<0.05]. Scheffe comparison test was conducted to determine the education levels between which there was a significant difference. Scheffe comparison test results revealed the mean spatial reasoning score of the children

whose fathers were college graduates ($\bar{X}$ =13.85) was higher than those of the spatial reasoning scores of the children whose fathers graduated from primary ($\bar{X}$ =10.00), junior high ($\bar{X}$ =10.24) and high school ($\bar{X}$ =11.54) graduates. Also, the spatial reasoning mean score of the children whose father had a graduate degree ($\bar{X}$ =15.95) was higher than those of the students whose father was primary ($\bar{X}$=10.00), junior high ($\bar{X}$ =10.24) and high school ($\bar{X}$=11.54) graduates. The effect size of the paternal education level variable was .144.

The Seventh Research Problem

Table 7a. Descriptive maternal occupation findings

Occupation	N	X̄	Ss
Unemployed	285	11.13	4.72
Small business owner	18	12.78	4.71
Public servant	72	14.36	4.13
self-employed	43	10.67	5.35
Worker	67	11.86	4.30
Total	485	11.73	4.77

Table 7b. One-way ANOVA results on the variation of reasoning scores of the students based on maternal occupation

Source of the variance	KT	sd	KO	F	p	Scheffe difference	η2
Inter-group	668.800	4	167.200	7.771	.000	Public servant-unemployed, self-employedand worker	.061
Intra-group	10327.888	480	21.516				
Total	10996.689	484					

There was a significant difference between the spatial reasoning test scores of the students based on the maternal occupation variable [F(4-480)=7.771; p<0.05]. Scheffe comparison test was conducted to determine the occupations between which there was a significant difference. Scheffe comparison test demonstrated that the mean score of the children whose mother was a public servant ($\bar{X}$=14.36) was higher than those of the children whose mother was unemployed ($\bar{X}$=11.13), self-employed ($\bar{X}$=10.67), and worker ($\bar{X}$=11.86). The effect size of the maternal occupation variable was .061.

The Eighth Research Problem

Table 8a. Descriptive paternal occupation findings

Occupation	N	X̄	Ss
Unemployed	38	10.55	4.75
Small business owner	68	11.74	4.39
Public servant	117	14.03	4.65
self-employed	104	11.58	4.75
Worker	159	10.42	4.43
Total	486	11.73	4.76

Table 8b. One-way ANOVA results on the variation of reasoning scores of the students based on paternal occupation

Source of the variance	KT	sd	KO	F	p	Scheffe difference	η2
Inter-group	943.984	4	235.996	11.289	.000	Public servant-small business owner, unemployed, self-employed and worker	.086
Intra-group	10055.705	481	20.906				
Total	10999.689	485					

There was a significant difference between the spatial reasoning test scores of the students based on the paternal occupation variable [F(4-481)= 11.289; p<.05]. Scheffe comparison test was conducted to determine the occupations between which there was a significant difference. Scheffe comparison test demonstrated that the mean score of the children whose father was a public servant ($\bar{X}$=14.03) was higher than those of the children whose father was unemployed ($\bar{X}$=10.55), self-employed ($\bar{x}$=11.58), and worker ($\bar{x}$=10.42). The effect size of the paternal occupation variable was .086.

The Ninth Research Problem

Table 9: Correlations between the spatial reasoning components

		Mental rotation	Spatial visualization	Spatial orientation
Mental rotation	r	1	.49**	.57**
	p		.000	.000
	N	486	486	486
Spatial visualization	r	.49**	1	.42**
	p	.000		.000
	N	486	486	486
Spatial orientation	r	.57**	.42**	1
	p	.000	.000	
	N	486	486	486
**p<.05				

Based on the correlation coefficients presented in the table, there was a moderate positive correlation between mental rotation and spatial visualization (r=.49; p<.05), a moderate positive correlation between mental rotation and spatial orientation (r=.57; p<.05), and a moderate positive correlation between spatial orientation and spatial visualization (r=.42; p<.05).

CONCLUSION AND DISCUSSION

The study findings demonstrated that the spatial reasoning levels of the junior high school students were moderate. Turğut (2007) reported that the spatial skills of the junior high school students were quite low.

In the study, it was determined that the spatial reasoning scores of male and female students were similar. Although certain studies reported similar findings (Ertekin and İrioğlu 2011; Lowrie, Logan and Ramful 2016; Seng and Chan 2000; Shavalier 1999; Turğut 2007), others reported contradicting results (Geiringer and Hyde 1976; Guay and McDaniel 1977; Ben-Chaim, Lappan and Houang 1988; Mazman and Altun 2013; Joh 2016). Based on the current study and the literature, it could be suggested that gender did not lead to a significant difference.

It was determined that there were significant differences between the spatial reasoning scores of the students based on age and grade. As the students got older and their grade increased, their mean scores increased as well. It could be suggested that the increase in the cognitive levels of children with their age was effective on this development. Because as they grow old, children are transformed into the stage of abstract operations. Also, the increase in grade and age improves the employment of spatial skills in the class. In other words, it could be suggested that the increase in grade has a positive effect. The study conducted by Türk (2016) supported these findings. In general, it could be concluded that the biological age of the students and their education positively affected their spatial reasoning skills. It was reported that both spatial skill education programs and taking various courses in the program improved spatial skills (Adak Özdemir 2011; Battista, Wheatley and Talsma 1982; Ben-Chaim 1982; Ben-Chaim, Lappan and Houang 1988; Bulut and Köroğlu 2000; Denier and Serbin 1978; Ertekin and İrioğlu 2011; Gazit, Yair and Chen 2005; July 2001; Kayhan 2005; ; Kök 2012; Kösa 2011; Olkun 2003; Pallrand and Seeber

1984; Smyser 1994; Sorby 2009; Stancil and Melaer 1991; Tillotson 1985 ; Turgut 2007; Turgut 2010; Werthessen 1999; Yılmaz 2012; Yolcu 2008).

Other present study findings demonstrated that maternal and paternal education level had a significant effect on the spatial reasoning scores of the children. A study by Ertekin and İrioğlu (2011) supported these findings. In the study, it was observed that as the parental education level increased, the spatial reasoning scores of the children increased as well. It was also observed that the effect size of these variables was significant. Thus, it could be suggested that educated families are more likely to support the education of their children since they have attended a higher number of courses associated with spatial skills. It could also be suggested that the awareness of the educated parents about the general education of their children was higher.

The study findings also revealed that maternal and paternal occupation were effective on the spatial reasoning levels of the children. It was observed that the spatial reasoning scores of the children of the civil servant parents were higher than those of the children of other occupational groups. These findings were consistent with the present study findings on parental education levels. Because it could be suggested that parents with undergraduate and graduate degrees are generally employed by the state in Turkey. In a previous study, a positive and significant correlation was determined between the spatial experiences of child participants and parental occupation. In other words, the participants whose maternal occupation required the employment of spatial visualization had higher spatial experiences in childhood when compared to the participants whose paternal occupation did not require spatial visualization (Rodrigue Robichaux 2000). In Turkey, it would be difficult to argue that the occupations of civil servant parents required spatial experiences. However, it could be suggested that parents with higher education would be more aware in providing spatial experiences for their children.

Finally, the correlations between the spatial reasoning components were investigated in the study. It was determined that there were positive, moderate and significant correlations between all sub-dimensions (mental rotation, spatial visualization, spatial orientation). Since these components support one another, it could be suggested that the correlations between these variables were significant.

SUGGESTIONS

Based on the study findings, the following could be recommended: In the current study, it was observed that there were differences based on the variables across the subgroups, and it could be suggested that these variables were logically associated. Thus, structural equation modeling can be established. Thus, more holistic findings could contribute to the literature even further.

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