MENTAL ROTATION TEST PERFORMANCE OF UNIVERSITY STUDENTS: EYE TRACKING STUDY

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ABSTRACT

MENTAL ROTATION TEST PERFORMANCE OF UNIVERSITY STUDENTS: EYE TRACKING STUDY

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Mental rotation is defined as the ability that to mentally transform two-or three-dimensional objects. (Taragin etc., 2019). It is identified as the most important spatial ability that varies regarding individual differences. (Rafi et al. 2005; Turos and Ervin 2000). Gender differences and different academic programs affect mental rotation test performance. Thus, it is significant to understand whether students who have different gender and are enrolled in different academic programs perform differently in mental rotation tests (MRTs). In the literature, numerous studies have documented that gender differences affect mental rotation test performance, but there are. Few studies, which have documented the impact of different academic programs on mental rotation test performance. In investigating the mental rotation test performance of students, there is a need to investigate the effect of being enrolled in different academic programs on performance, as well as investigating the gender difference. Sixty-four university students aged between 18-27 who enrolled in different academic programs at Middle East Technical University completed the MRT using the identical test procedures throughout the entire study.

As a result of mental rotation test performance on gender differences in easy level MRT, male participants' test performance is more positive than female participants' test performance while female participants' test performance is more positive than male participants' in difficult level MRT. In mental rotation test performance on different academic backgrounds both easy and difficult level MRT, science group participants' test performance is more positive than humanities major group participants' test performance.

Keywords: Mental Rotation, spatial ability, eye tracking

ÖZ

ÜNİVERSİTE ÖĞRENCİLERİNDE ZİHİNSEL DÖNDÜRME TESTİ SÜRECİNİN İNCELENMESİ: GÖZ TAKİP ÇALIŞMASI

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Zihinsel döndürme, zihinsel olarak iki veya üç boyutlu nesnelere dönüştürülen bir yetenek olarak tanımlanır. (Taragin vb., 2019). Zihinsel döndürme, önemli bireysel farklılıklar yaratan en önemli uzamsal yetenek olarak tanımlanmaktadır. (Rafi ve diğerleri 2005; Turos ve Ervin 2000). Cinsiyet farklılıkları ve farklı akademik programlar zihinsel döndürme testi performansını etkiler. Bu nedenle, farklı cinsiyetteki ve farklı akademik programlara devam eden öğrencilerin farklı zihinsel döndürme testi performansları gerçekleştirip gerçekleştirmediklerini anlamak önemlidir. Literatürde çok sayıda çalışma, cinsiyet farklılıklarının zihinsel döndürme testi performansını etkilediğini belgelemiştir. Öğrencilerin zihinsel döndürme testi performanslarının araştırılmasında, cinsiyet farkının araştırılmasının yanında farklı akademik programlara kayıtlı olmanın performansa etkisinin araştırılmasına da ihtiyaç duyulmaktadır. Orta Doğu Teknik Üniversitesi'nden 18-27 yaşları arasındaki 64 üniversite öğrencisi tüm çalışma boyunca aynı test prosedürlerini kullanarak testi tamamladı. Cinsiyet farklılıklarına yönelik kolay seviye zihinsel döndürme testi performansı sonucunda erkek katılımcıların test performansı kadın katılımcılara göre daha pozitif iken, zor seviye test için kadın katılımcıların test performansı erkek katılımcılara göre daha pozitiftir. Hem kolay hem de zor seviye test sonuçlarına göre, farklı akademik geçmişlerdeki zihinsel döndürme testi performansında, bilim grubu

katılımcılarının test performansı, beşeri bilimler ana grup katılımcılarının test performansından daha olumludur.

Anahtar Kelimeler: Zihinsel Döndürme Testi, Uzamsal Yetenek, Göz Hareketleri Takip

To my family

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This chapter presents the background of the study, problem statement based on this background, the purpose of the study and research questions, the significance of the study, definitions and abbreviations used in this study, and the organization of the study.

1.2 Background of the Study

According to Lohman (1996), spatial ability is described as “the ability to generate, retain, retrieve and transform well-structured visual images” (p. 112). Voyer and Doyle (2012) emphasized that spatial ability is the ability to perceive, transform and modify one’s internal visual world. A wide range of activities includes spatial activity and spatial activity is important to every day. However, individual differences play an important role in spatial abilities. Also, mental rotation test performance produces individual differences. (Voyer, et. al. 2020). Many studies regarding mental rotation are concerned with gender differences. (Maeda & Yoon, 2013; Yurt & Tünkler, 2016; Keehner et al., 2008). There is a general agreement on men can perform better than women in activities involving spatial abilities. (Voyer, et. al. 2020). In the literature, numerous studies were conducted to examine the effects of gender differences on MRT prformance. Voyer,performance2020) stated that it is generally accepted that some researchers argued gender differences might be related to “one’s level of spatial ability” in MRT performance. (p. 2). In contrast to this general agreement, gender differences should not be shown as the only difference in spatial ability and some other factors that affect the mental rotation test performance. (Voyer, et. al. 2020). Sociocultural, biological items and measurement

variables can have some influence on mental rotation test performance. Brain structure (Jordan, et. al. 2002) and hormone levels (Courvoisier et al., 2013) are the biological factors that affect mental rotation test performance. Sociocultural factors contain childhood activities and gender role identification. (Voyer, et. al. 2020). Item type which is related to measurement variables is another factor for mental rotation test performance. (Voyer, et al., 2020). Unlike the current literature, the present study will focus on students' mental rotation performance tests who enrolled in different academic programs as well as having different gender.

1.3 Problem Statement

In the literature, many studies have documented that gender differences affect mental rotation test performance. Gender differences affect the mental rotation test performance, marked by a large male performance advantage. (Toth & Campbell, 2019). Voyer (2011) emphasized that women perform cautiously and slowly during the mental rotation test whereas men work faster. These performance factors lead to gender differences in mental rotation. (Voyer, 2011). Individual differences are common in spatial abilities. In the literature, it is generally accepted that men can perform better than women on spatial ability tasks. (Voyer & Doyle, 2012). However, while research has examined the mental rotation test performance between gender differences, few studies have documented the impact of different academic programs on mental rotation test performance. Accordingly, a better understanding of the mental rotation test performance on different academic performances and gender differences particular is needed. Therefore, the purpose of the study is to examine the mental rotation test performance of students who have different gender and academic program regarding task complexity.

1.4 Purpose of the Study

The purpose of this study is to examine college students' mental rotation abilities and whether gender and different academic programs have an effect on mental

rotation test performances at different difficulty levels. In this study, eye movement metrics are measured in aspects of time to first fixation, fixation count, and fixation duration

1.5 Research Question

The following research questions were investigated in the present study.

1. Is there a difference between the mental rotation test performance of male and female students depending on the difficulty level of mental rotation test?
2. Is there a difference between the mental rotation test performance of students enrolled in different academic programs considering the difficulty level of the mental rotation test?
3. Do the metrics of eye movements differ according to different levels of mental rotation tests?

1.6 Definition of Terms

The following definitions are identified in the scope of this study.

Mental rotation is the ability to rotate 3D objects while imagining these objects on the x y z axes mentally (Rafi et al. 2005; Turos and Ervin 2000).

The cognitive task is one of the MRT and the cognitive task involves 3D objects which humans imagine mentally (Hyde, 2005; Voyer et. al, 2020).

Spatial ability is the ability to perceive, transform and modify one's internal visual world. (Voyer & Doyle 2012).

Eye tracking is a technology that tracks the eye movements of a user.

Fixation duration is defined as the amount of attention. (Tsai et al. 2012)

Fixation count is the number of fixations that are identified within a specific period.

Time to the first fixation is defined as the amount of time from the start of a task until a particular AOI is fixated for the first time.

1.7 Brief overview of the Thesis

According to Lohman (1996) spatial ability is "the ability to generate, retain, retrieve and transform well-structured visual images" (p. 112). Mental rotation requires retaining and transforming visual images and it is described as spatial ability. (Peters et al., 2006). The goal of this study is to assess college students' mental rotation test performance according to task difficulty in terms of different academic programs and gender. To reach this goal, this study was conducted with an experimental method. An experiment is designed to monitor participants' performance during cognitive problem-solving. Gender differences and different academic programs affect mental rotation test performance. Thus, it is significant to understand whether students who have different gender and are enrolled in different academic programs perform different mental rotation test performance (MRT). In this study, participants' performance was monitored with an eye-tracker device, and data were collected with an eye-tracker device. Also, this study includes 16 MRT questions both easy level and difficult level MRT. Response alternatives consisted of block image perspective rotated in space. Two of the response alternatives were correct alternatives whereas other response alternatives were not correct alternatives. Participants decided on two correct answers. When participants selected the correct answer, they had 1 point and they did not have lower points when selecting wrong answers. There was no time-restricted. college students from Middle East Technical University, between the ages 18-27 completed the MRT, using identical test procedures in all studies. Individual random sampling methods were used. The present study investigated the effects of gender differences and different academic programs and task difficulty on mental rotation performance as a cognitive task. Mental rotation task performance of college students was explained with task difficulty. Moreover, the effects of gender and different academic programs on mental rotation test performance. Middle East Technical University students were handled as constant by sampling method. Gender

and different academic programs were independent variables and mental rotation test performance was the dependent variable. They were distributed homogenously in groups in terms of number. This study is generalized to students from the science department and humanities departments. Before the experiment, a pilot study was conducted with 6 college students to control the validity of the experiment design. In the first group, participants answered the 16 complex mental rotation test questions and participants will be from science major departments. In the second group, 16 simple mental rotation test questions were given to participants and this group was of students enrolled science major department. In the third group, students answered the 16 complex mental rotation test questions and they were from students enrolled in humanities departments, not a science major dartment. In the final group, 16 simple mental rotation test questions were presented to participants from humanities departments.

CHAPTER 2

LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Introduction

According to Lohman (1996), spatial ability defines as “the ability to generate, retain, retrieve and transform well-structured visual images” (p. 112). Spatial ability is described as a skill to comprehend mental images through space. (Terlecki & Newcombe, 2005; (Ifenthaler, 2013). Shephard and Metzler (1971) state that people can imagine two-dimensional pictures as three-dimensional objects, and that this process requires cognitive load. Spatial ability includes cognition properties such as location, distance, direction, shape, and movement. (Ifenthaler, 2013)). Spatial abilities are engaged in main activities such as when doing sports, calculating mathematical problems, and observing the environment. (Voyer & Doyle, 2012). Spatial ability investigates strong individual differences in mental rotation tasks. (Ifenthaler, 2013).

Individual differences play important role in spatial abilities. Previous studies selected mental rotation tasks to measure individual differences in spatial ability. (Terlecki & Newcombe 2005.) Mental rotation test performance produces individual differences. (Voyer, et. al. 2020). Mental rotation is one of the spatial abilities which requires retaining and transforming visual images.

2.1.2 Gender Differences and Different Academic Programs in Mental Rotation Test

Mental rotation is one of the spatial abilities which requires retaining and transforming visual images. In the literature, there are several studies indicating that individual differences have important effects on spatial activities. (Voyer & Doyle, 2012) and individual differences play an important role in mental rotation test performance. (Hyde, 2005; Voyer et al. 2020). Individual differences affect mental rotation test performance, like so many cognitive skills. (Hyde, 2005; Voyer et. al, 2020). Considering individual differences in mental rotation test performance is the crucial point. Gender differences might be one of the important individual differences in mental rotation test performance. (Voyer et. al, 2020). There is a general agreement about achievement that men have better performance than women in activities related to spatial abilities. (Voyer & Doyle, 2012.) Kaltner and Jansen (2018) stated that gender differences in MRT performance are established, with men outperforming women. However, Voyer, et, al. (2020) stated that it is generally accepted that some researchers argued gender differences might be related to "one's level of spatial ability" in MRT performance. (p. 2). In contrast to this general agreement, gender differences should not be shown as the only difference in spatial ability and some subjects affect the mental rotation test performance. (Voyer, et. al. 2020). Sociocultural, biological factors and measurement variables can have some influence on mental rotation test performance. Brain structure (Jordan, et. al. 2002) and hormone levels (Courvoisier et al., 2013; Peters et al., 2007) are the biological factors that affect mental rotation test performance. Sociocultural factors contain childhood activities and gender role identification. (Voyer, et. al. 2020). Item type which is related to measurement variables is another factor for mental rotation test performance. (Voyer, et al., 2020).

In contrast to this general agreement, gender differences should not be shown as the only difference in spatial ability and some subjects affect the mental rotation test performance. (Voyer, et. al. 2020). Moreover, students enrolled in different academic programs perform differently in mental rotation test performance (Peters, et al.,

2006). Chen and Yang, (2014) stated that spatial ability is usually regarded to be related to science learning. Spatial thinking is an important part of the science domain (Chen & Yang, 2014). Adolescents who select professional careers in the science, mathematics, and engineering domains perform better on tasks in spatial abilities. (Wai, Lubinski & Benbow, 2009). However, Voyer et. al. (1995) and Linn and Peterson (1985) did not agree that different academic programs have an important effect on MRT performance. In the literature, there is not enough research on eye trackers to indicate mental rotation test performance.

2.1.3 Eye Movements in the Mental Rotation Test

Chen and Yang (2013) stated that the eye-tracking method is a technique that records online cognitive processes. Temporal changes in visual attention were revealed with the eye-tracking method. The eye-tracking method is applied in a research field that contains reading, problem-solving, human-computer interaction, and information processing. (Tsai et. all. 2012). Eye movement data are collected with the eye tracking method. Eye movement data is used to explain cognitive processes. According to De'Sperati (2003) eye movements include the amount of information which reaction time and they follow both in time and space the evolution of mental events. The fundamental parameters in eye movements are data fixation and saccades. In the literature, there were eye tracking studies related to mental rotation tests. Baran et al. 2007 studied the process of solving tangram-based geometry problems that contain mental rotation ability with the eye tracking method on the computer screen. In this study, people selected different strategies when solving tangram-based geometry problems when eye movement data which include fixation duration, fixation count, task completion duration, and transition were analyzed. In another study, Khooshabeh and Hegarty (2010) investigated mental rotation test performance with the eye tracking method. They analyze the eye movement data which contains areas of interest (AIO). They circumscribed each figure and compare fixations. As a result of this analysis, people used different strategies while solving the mental rotation test. Eye movement metrics which include fixation duration,

fixation count, etc. can be used to analyze the cognitive process and different strategies of individuals. However, some researchers think that there is no sufficient study that investigates mental rotation ability with eye movement metrics.

2.2 Summary

Mental rotation is one of the major spatial abilities and mental rotation produces individual differences. In the literature, many studies of mental rotation tasto measure individual differences in spatial ability. Also, gender differences are one of the most important individual differences in a mental rotation test performance. (Voyer et. al, 2020). Many researchers argue that men outperform women in mental rotation tasks. In contrast to general agreement, Voyer, et. al. (2002) stated that there are only gender differences affecting mental rotation abilities but also sociocultural factors which include childhood activities and gender role identification, biological factors such as brain structure (Jordan, et. al. 2002), hormone levels (Courvoisier et al., 2013; Peters et al., 2007) and measurement variables which are related to item type should affect mental rotation ability. In addition to that, students enrolled in different academic programs perform differently in mental rotation test performance (Peters, et al., 2006). Wai, Lubinski, and Benbow (2009) argued that adolescents who select professional careers in the science, mathematics, and engineering domains perform better on mental rotation tasks. However, there is no common thought about that. Voyer et. al. (1995) and Linn and Peterson (1985) did not agree that different academic programs have an important effect on MRT performance.

The eye-tracking method is used to record the online cognitive process by revealing temporal changes in visual attention. (Chen & Yang, 2013). Eye movement data which include fixations and saccades explain the cognitive process. In the literature, there were eye tracking studies related to mental rotation tests. According to Baran et. al. (2007) study, people selected different strategies when solving tangram-based geometry problems when eye movement data which include fixation duration, fixation count, task completion duration, and transition were analyzed. Some

cognitive processes can be analyzed with eye movement metrics and an individual's cognitive profile can be determined with mental rotation ability.

CHAPTER 3

METHODOLOGY

3.1 Research Design

This study aims to disclose the effects of gender and different academic program role on college students' mental rotation test performance for different levels of mental rotation tests. In this study, eye movement metrics which include time to first fixation, fixation count, and fixation duration are obtained. This experiment was conducted with an eye tracker to evaluate participants' performance through the mental rotation test. Test questions were classified into two categories to ensure task difficulty. These categories include easy and difficult test questions. Before the experiment, a pilot study was conducted with 6 college students. All participants were instructed about what they did during the experiment. In the experiment, participants answered mental rotation test questions. Volunteer participants were between 17 and 27 ages, and the participants' academic program and gender ratio were balanced. This study was conducted in an isolated room with minimal distraction. The participants sat in an adjustable chair. This study follows the experimental method and this study is an experimental quantitative study. An experiment is designed to monitor participants' performance during cognitive problem solving.

Quantitative data were gathered in person. The first step in gathering data is asking participants for filling out the questionnaire. The second step is to experiment in front of the monitor eye tracker.

3.2 Description of the Sample

A total of 64 Middle East Technical University students voluntarily participated in the study, of whom 33 were science-related majors while 31 were humanities-related

majors. Participants' academic program and gender ratio were balanced. Participants were recruited from classes at METU to ensure a common academic background between participants. Participants were excluded from participating if they suffer from any neuromuscular and neurological disorders. All participants had a normal vision to collect correct data. All of them were healthy adults between 17 and 27 years of age. In this study, an individual random sample method was used to decide the group participants. Subjects were divided into four groups. The first group had 15 participants in technical and Mathematics related departments which include the departments of mathematics, mechanical engineering, physics, computer engineering, computer, and educational technology and they answered the easy mental rotation test questions which consist of 16 questions. The second group was 15 participants from technical and Mathematics related departments which include the department of statistics, electric and electronic engineering, chemical and physics Computer Education and Instructional Technology, Elementary Science Education, Elementary Mathematics Education, Chemistry Education, Physics Education, Mathematics Education and they answered the difficult 16 MRT questions. The third group had 15 participants from technical and Mathematics related departments which are the department of foreign language education, early childhood education, and history and they answered the easy 16 MRT questions. The final group had 15 participants from humanities majors not in technical and Mathematics related departments which consist of the department of foreign language education, early childhood education, and history and they answered the difficult MRT questions. Students' participation was voluntary. The participant who did not want to continue the MRT was excluded from the experiment.

3.3 Description of the instruments used (including scoring procedures)

The instruments consisted of a mental rotation test, an eye tracking device.

3.3.1 Mental Rotation Test

In this study, Peters et al. (1995) revised the Mental Rotation Test was used and figures were from Peters and Battista's (2008) stimulus library as shown in **Figure 3-1**. In this multiple-choice test, there were 16 items and each item include a three-dimensional block image. The stimulus which placed on the left was the target and four response alternatives took place to the right. Response alternatives consisted of block image perspective rotated in space. Two of the response alternatives were correct alternatives whereas other response alternatives were not correct alternatives; i.e. distractors. Participants decided which two of these alternatives on the right of the target were rotated versions of the target stimulus. When participants selected the correct answer, they had 1 point and there weren't lower points when selecting wrong answers. There was no time restriction.

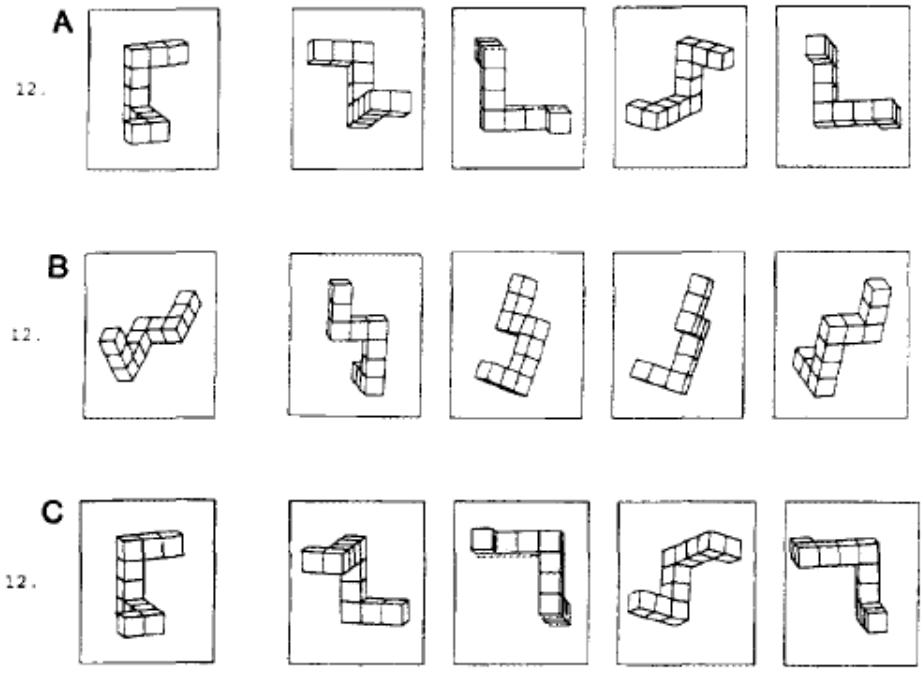

Figure 3-1 Sample question of mental rotation test

3.3.2 Eye Tracking Method

Eye tracking is a method which examine human visual attention. (Tsai, Hou and etc., 2011). The eye tracking technique are applied in many research field which include

problem solving. (Hegarty, Mayer & Green, 1992). This study is interested in how participants solve mental rotation test. In this study, eye movements metrics data were recorded with TOBII x2-60 eye tracking equipment. TOBII x2-60 eye tracking equipment follows eye movement, receives the reflections from the eyes and reveal the temporal changes in visual attention thus reflections are calculated. Participants solved mental rotation test on a computer with eye tracker device. Before the start of mental rotation test, five-point calibration test was performed in the eye tracker as shown as in the **Figure 3-2**. Participants were informed to follow a dot which moved on the screen during the calibration process. Eye movements metrics data which include time to first fixation, fixation duration and fixation count was obtained from eye tracker equipment. time to first fixation, fixation duration and fixation count are most used eye tracking metrics used in research and study as shown as in the **Figure 3-3**.

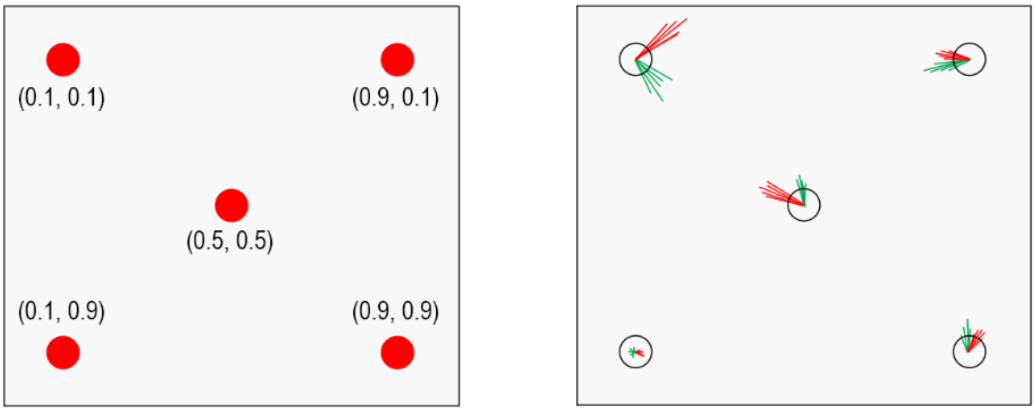

Figure 3-2 Five-point calibration test

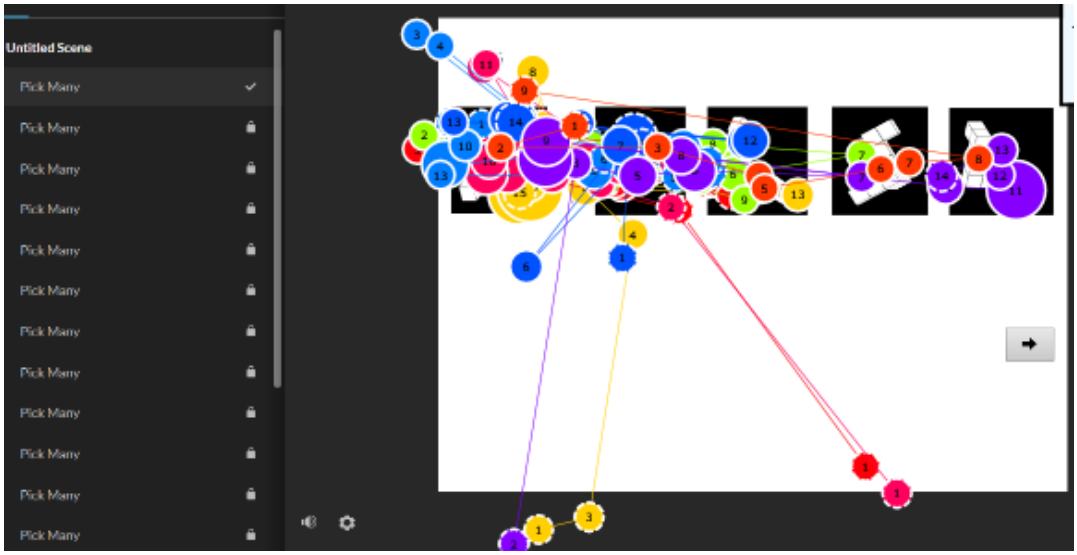

Figure 3-3 Eye movement metrics data

3.4 Explanation of the Procedures Followed (what, when, where, and how of the study)

The study was conducted in an isolated room where monitor eye tracker is arranged in a room with minimal distraction. The experimenter read aloud the instructions about the experiment. Every experiment session approximately took an hour. Participants were instructed to find two correct responses from alternative responses with figures identical to the target stimulus. Participants were tested within a single session during approximately 45 minutes. Data were collected with eye-tracker device in the experiment. Each participation was seated at a different computer and they worked alone. Each student answered the mental rotation test which have 16 multiple questions. When participants give true answer for each question, they had "1" points for correct alternatives whereas incorrect answers did not lose points. Thus, the maximum score are 16.

3.5 Discussion of Internal Validity

History can be a threat for collecting data in experiment process. Because of Covid-19, participants did not want to participate in experiment. Well sterilization of the

experimental environment and informing the participation about this can eliminate the thread of history. Another situation which can create threat for experiment is mortality. When participants move their body or their head, validity data was ruined and data was not correct data for experiment. Participants were informed that they did not move their body and head and eye movements were important for this experiment. This instruction can prevent to create mortality thread.

3.6 Discussion of External Validity

This study is generalized to students from science department and humanities departments. Also, participants have similar academic background and spatial intellection with sample group. The selected sample group represents all departments in METU and these groups represent the students in science and humanities-related departments in Turkey. Sample groups were selected randomly.

CHAPTER 4

RESULTS

Mental rotation test performance and eye movements metrics were computed for different levels of mental rotation tests which include easy and difficult levels. Three separate data analyses were computed. In analysis I, mental rotation test performance results was analyzed on both gender differences and different academic backgrounds in easy and difficult level MRT. In analysis II, eye movement metrics were computed on both gender differences and different academic backgrounds in easy and difficult level MRT. In analysis III, mental rotation test performance and eye metrics data were synthesized through both gender differences and different academic backgrounds in easy and difficult level MRT.

4.1 Mental Rotation Test Performance Result

4.1.1 Mental Rotation Test Performance on gender differences in Easy Level Mental Rotation Test

The mental rotation test results of male and female participants studying in science department were analyzed Whitney-U Test and result are presented in **Table 4-1** for easy level MRT. 15 students partcipanted in easy-level mental rotation test from science group. Among 15 students, 7 students are male, 8 students are female.

Table 4-1 Easy level MRT performance of male and female participants studying in science department

	Gender	N	$\bar{X}$	U	p
Score	Male	7	8.36	25.500	.769
	Female	8	7.69		

Mann Whitney U Test was conducted to compare test performance of female and male student from science gruop in easy level mental rotation test. When the MRT results of the participants from science departments were analyzed it is indicated that the averages of male students ($\bar{X}$ = 8.36) are higher than the averages of female students ($\bar{X}$ = 7.69). There was not a significant differences in the score for male and female participants (U=25.500, p=0.76). These result suggest that gender difference does not have an effect on mental rotation test performance for science group in easy level MRT.

The mental rotation test results of male and female participants studying in humanities department were analyzed with Independent Sample T-test and result are presented in **Table 4-2**. 14 students participated in easy-level mental rotation test from humanities group. Among 14 students, 7 students are male, 7 students are female.

Table 4-2 Easy level MRT performance of male and female participants from humanities department

	Gender	N	$\bar{X}$	SE	SS	t	p
Score	Male	7	5.29	1.107	2.928	.475	.644
	Female	7	4.57		2.699		

An independent-samples t-test was conducted to compare test performance of male and female students from humanities gruop in easy level mental rotation test. When the MRT results of the participants from humanities departments were analyzed it is indicated that the averages of male students ($\bar{X}$ = 5.29) are higher than the averages of female students ($\bar{X}$ = 4.57). There was not a significant differences in the score for male (X=5.29, SS=2.928) and female (X=4.57, SS=2.699) participants from humanities group. (t(12=0.475, p=0.644).

4.1.2 Mental Rotation Test Performance on Gender Difference in Difficult Level Mental Rotation Test

The mental rotation test results of male and female participants studying in science department were analyzed by Whitney-U Test and result are presented in **Table 4-3** for difficult level MRT. 16 students participanted in easy-level mental rotation test from sceinec gruop. Among 16 students, 8 students are male, 8 students are female.

Table 4-3 Difficult level MRT performance of male and female participants from science department

	Gender	N	$\bar{X}$	U	p
Score	Male	8	7.56	39.500	.442
	Female	8	9.44		

Mann Whitney U Test was conducted to compare test performance of female and male student from science group in difficult level mental rotation test. When the MRT results of the participants from science departments were analyzed it is indicated that the averages of female students ($\bar{X}$ = 9.44) are higher than the averages of male students ($\bar{X}$ = 7.67). There was not a significant difference in the scores for male and female participants (U=39.500, p=0.44). These result suggest that gender differences does not have an effect on mental rotation test performance for science group.

The mental rotation test results of male and female participants studying in humanities department were analyzed Independent Sample T-test and result are presented in **Table 4-4**. 16 students participated in easy-level mental rotation test from humanities group. Among 16 students, 8 students are male, 8 students are female.

Table 4-4 Difficult level MRT performance of male and female participants from humanities department

	Gender	N	$\bar{X}$	SE	SS	t	p
Score	Male	8	8.50	1.865	3.964	.871	.398
	Female	8	6.88		3.482		

An independent-samples t-test was conducted to compare test perfromance of male and female students from humanities gruop in difficult level mental rotation test. When the MRT results of the participants from science departments were analyzed it is indicated that the averages of male students ($\bar{X}$ = 8.50) are higher than the averages of female students ($\bar{X}$ = 6.88). There was not a significant differences in the score for male (X=8.50, SS=3.964) and female (X=6.88, SS=3.482) participants from humanities group. (t(14)=0.871, p=0.398).

4.1.3 Mental Rotation Test Performance on different academic programs in Easy Level Mental Rotation Test

Easy level mental rotation test across different Mental Rotation groups was investigated by Independent Sample T-Test and results were presented in **Table 4-5**. 30 students who studied different academic programs participated in easy level mental rotation test. One of the 30 students, 15 students study in a science program and 15 students study in humanities.

Table 4-5 Mental rotation test performance on the different academic programs in easy level mental rotation test

	Academic Program	N	$\bar{X}$	SE	SS	t	p
Score	Science	15	6.13	1.228	3.889	.871	.264
	Humanities	15	4.73		2.738		

Revealing the differences in mental rotation test performance of students who enrolled in different academic programs, an independent sample t-test was used. As a result of the analysis, statistically significant no difference was found in the mental rotation test performance in the easy level test between the science groups (X=6.13, SD=3.88) and humanities major groups (X=4.73, SD=2.73) groups (t(28)=1.14, p= 0.26). According to these results, although science group participants' test performance is more higher than humanities major group participants' test performance, the difference is not statistically significant.

4.1.4 Mental Rotation Test Performance on different academic programs in Difficult Level Mental Rotation Test

Difficult level mental rotation test across different Mental Rotation groups was investigated by Independent Sample T-Test and results were presented in **Table 4-6**. 30 students who studied different academic programs participated in the difficult-level mental rotation test. One of the 30 students, 15 students study in a science program, and 15 students study in humanities.

Table 4-6 Mental rotation test performance on the different academic programs in difficult level mental rotation test

	Academic Program	N	$\bar{X}$	SE	SS	t	p
Score	Science	18	8.50	1.352	3.854	1.602	.119
	Humanities	15	6.33		2.885		

Indicating the differences in mental rotation test performance of students who enrolled in different academic programs, an independent sample t-test was used. As a result of the analysis, statistically significant no difference was found in the mental rotation test performance in the easy level test between the science groups (X=8.50, SD=3.85) and humanities major groups (X=6.33, SD=3.88) groups (t(31)=1.60, p= 0.11). According to these results, although science group participants' test

performance is more higher than humanities major group participants' test performance, the difference is not statistically significant.

4.2 Eye-Movements Result

Eye movement metrics such as fixation length, fixation count , and time to first fixation, gaze plots, and heat maps were used to indicate the differences in test performance of students in terms of them.

In this study, volunteer participants solved mental rotation test questions at different levels. Thus, heat map, gaze plot, and fixation metrics were tried to be measured.

Heat maps that show which regions and how much time users focus. It is color-coded measurement data that is formed by combining viewing points, fixation points, and dynamic (moving) points. It is a method of visualizing which elements of the stimulus attract attention. Heatmaps show the regions where users are concentrated from green to red, from less intense to more intense. (Baş & Tüzün, 2014).

Gaze plots can also be expressed as road maps or gaze movements. It shows the user's eye movements consisting of glances and jumps, respectively. It consists of flats numbered with 1 being the first place to be looked at. The size of the circle is directly proportional to the viewing time. The circles indicate the location of their fixation in the viewer's gaze, and the size of a circle represents the focusing time; a larger circle indicates a longer fixation. (Maughan etc., 2007).

Areas of interest (AOIs) were created on images in each option and trial to follow the classification of time to first fixation, fixation duration, and fixation count within TOBII.

4.2.1 Eye movement metrics on gender differences in Easy Level Mental Rotation Test

When heat maps and gaze plot data are examined, female participants mostly focused on the stimulus placed on the left as the target. After that, the second thing that they focused on was the options they selected. However, female participants looked at other things such as the question menu, and settings icon, but they did not focus mostly. After they selected two answers to questions, they focused on the next button. Heatmaps and gazeplots of female participants were showed as in **Figure 4-1** and **Figure 4-2** below.

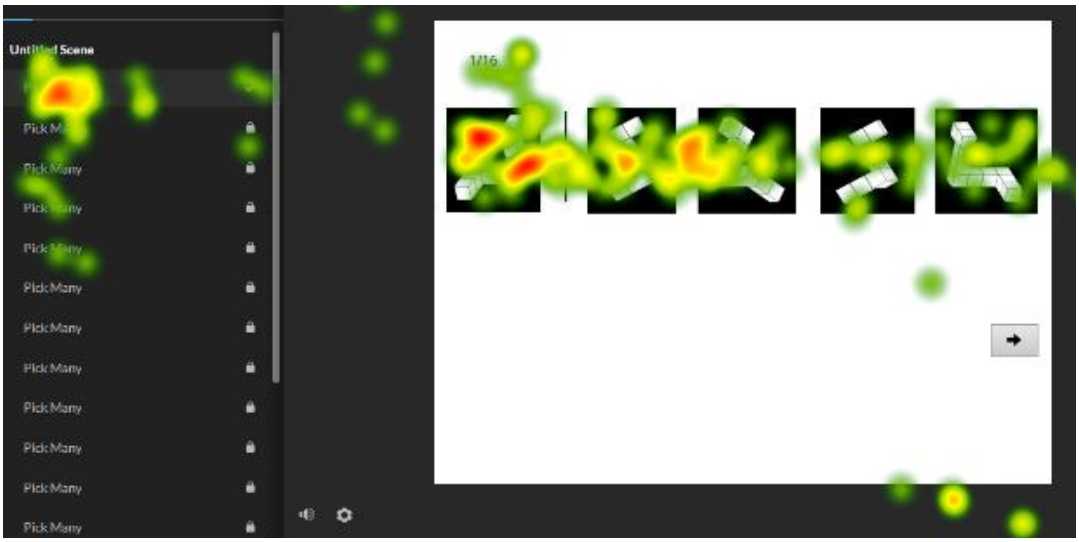

Figure 4-1 Female participants of heatmaps on easy level mental rotation test

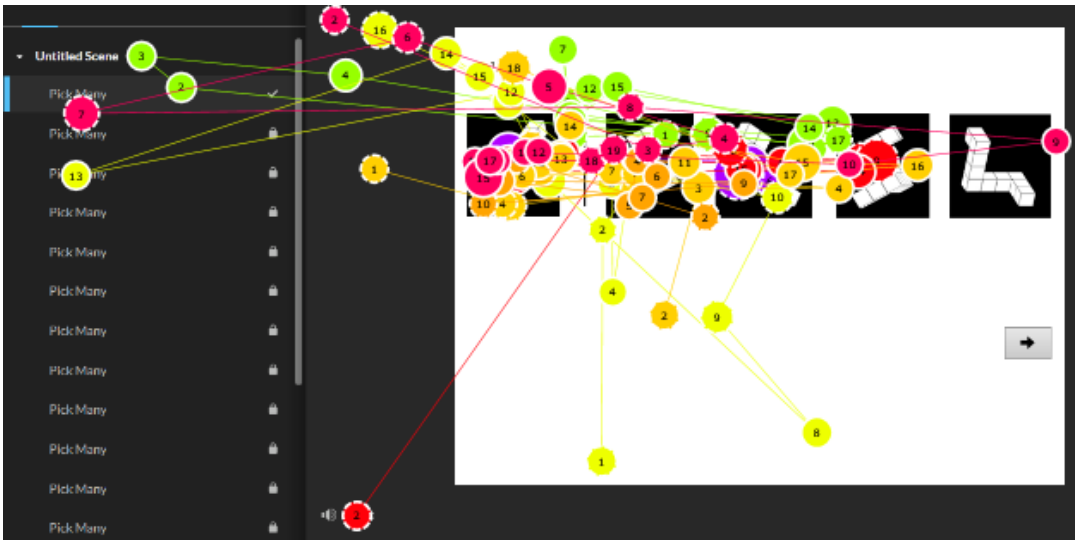

Figure 4-2 Female participants of gazeplots on easy level mental rotation test

When heat maps and gaze plots data are examined, male participants mostly focused on the stimulus which was placed on the left the target, the options they selected, and the question menu placed left. Heatmaps and gaze plots of male participants were showed as in **Figure 4-3** and **Figure 4-4** below.

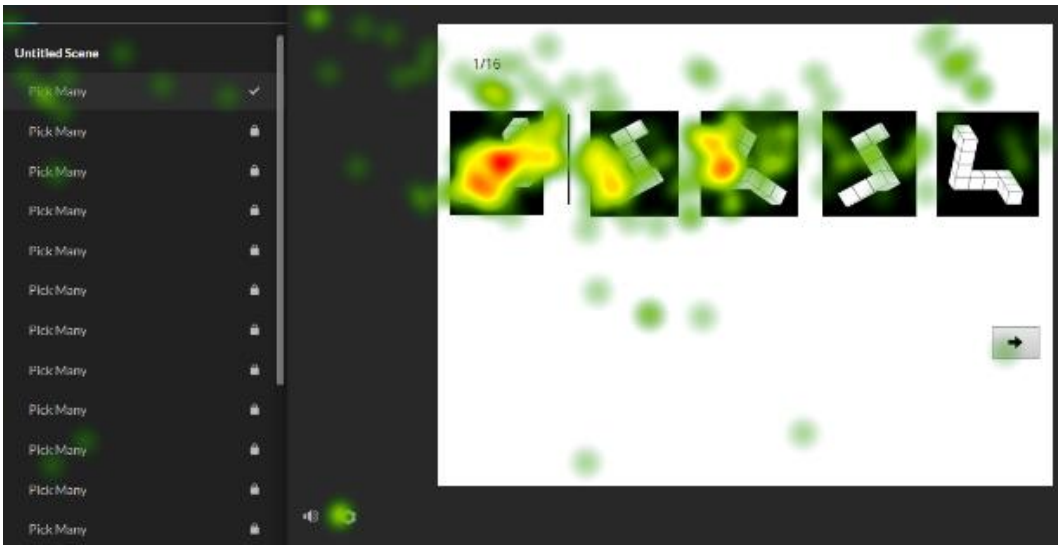

Figure 4-3 Male participants of heat maps on easy level mental rotation test

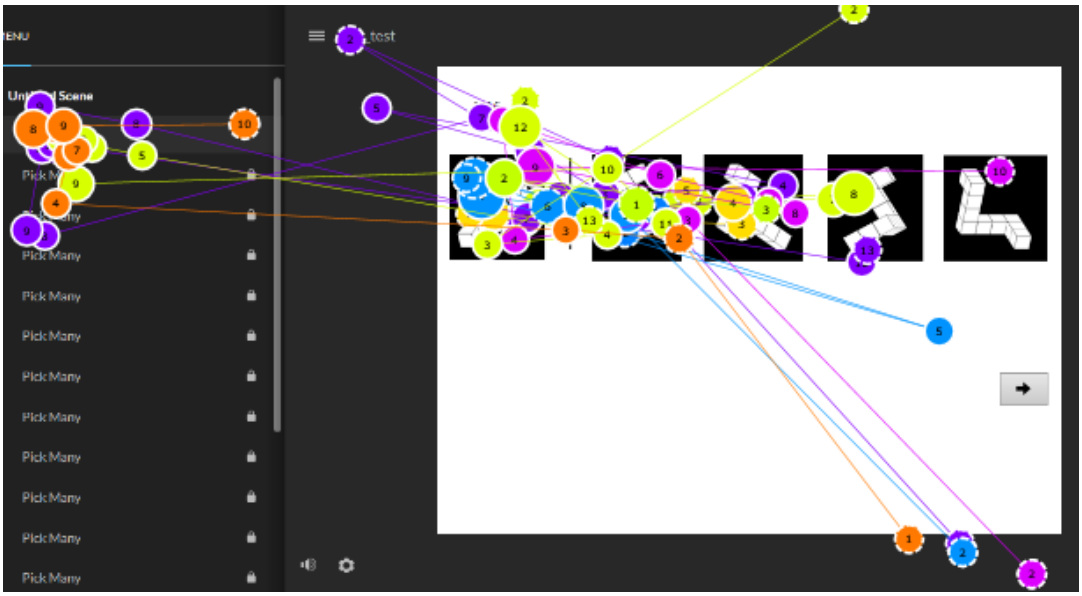

Figure 4-4 Male participants of gaze plots on easy level mental rotation test

When female and male participants compare aspects of gaze plots and heat maps data on easy level mental rotation test, both female and male participants mostly focused on the stimulus target and options that they selected. Also, male participants mostly focused questions menu, female participants did not mostly focus. Apart from that, no significant difference was observed between gender in aspects of heatmaps and gaze plots data for easy-level mental rotation test performance.

Differences in eye movement metrics on target stimulus and response alternatives at easy level mental rotation test performance between female and male MRA groups were analyzed and results are indicated in **Table 4-7** and **Table 4-8**.

A significant difference was found on the target stimulus field in the easy level mental rotation test between female and male groups in terms of time to first fixation and fixation count. When the time to first fixation fixation count on the target stimulus field was found significantly higher for female groups, fixation duration on target stimulus was found significantly male group. While female groups viewed the response alternatives field more frequently and longer on time to first fixation and fixation count, the male group viewed the response alternatives more frequently and longer on fixation duration.

In addition to that, the analyses of the area of interest (AIO) indicated that male and female participants mostly focused on response alternatives for time to first fixation and fixation duration, while participants mostly focused on target stimulus for fixation duration.

Table 4-7 Female and male participants of eye movement metrics from science group on easy level mental rotation test

Eye Movement Metrics	Area of Interest (AIO)	Mental Rotation Group	N	Mean Rank
Time to First Fixation	Target Stimulus	Female	7	20.31
		Male	7	13.85
	Response Alternatives	Female	7	20.51
		Male	7	15.13
Fixation Duration	Target Stimulus	Female	7	20.3
		Male	7	25
	Response Alternatives	Female	7	19.31
		Male	7	23.18
Fixation Count	Target Stimulus	Female	7	17.42
		Male	7	12.44
	Response Alternatives	Female	7	9.89
		Male	7	9.17

Table 4-8 Female and male participants of eye movement metrics from humanities group on easy level mental rotation test

Eye Movement Metrics	Area of Interest (AIO)	Mental Rotation Group	N	Mean Rank
Time to First Fixation	Target Stimulus	Female	7	19.31
		Male	7	15.95
	Response Alternatives	Female	7	24.89
		Male	7	18.19
Fixation Duration	Target Stimulus	Female	7	19.09
		Male	7	21.78
	Response Alternatives	Female	7	17.34
		Male	7	21.17
Fixation Count	Target Stimulus	Female	7	16.93
		Male	7	13.87
	Response Alternatives	Female	7	8.98
		Male	7	8.30

4.2.2 Eye movement metrics on gender differences in Difficult Level Mental Rotation Test

When heat maps and gaze plot data are examined, female participants mostly focused on the stimulus placed on the left as a target. After that, the second thing that they focused on was the options they selected. However, female participants did not focus on other things such as the question menu, and settings icon. Rather than the menu which includes questions, female participants focused on the number of questions at the top level of the page. Heatmaps and gaze plots of female participants were showed as in **Figure 4-5** and **Figure 4-6** below.

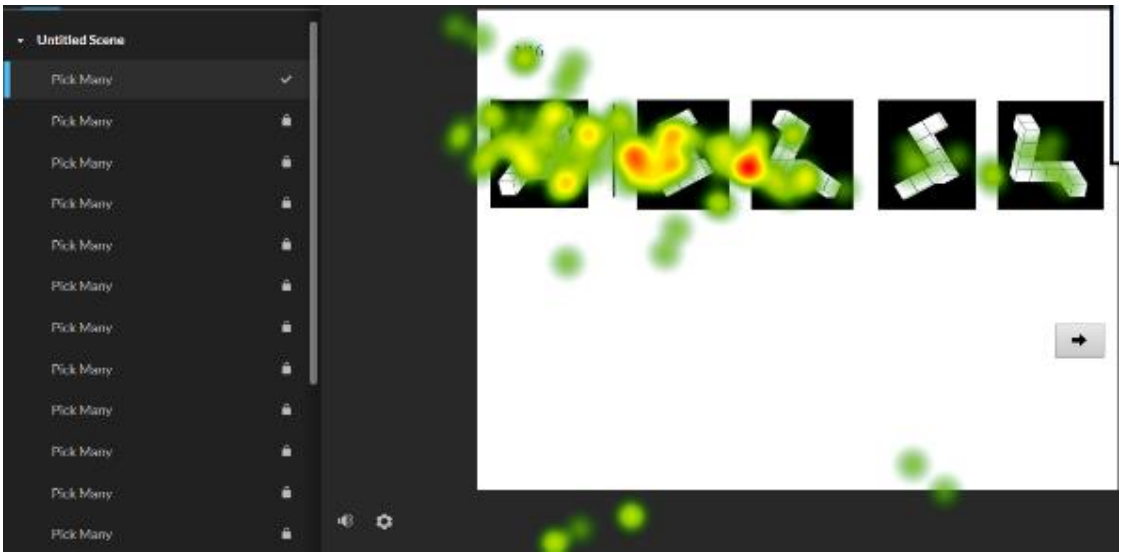

Figure 4-5 Female participants of heat maps on difficult level mental rotation test

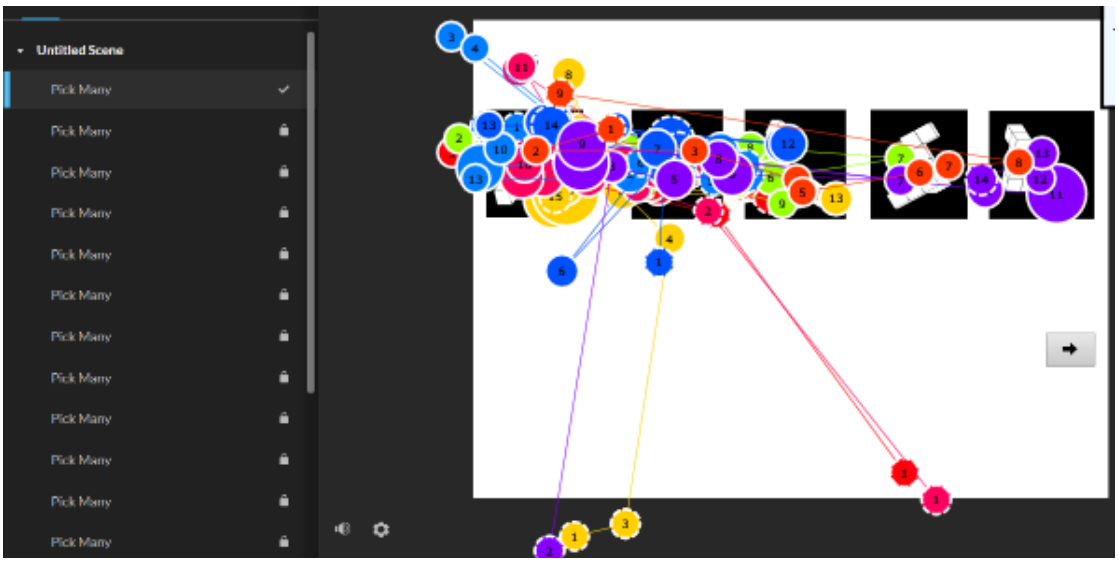

Figure 4-6 Female participants of gaze plots on difficult level mental rotation test

When heat maps and gaze plots data are examined, male participants mostly focused on the stimulus placed on the left as a target, options they selected. They did not focus on other things such as the settings icon or question menu. Like females, male participants looked at the number of questions at the top level of the page . Heatmaps and gaze plots of male participants were showed as in **Figure 4-7** and **Figure 4-8** below.

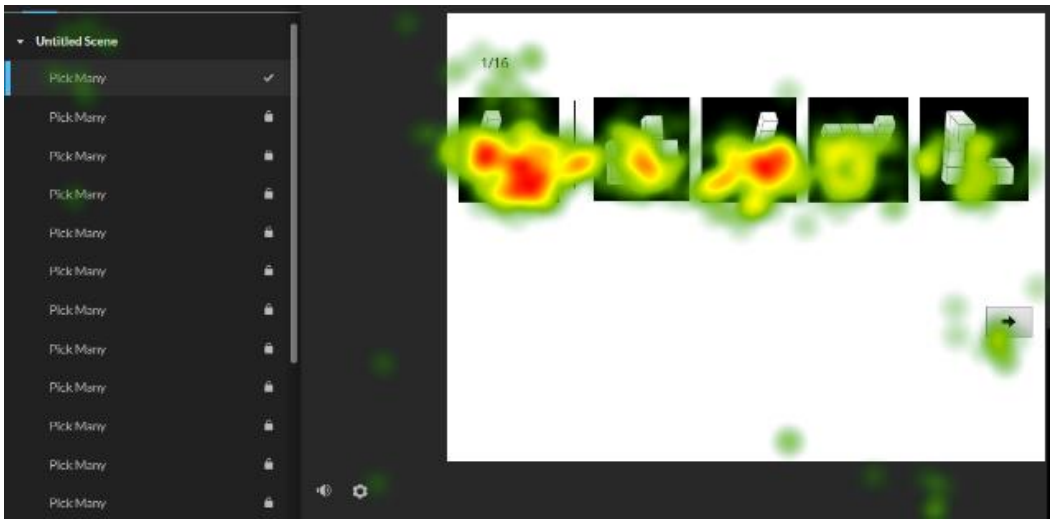

Figure 4-7 Male participants of heat maps on difficult level mental rotation test

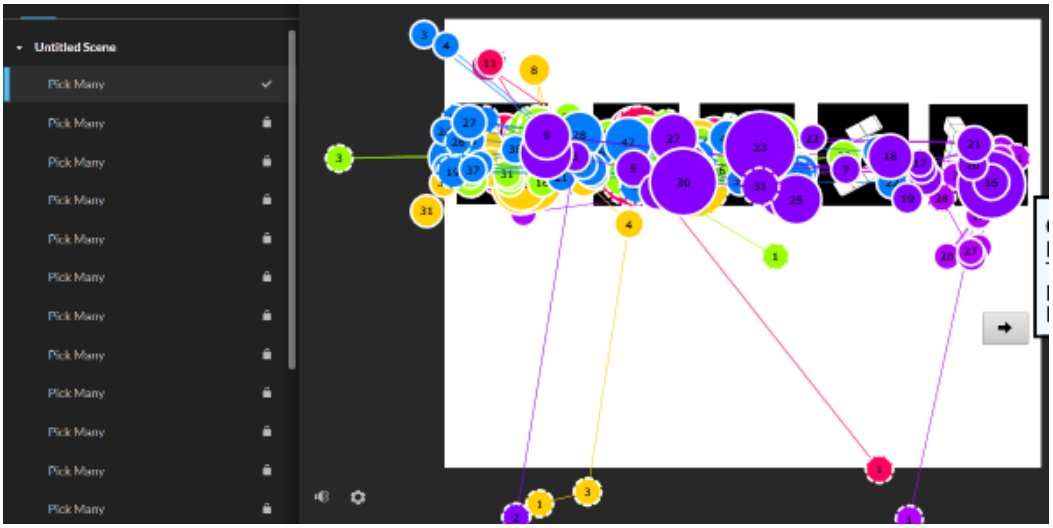

Figure 4-8 Male participants of gaze plots on difficult level mental rotation test

When examining female and male participants‘ gaze plots and heat maps for difficult-level mental rotation tests, both of them mostly focused on the target stimuli. The second thing which they focus on the options that they selected. They did not focus on other things like the question menu, settings, speaker icons, the and next button.

Differences in eye movement metrics on target stimulus and response alternatives at difficult level mental rotation test performance between female and male MRA groups were analyzed and results are indicated in **Table 4-9** and **Table 4-10**.

A significant difference was found on the target stimulus field in difficult level mental rotation test between female and male groups in terms of time to first fixation and fixation count. When the time to the first fixation on the target stimulus field was found significantly higher for female groups, fixation duration and fixation count on target stimulus were found significantly male group.

While female groups viewed the response alternatives field more frequently and longer on time to first fixation and fixation duration, the male group viewed the response alternatives more frequently and longer on fixation count.

In addition to that, the analyses of the area of interest (AIO) indicated that male and female participants mostly focused on response alternatives for fixation duration, while participants mostly focused on target stimulus for time to first fixation and fixation count.

Table 4-9 Female and male participants of eye movement metrics for science group on difficult level mental rotation test

Eye Movement Metrics	Area of Interest (AIO)	Mental Rotation Group	N	Mean Rank
Time to First Fixation	Target Stimulus	Female	7	23.18
		Male	7	20.95
	Response Alternatives	Female	7	23.07
		Male	7	20.37
Fixation Duration	Target Stimulus	Female	7	21.3
		Male	7	22.47
	Response Alternatives	Female	7	22.75
		Male	7	21.69
Fixation Count	Target Stimulus	Female	7	17.61
		Male	7	26.85
	Response Alternatives	Female	7	9.12
		Male	7	17.51

Table 4-10 Female and male participants of eye movement metrics for humanities group on difficult level mental rotation test

Eye Movement Metrics	Area of Interest (AIO)	Mental Rotation Group	N	Mean Rank
Time to First Fixation	Target Stimulus	Female	7	29.26
		Male	7	26.74
	Response Alternatives	Female	7	29.09
		Male	7	26.54
Fixation Duration	Target Stimulus	Female	7	26.8
		Male	7	27.41
	Response Alternatives	Female	7	28.15
		Male	7	27.29
Fixation Count	Target Stimulus	Female	7	19.83
		Male	7	28.62
	Response Alternatives	Female	7	11.39
		Male	7	19.37

4.2.3 Eye movement metrics on different student groups who enrolled in different academic programs in Easy Level Mental Rotation Test

When heat maps and gaze plots data are examined, students who enrolled in mathematics and engineering departments mostly focused on target stimuli. Other things which they focused mostly options which they clicked. In addition to that, although they did not mostly focus next button, a menu that includes questions, the number of questions at the top level of the page, and the symbol of setting, these items were realized from them. Heatmaps and gaze plots of participants who study mathematics and engineering departments were showed as in **Figure 4-9** and **Figure 4-10** below.

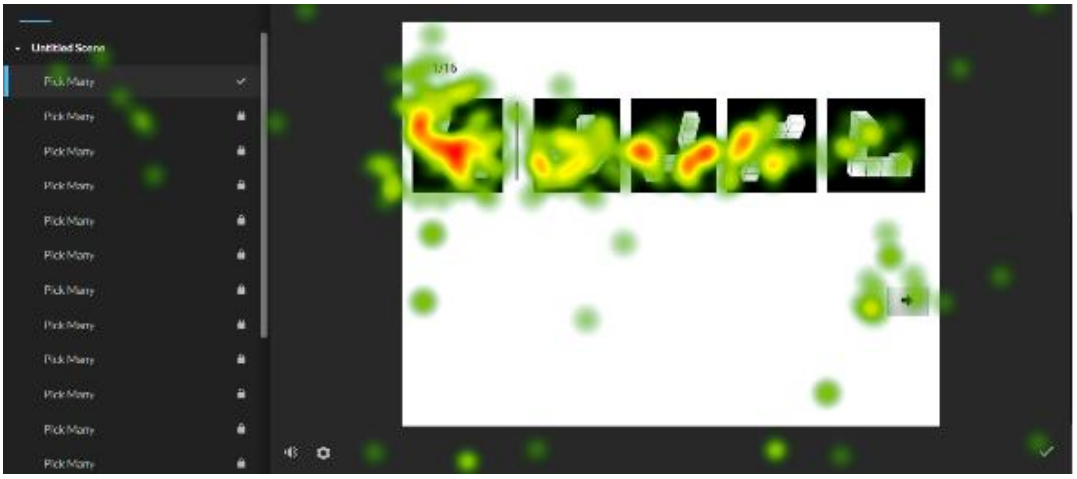

Figure 4-9 Participants who study mathematics and engineering departments of heatmaps on easy level mental rotation test

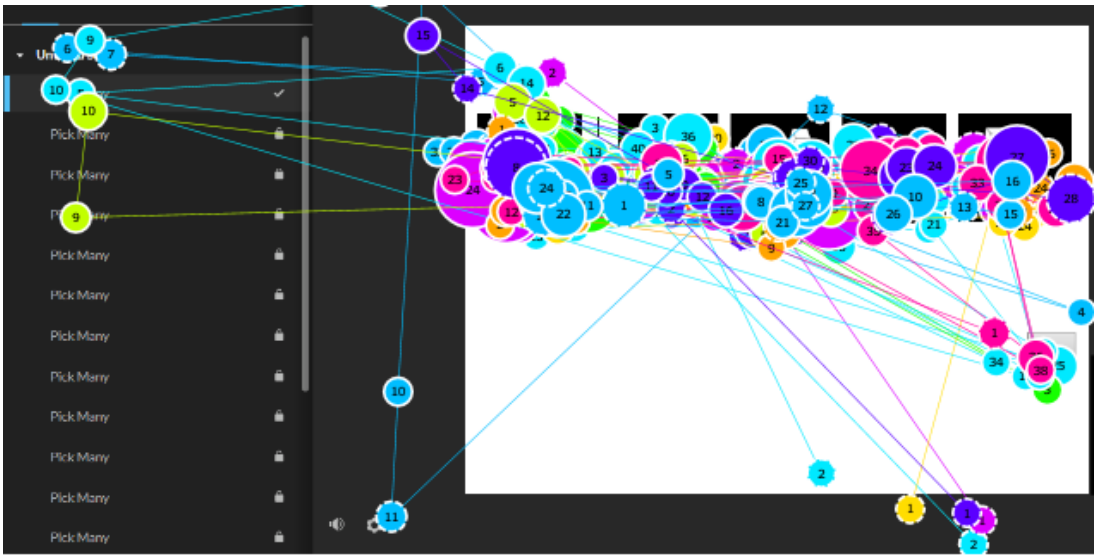

Figure 4-10 Participants who study mathematics and engineering departments of gazeplots on easy level mental rotation test

When heat maps and gaze plots data are examined, students who did not enroll in mathematics and engineering departments mostly focused on target stimuli and options. It was observed that the next button, a menu that includes questions, the number of questions at the top level of the page, a symbol of setting, and other icons were realized from them. Heatmaps and gaze plots of participants who study humanities departments were showed as in **Figure 4-11** and **Figure 4-12** below.

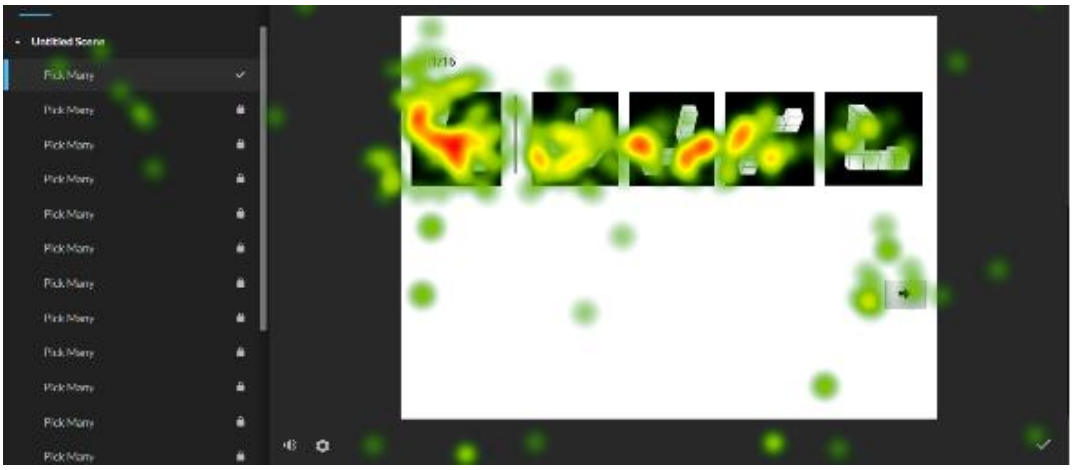

Figure 4-11 Participants who study humanities departments of heatmap on easy level mental rotation test

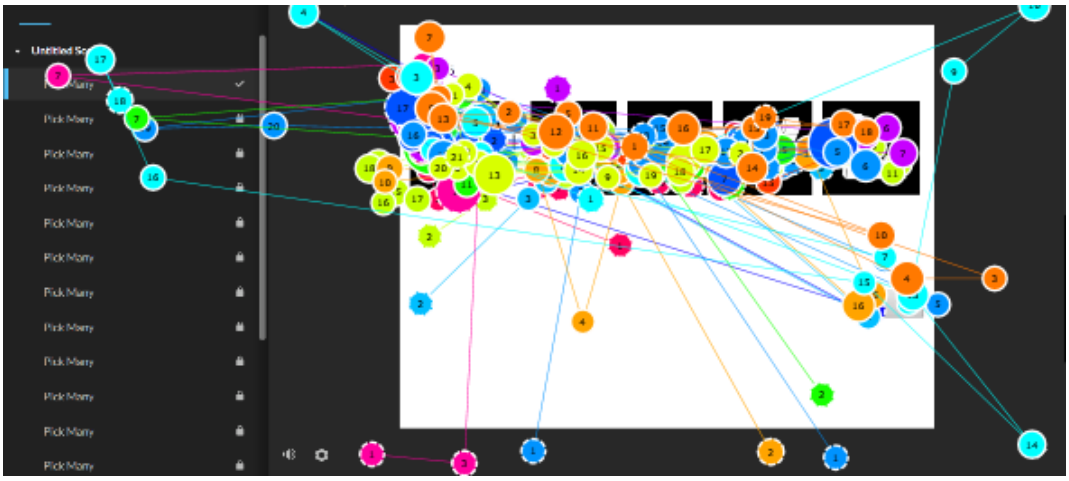

Figure 4-12 Participants who study humanities departments of gaze plot on easy level mental rotation test

When comparing students who enrolled in different department and academic background heat maps and gaze plots data on easy level mental rotation test, it was observed that students mostly from humanities departments looked around the test page unlike the students from mathematics and engineering departments. Both of them mostly focused on target stimulus and options.

Differences in eye movement metrics on target stimilus and response alternatives at easy level mental rotation test performance between participants of Group I who study mathematics and engineer departments and Participants and Group II who study humanities departments was analyzed and results are indicated in **Table 4-11**.

A significant difference was found on the target stimilus field in easy level mental rotation test between Group I and Group II in terms of fixatition count. When time to first fixation and fixation count on the target stimilus field was found significantly higher for Group I, fixatiton duration on target stimilus was found significantly Group II.

While Group I viewed the response alternatives field more frequently and longer on time to first fixation and fixation count, Group II viewed the response alternatives more frequenly and longer on fixation duration.

In addition to that, the analyses of area of interest (AIO) indicated that Group I and Group II participants mostly focused on response alternatives for time to first fixation and fixation duration, while participants mostly focused on target stimilus for fixation count.

Table 4-11 Eye movement metrics of group I and group II on easy level mental rotation test

Eye Movement Metrics	Area of Interest (AIO)	Mental Rotation Group	N	Mean Rank
Time to First Fixation	Target Stimulus	Group I	7	26.25
		Group II	7	18.67
	Response Alternatives	Group I	7	27.53
		Group II	7	18.64
Fixation Duration	Target Stimulus	Group I	7	20.19
		Group II	7	22.67
	Response Alternatives	Group I	7	21.3
		Group II	7	24.47
Fixation Count	Target Stimulus	Group I	7	19.96
		Group II	7	12.42
	Response Alternatives	Group I	7	11.23
		Group II	7	7.73

4.2.4 Eye movement metrics on different student groups who enrolled in different academic programs in Difficult Level Mental Rotation Test

When heat maps and gaze plots data are examined, students who enrolled mathematics and engineer departments mostly focused on target stimulus on difficult level mental rotation test. Other things which they focused mostly options which they clicked. In addition to that, although they did not mostly focus, menu which include questions were realized from them. In addition to that, participants looked next button, settings symbol. Heatmaps and gaze plots of participants who study mathematics and engineering departments were showed as in **Figure 4-13** and **Figure 4-14** below.

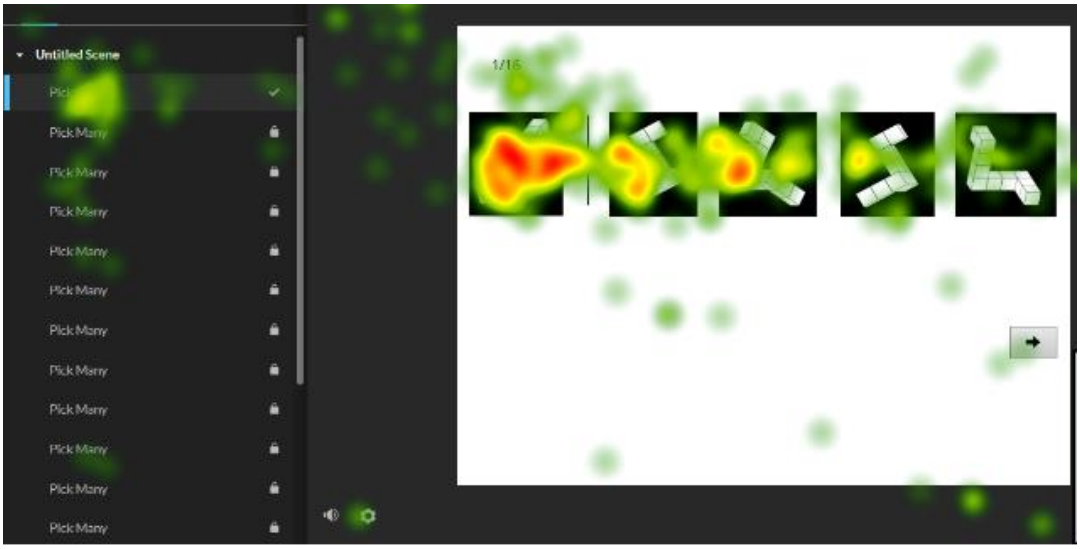

Figure 4-13 Participants who study mathematics and engineer departments of heat maps on difficult level mental rotation test

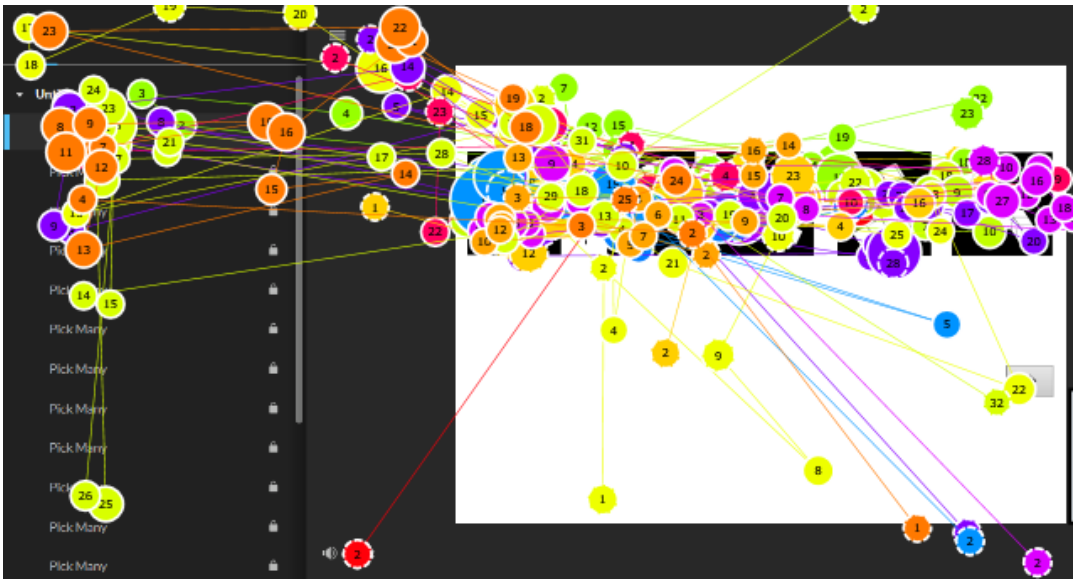

Figure 4-14 Participants who study mathematics and engineer departments of gaze plot on difficult level mental rotation test

When heat maps and gaze plots data are examined, students who enrolled humanities mostly focused on target stimulus on difficult level mental rotation test. Other things which they focused mostly options which they clicked. In addition to that, although they did not mostly focus, speaker symbol and the number of questions at the top level of page were realized from them. Heatmaps and gaze plots of participants who study humanities departments were showed as in **Figure 4-15** and **Figure 4-16** below.

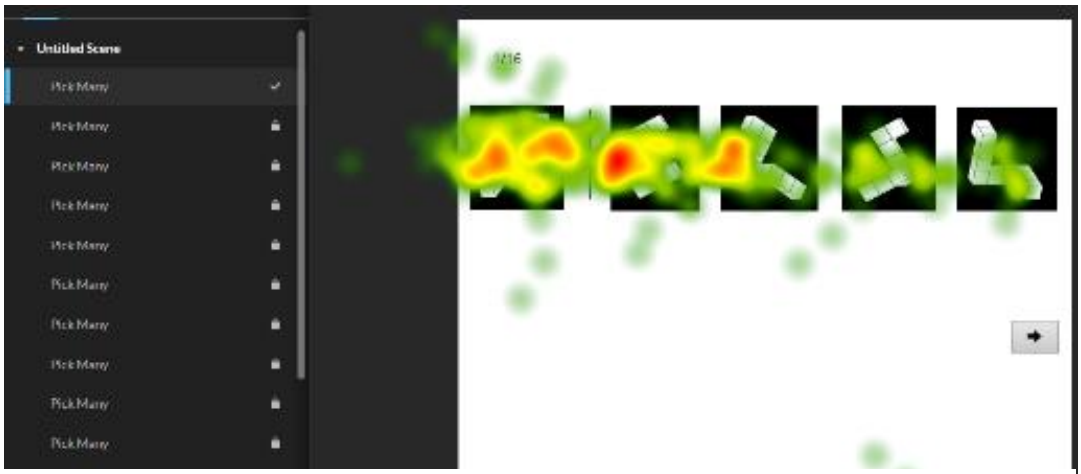

Figure 4-15 Participants who humanities departments of heat maps on difficult level mental rotation test

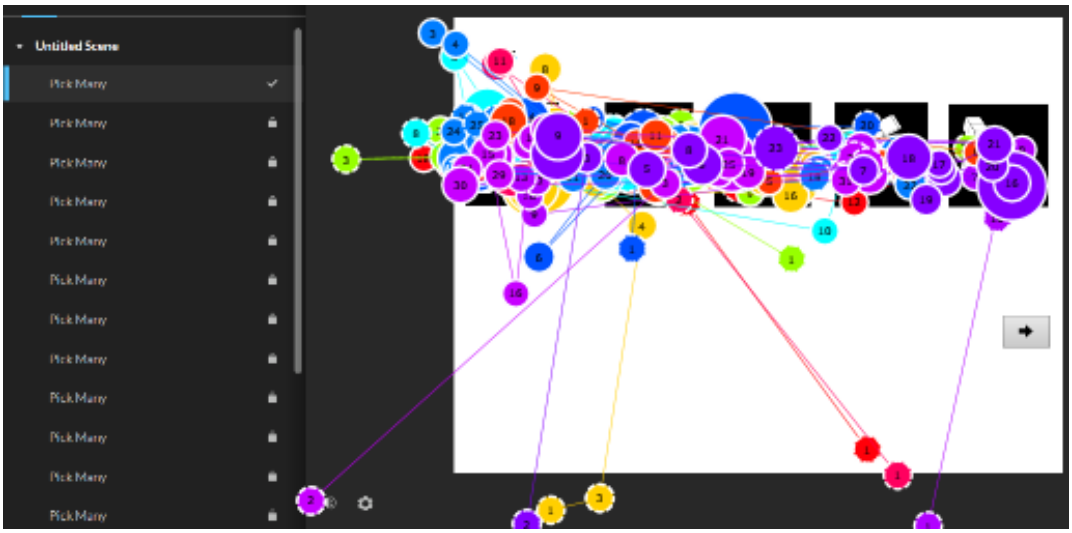

Figure 4-16 Participants who humanities departments of gaze plots on difficult level mental rotation test

While interpreting students' who enrolled different departments gaze plots and heat maps data on difficult level mental rotation test, participants from departments of mathematics and engineering mostly focused on menu which include questions while participants from humanities department did not focus on question menu. Both of groups mostly focused on target stimuli and options. When students who did not enroll mathematics and engineering department did not look next button, another group realize it.

Differences in eye movement metrics on target stimulus and response alternatives at difficult level mental rotation test performance between participants of Group I who study mathematics and engineering departments and Participants and Group II who study humanities departments were analyzed and results are indicated in **Table 4-12**.

A significant difference was found on the target stimulus field in the difficult level mental rotation test between Group I and Group II in terms of fixatition count. When time to first fixation and fixation count on the target stimilus field was found significantly higher for Group I, fixatiton duration on target stimilus was found significantly Group II.

While Group I viewed the response alternatives field more frequently and longer on time to first fixation and fixation count, Group II viewed the response alternatives more frequenly and longer on fixation duration.

In addition to that, the analyses of area of interest (AIO) indicated that Group I and Group II participants mostly focused on response alternatives for time to first fixation and fixation duration, while participants mostly focused on target stimilus for fixation count.

Table 4-12 Eye movement metrics of group I and group II on difficult level mental rotation test

Eye Movement Metrics	Area of Interest (AIO)	Mental Rotation Group	N	Mean Rank
Time to First Fixation	Target Stimulus	Group I	7	27.47
		Group II	7	22.3
	Response Alternatives	Group I	7	27.99
		Group II	7	23.53
Fixation Duration	Target Stimulus	Group I	7	23.51
		Group II	7	24.41
	Response Alternatives	Group I	7	25.07
		Group II	7	26.31
Fixation Count	Target Stimulus	Group I	7	28.6
		Group II	7	17.28
	Response Alternatives	Group I	7	19.06
		Group II	7	9.48

4.3 The Association Between Mental Rotation Test Performance Result and Eye Movement Metrics

According to easy level mental rotation test results in science group and humanities gruop, male participants' test performance is more higher than female participants'

test performance although the difference is not statistically significant. Male participants' fixation duration of eye movement metrics was found significantly on target stimulus while male participants' fixation count and time to first fixation on target stimulus field was lower. While female groups viewed the response alternatives field more frequently and longer on time to first fixation and fixation count, male group viewed the response alternatives more frequenly and longer on fixation duration. It can be concluded that male participants were more successful because they had longer fixation duration both on the target stimulus and alternative stimulus in easy level mental rotation test. Men participants looked at response target stimilus and alternatives more quiclky and did not spend much time for target stimilus and response alternatives while female participants spent much time for target stimilus and response aşternetives and fixatioun count is lower than male.

According to difficult level mental rotation test results, female participants' test scores is higher than male participants' test scores in science group while men participants' test scores is more higher than female participnats' test score in humanities group. When the time to first fixation on the target stimulus field was found significantly higher for female groups, fixation duration and fixation count on target stimulus were found significantly male group. Female groups viewed the response alternatives field more frequently and longer on time to first fixation and fixation duration.

It can be concluded that female participants from sceince group were more succesfful because they had longer time to first fixation and fixation duration on the response alternatives in the difficult level mental rotation test. Female participants looked at response alternatives and target stimilus more quickly.

When science group participants called Group I and humanities major group participants called Group II are compared in easy level mental rotation test performance, science group participants' test performance is more positive than humanities major group participants' test performance. Group I participants' time to first fixation and fixation count eye movement metrics were found significant on target stimulus. While Group I viewed the response alternatives field more frequently

and longer on time to first fixation and fixation count, Group II viewed the response alternatives more frequently and longer on fixation duration on easy level mental rotation test.

When science group participants called Group I and humanities major group participants called Group II are compared in difficult level mental rotation test performance, science group participants' test performance is more positive than humanities major group participants' test performance. Group I participants' time to first fixation and fixation count eye movement metrics were found significant on target stimulus. While Group I viewed the response alternatives field more frequently and longer on time to first fixation and fixation count, Group II viewed the response alternatives more frequently and longer on fixation duration on difficult level mental rotation test.

CHAPTER 5

DISCUSSION AND CONCLUSION

5.1 Introduction

In this section, the results of this study are discussed and compared to other studies related to this research field. Later, the study was concluded, and recommendations were given for further studies.

5.2 Discussion

A mental rotation test was used in this study to help identify the differences in cognitive processes used in mental rotation tasks among different MRA-level groups. Eye movements as a measure of cognitive processes can be explored further be examined in various settings. Because spatial ability is a key predictor of task performance and completion time, future studies should consider creating an adaptable learning environment to make up for low MRA.

This study aimed to explore the effects of task difficulty, gender, and different academic program role on college students' mental rotation test performance. The mental rotation test was selected because mental rotation requires retaining and transforming visual images and it is described as spatial ability. (Peters et al., 2006). Gender differences and different academic programs affect mental rotation test performance. Thus, it is significant to understand whether students who have different gender and are enrolled in different academic programs perform different mental rotation test (MRT) performance.

The number of female and male participants was selected equally because in the literature there is a general agreement about achievement that men have better performance than women in activities which related to spatial abilities. (Voyer &

Doyle, 2012.) Kaltner and Jansen (2018) stated that gender differences in MRT performance are established, with men outperforming women. Results of easy mental rotation test performance in science group and humanities group showed that male students were more successful than female students on easy-level mental rotation tests. However, in contrast to the first analysis, female students from science group were more successful than male students from science group in difficult-level mental rotation test results. In addtion to that, like the first analysis, male students from humanties group were more successful than female group from humanities group in difficult level mental rotation test. Remember that, in contrast to this general agreement, gender differences should not be shown as the only difference in spatial ability and some subjects affect the mental rotation test performance. (Voyer, et. al. 2020). When comparing to analysis for the easy and difficult level tests, students who enrolled in science were more successful than students who study humanities major groups both of two different tests. While different academic programs were found to affect test performance, gender differences did not have only an effect on mental rotation tests. Chen and Yang, (2014) stated that spatial ability is usually regarded to be related to science learning. Spatial thinking is an important part of the science domain (Chen & Yang, 2014). Adolescents who select professional careers in the science, mathematics, and engineering domains perform better on tasks in spatial abilities. (Wai, Lubinski & Benbow, 2009).

In easy-level mental rotation test results for science and humanities group, male participants' test performance is higher than female participants' test performance. Also, science group participants' test performance is more higher than humanities major group participants' test performance. Easy-level mental rotation test results indicate similar results with in previous studies because, in previous studies, male participants had higher scores than female participants, and science group participants' test performance is more positive than humanities major group participants' test performance. In eye tracker metrics data, male participants' fixation duration of eye movement metrics was found significantly on the target stimulus while male participants' fixation count and time to the first fixation on the target stimulus field was lower. While female groups viewed the response alternatives field

more frequently and longer on time to first fixation and fixation count, the male groups viewed the response alternatives more frequently and longer on fixation duration. Also, science group participants' time to first fixation and fixation count eye movement metrics were found significant on target stimulus. While the science group viewed the response alternatives field more frequently and longer on time to first fixation and fixation count, the humanities group viewed the response alternatives more frequently and longer on fixation duration on easy level mental rotation test.

In difficult level mental rotation test results, unlike the literature, female participants' test scores are higher than male participants' test scores in sceince group while science group participants' test performance is more positive than humanities major group participants' test performance like literature. Science group participants' time to first fixation and fixation count eye movement metrics were found significant on target stimulus. While the science group viewed the response alternatives field more frequently and longer on time to first fixation and fixation count, the humanities group viewed the response alternatives more frequently and longer on fixation duration on difficult level mental rotation test.

5.3 Conclusion

This study aims to explore the differences between different mental rotation ability groups who are female, male, science, and humanities group participants in their cognitive process by different difficulty level mental rotation tests. Mental rotation problems were selected because mental rotation abilities are one of the most important spatial abilities. This study used eye-tracking methods to demonstrate cognitive strategies. The analyses showed that male students had higher scores than female students in the easy-level mental rotation test both of sceince and humanities group while female students from science group were more successful in the difficult level mental rotation test. The result of difficult level mental rotation test was contrary to the expectation that men had higher score than female. Therefore, this study suggest that only gender differences do not affect mental rotation test results,

but also different level of MRT affects mental rotation test result. Students from science group were more successful than students from humanities major group in both difficult and easy level mental rotation test. In result of eye movements metric data in easy level MRT, while female groups viewed the response alternatives field more frequently and longer on time to first fixation and fixation count, the male groups viewed the response alternatives more frequently and longer on fixation duration in easy level mental rotation test. While Group I who study mathematics and engineer departments viewed the response alternatives field more frequently and longer on time to first fixation and fixation count, Group II study humanities departments viewed the response alternatives more frequenly and longer on fixation duration. While female groups viewed the response alternatives field more frequently and longer on time to first fixation and fixation duration, male group viewed the response alternatives more frequently and longer on fixation count in difficult level MRT. Also, While Group I viewed the response alternatives field more frequently and longer on time to first fixation and fixation count, Group II viewed the response alternatives more frequenly and longer on fixation duration in difficult level MRT. In conclusion, this study allows to rejection of some common thoughts about the effecting mental rottaion test performance. This study suggests that there should be only questions and options on the screen so that students cannot focus other items such as menu bar etc.

5.4 Limitations

In this study, a small sample size was used for the experiment. A small sample size decreases the effects of statistical analysis. When further studies use larger sample sizes, study findings will strengthen. Nonetheless, it should be realized that 30 participants solved 16 questions in the easy level mental rotation test and 30 participants solved 16 questions in difficult level mental rotation test. As a result, there were 960 sets of eye movement data in total group. Eye tracker data got together and size of data were large for this study. When eye tracker data is actually quite large, using eye tracking method is considerable difficult for educational

research. In addition to this, as the number of samples increases, it becomes more complex to analyze eye tracking data.

5.5 Future Works

This study aimed to explore the differences of cognitive processes in different level mental rotation tasks for different mental rotation level groups using the digital mental rotation test. In further study, eye movements can be shown in 3-D environments for mental rotation test performance. In addition to this, completion time was not mentioned in this study. Since task performance and completion time have an important effect on spatial ability (Baran et. al. 2007), completion time can be measured for future works. In further studies, completion time, eye movements and task performance can be investigated for different level mental rotation test to calculate effects of different participation.

In literature, eye movement metric data in different level questions determined problem solving strategies (Baran et al. 2007), the relation of problem solving strategy and mantal rotation ability have not studied. Thus, in future works, different strategies of different level MRT in different groups could be investigated. In this study, differences between groups for different level mental rotation test were investigated yet, this study did not investigate different strategy in mental rotation test.

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APPENDICES

A. Informing Mental Rotation Test Procedure

Participants will be informed about the mental rotation test. The test includes 16 items and each item includes a three-dimensional block image. The stimulus which will place on the left is the target and four response alternatives take place to the right. Response alternatives consist of block image perspective rotated in space. Two of the response alternatives are correct alternatives whereas other response alternatives are not correct alternatives; i.e. distractors. You will decide which two of four response alternatives on the right of the target will be rotated versions of the target stimulus. When you select the correct answers, you will have 1 point and there will be no lower points when selecting wrong answers. There will be no time restriction. Your eye movements will be followed by the monitor. It is important not to move your body or head. Please, you will follow the questions only eyes. If you want to attend this study, you can sign a consent letter. When you do not feel comfortable during the study, you cannot continue. When you are ready, we can begin this study.

B. Ethics Committee Approval Form

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İlgi : İnsan Araştırmaları Etik Kurulu Başvurusu

Sayın Kürşat ÇAĞILTAY

Danışmanlığını yürüttüğünüz Eda BAHÇIVAN'ın "3 Boyutlu Görselleri Döndürme Sürecini Analiz Etme" başlıklı araştırmanız İnsan Araştırmaları Etik Kurulu tarafından uygun görülmüş ve **0026-ODTUİAEK-2022** protokol numarası ile onaylanmıştır.

Saygılarımızla bilgilerinize sunarız.