International Journal of Asian Social Science
ISSN(e): 2224-4441/ISSN(p): 2226-5139
journal homepage: http://www.aessweb.com/journals/5007

THE EXTENT OF MENTAL ROTATION AMONG A SAMPLE OF MATHEMATICS STUDENTS AT AL-QASSIM UNIVERSITY

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ABSTRACT

The study aims at identifying the ability of mental rotation, according to gender and rotation angle, among a sample of Al-Qassim university postgraduates enrolled in first, second, third and fourth years and majoring in mathematics. The sample consisted of (160) student randomly assigned to the mental rotation test. The study utilized a mental rotation computerized test (Classmaker) to measure student's ability, the test included (144) tasks. Six stimuli are used; each one is represented by two 3-Dimentional shapes, each stimulus is rotated (24) times, (12) with and (12) counterclockwise. Identical shapes following rotation were (72) and non-identical shapes were (72) according to the rotation angles (30˚, 60˚, 90˚, 120˚, 150˚, 180˚). Validity and reliability of the test were insured. Results proved that mental rotation ability increased by the academic year increase, the correct answers number increased and the reaction time decreased. Results also showed that when the rotation angle is larger the correct answers number decreased, and significant differences appeared in reaction time due to the rotation angle. No significant differences were found in the relationship between the gender and means of the reaction time.

Keywords: Mental rotation, Reaction time, Academic year, Postgraduates, Rotation angle, Stimulus.

Contribution/ Originality

This study is the first to assess mental rotation ability among a relatively small sample of postgraduates in a Saudi culture. Findings may help mathematics teachers in planning activities for students.

1. INTRODUCTION

Mental rotation received cognitive psychological scientist's interest since early seventies, researchers exhausted efforts each in his domain to explain mental rotation because they wanted to

DOI: 10.18488/journal.1/2015.5.11/1.11.641.655
ISSN(e): 2224-4441/ISSN(p): 2226-5139

develop strategies and aspects to help improve this ability, and to enable individuals to imply it in adapting and enhancing life conditions in different domains.

Mental perception is studied by philosophers and scholars such as Plato, Aristotle, Hume and Luke. Added to that, trials by some pioneer psychologists to study mental perception and internal processes such as Wundt and James, but their attempts failed because they didn't use appropriate scientific methodologies. The method they used was introspection, in the time of behaviorism dominancy which confirms direct observation of external behaviors as a method not considering internal processes where mental perception forms a key process. Mental rotation studies link psychometric psychology with experimental psychology, in addition to cognitive neuroscience interest in internal cognitive processes over the last four centuries (Cooper and Shepard, 1973; Thompson, 1990; Tye, 1991; Kosslyn, 1994).

Mental rotation represents a part of spatial ability in its holistic concept including the ability of cognitive representation, transformation and nonverbal symbolic information recalling. Mental rotation also includes the abilities of spatial cognition and special imaging (Linn and Petersen, 1985; Lohman, 1986).

Many cognitive psychology researchers examined mental rotation; they also developed different definitions for it according to the cognitive field dealing with it. There is no doubt that they agree on gender differences in spatial abilities.

Shepard and Metzler (1971) defined mental rotation as the individuals' spatial ability to rotate a second object in the same direction of a first object, then to respond if they are identical match or just a mirror-image (enantiomorph).

Cooper (1975) believes that mental rotation is the individuals' spatial ability to form mental perceptions for a second 2D stimuli to put it in the same direction of the first stimuli then to respond if they are identical match or not. A linear relation results between reaction time and rotation angular. Wohlschläger (1996) defines mental rotation as the ability to decide if two stimuli are identical matches or enantiomorphs, and that the difference in reaction time is due to the rotation angular between both.

Metal rotation means the individual's ability to rotate shapes to different angles mentally, it entails comparing two dimensional or three dimensional shapes and respond if they are identical or enantiomorphs. This ability is usually tested through pairs of pictures where one of the pictures is rotated at a certain degree (0˚, 60˚, 120˚ or 180˚), where one of the pictures is a rotation of the original and the others are mirror images. A tested individual is given a set of these pairs to measure his ability of distinguishing the enantiomorphs from others. Shepard and Cooper (1986)

Shepard and Metzler (1971) were the first to introduce the idea of mental rotation, the provided eight students in a first experiment with pairs of random angular shapes as shown in Figure (1).

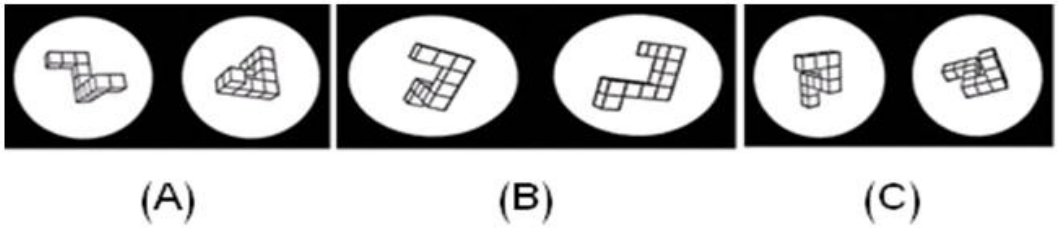

Figure-1. A sample stimuli used in Shepard and Metzler (1971) experiment.

The students attempted in (8-10) sessions to respond to the stimulus making (1600) trials, half of which are identical and the other half are enantiomorphs. Stimuli are rotated into different angles (0˚-180˚) with a (20˚) difference in each rotation, whether it was two dimensional (as in stimuli A) or three dimensional rotation (as in stimuli B). The students were asked to respond as quickly as possible with utmost accuracy if stimuli are identical or enantiomorphs, regardless the rotation angle. It should be noted that stimulus in (A) and (B) are identical although the three dimensional rotation angle is (80˚). The students mentally rotated one of the stimuli in pairs (A, B) to match it with the second stimuli. Stimulus (C) represents an enantiomorph so it is not possible to rotate it. The researchers found a linear relationship between the rotation angle and the reaction time, the increase in the rotation angle needs more time to react by the student, and figure (2) shows the reaction time diagrams.

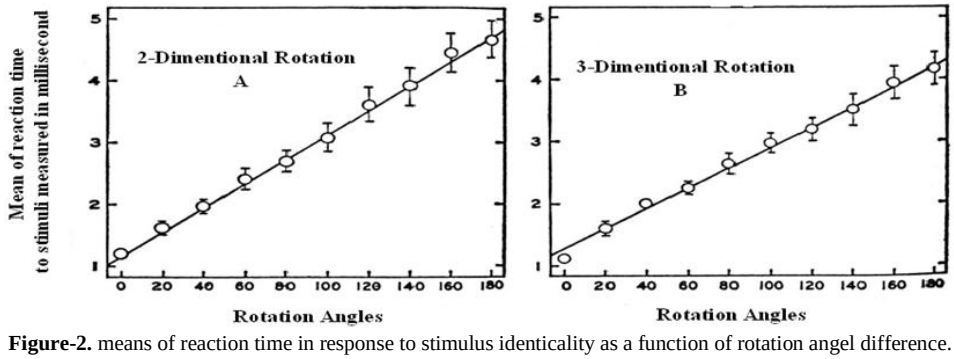

Figure-2. means of reaction time in response to stimulus identicality as a function of rotation angel difference.

Stimuli (A) represent rotation in two dimensional angles, while a stimulus (B) is a three dimensional rotation angle (Shepard and Metzler, 1971).

Mental rotation definition is summed by: individual's ability to mentally retain a figure and to rotate it in space, this ability is important for academic achievement, and is used in predicting in the domains where spatial ability is a major concern such as sciences, engineering, mathematics, chemistry and physics (Samsudin and Ismail, 2004).

Mental rotation is associated with imagining skills that require encoding and mental processing of spatial figures. Mental rotation motivates students to form more imaginative solutions to a lot of learning problems confronting them, especially in mathematics courses (Hooven *et al.*, 2004).

Mathematics is considered as an activity of forming figures and geometric relations that require spatial sense and flexibility in dealing with mental images, that means to have an ability of visual spatial perception. A learner of mathematics has to have the ability to create abstract objects in his mind for what he sees or touches, so lack of this ability leads to a low level of academic

achievement. Students majoring in mathematics definitely need to have the ability of mental rotation to be able to know relations between things. Many studies showed correlations between mental rotation and achievement in mathematics. If there is such appositive correlation it is more fortiori for a mathematics teacher to have this ability and to be conscious to its importance in a way that benefits him while learning and teaching mathematics in order to improve his performance level and student's achievement concepts (Hooven *et al.*, 2004).

Indicators referring to mental rotation ability may be summarized as Shepard and Cooper (1986) reinforced into; reaction time, which means the time between providing an instant response and the moment the stimuli is seen. The increase in the rotation angle increases the reaction time to give a response about stimulus identicality or enantiomorphy, whether the rotation axis is vertical or horizontal. Depth is also correlated with reaction time; 2-D rotation requires shorter time than 3-D rotation. Response accuracy in mental rotation ability is represented by low number of errors. The current study aims at exploring mental rotation ability among a sample of Al-Qassim university students from the department of mathematics.

1.1. Study Problem

Mental rotation received interest among cognitive psychology scientists because of its correlation with achievement in the domains that require spatial skills. The author noticed weakness in student's mental rotation abilities in mathematical questions that require mental imagination and the ability to work with geometric shapes. Therefore, the current study aims at exploring mental rotation ability among a sample of Al-Qassim university students majoring in mathematics, and whether there are significant gender differences. The study aims at exploring the difference in light of the angular rotation. Mental rotation ability is determined by reaction time and the number of the correct answers. Accordingly, the research tried to answer the following questions: Is mental rotation ability (measured by the number of correct answers) different according to academic year, gender, and angular rotation?

Is mental rotation ability (measured by reaction time) different according to academic year, gender, and angular rotation?

1.2. Importance of the Study

The study explores mental rotation among Al-Qassim university students majoring in mathematics, a group which requires special abilities in learning mathematics, such as the ability to imagine geometric shapes and to perform mental processing of geometric shapes such as mental rotation. Another importance is manifested by the instruments implemented, where a computerized program of three dimensional shapes rotated in different angles and a mirror-image.

It may also be considered a part of the theoretical and practical literature that emphasizes mental rotation. It may add new knowledge to the educational thought, and be the core for further studies in future. Lack of Arabic and local studies examining mental rotation, urged the author to undertake the current study.

1.3. Procedural Definitions

For the purpose of the study, the following definition is used:

Mental rotation, is a part of spatial ability that requires mental rotation of three dimensional stimulus, where the student is asked to rotate in order to match with the original and respond whether the stimulus are matches, it is measured in the current study by reaction time and number of the correct answers.

Rotation angle, is the angle which the stimuli is being rotated by, in the computerized program it includes (30˚, 60˚, 90˚, 120˚, 150˚, 180˚).

Reaction time, is the time interval between seeing the stimulus and giving a response, in the present study it is measured by second.

Academic year: students are termed 1st, 2nd, 3rd and 4th year students if they passed successfully 34, 68, 102, 136 credited hours respectively.

1.4. Limitations of the Study

Generalizing the results of this study can be inhibited by the following:

1. The sample was chosen from al-Qassim university mathematics student's total number of (160). Hence the results are valid to generalize only on the population of this study and similar populations.
2. The author are using only three dimensional stimuli.
3. The rotation angles are regular and they are (30˚, 60˚, 90˚, 120˚, 150˚, 180˚).

1.5. Previous Studies

The study focuses on university students majoring in mathematics, and the challenge to understand visual-spatial tasks amounts. The following review scope is to provide a synthesis of the literature on mental rotation and its correlation with different dimensions. Researchers were interested in mental rotation; they studied it according to the subject of the study, which may be divided into three sections according to the study variables:

1.5.1. Mental Rotation and Gender

Explanations of the nature of cognitive processes that happen in mental rotation tasks which have differences between males and females varied, one explanation is by the holistic processing, it compares the two stimulus by a visual scan of all parts of stimuli and its relations and connections, without considering the subparts. Thus, students applying this strategy need less reaction time to respond to the stimulus identicality. The second explanation works through analytic processing, parts of the stimulus are compared without considering relations and connections between them (Just and Carpenter, 1976).

It is shown that mental rotation reveals gender differences in favour of males, they were faster, more accurate and had less mistakes due to using holistic processing (Jordan *et al.*, 2002). In light of the two previous explanations a third view appeared, it assured the role of genetic and environmental factors that are able to heighten the differences between males and females (Lord, 1987). Differences appeared between children too in favour of males as well (Marmor, 1975).

Khairul and Azniah (2006) explored the effectiveness of a computer-mediated Engineering Drawing instruction in improving spatial ability namely spatial visualization and mental rotation in Engineering, Computer Graphics, Architectural and other scientific courses. The researchers utilized the online mental rotation test developed by Vandenberg and Kuse (1978); it included (30) evaluation items, each composed of a target and comparison figure positioned at various degrees of orientation. The test evaluates speed and precision. One hundred thirty eight (69 male and 69 female) students enrolled in Pendidikan Sultan Idris University, Malaysia. Gender differences were found to be insignificant.

Titze *et al.* (2009) explored gender effect on mental rotation among younger children, older children and adults, total number (96 (48 males and 48 females)). Mental rotation test comprised (12) 3D shapes was used. Large gender effects in older children as well as in adults was observed favouring males, but younger children showed no effect.

1.5.2. Mental Rotation and the Educational Level

Leone *et al.* (1993) aimed to verify the long-term practice on the performance of a mental rotation task in which subjects judged whether two 3-D objects presented in different orientations were identical. Ten males and sex females enrolled in different educational levels, ages range from (20-25) years participated in the study. The students were seated at a distance of a computer screen; they viewed the stimuli through a cylindrical black optical tube to avoid any external reference frames. The task was to press a button on the right indicating to an identical object or a left button referring to the mirror-reflecting image. The student's responded to (156) stimulus rotated by different angles (0˚, 30˚, 60˚, 90˚, 120˚, 150˚, 180˚). The results revealed the existence of statistical differences in mental rotation among the students due to educational level.

Ferk *et al.* (2003) studied the effect of mental rotation on science students to understand the molecular formula and to give examples of it, which requires mental rotation ability. The sample was chosen from primary, secondary and university male and female students. They completed a mental rotation test. The results revealed an increase in mental rotation abilities among the students in higher educational levels.

Wilkenning and Brugger (2003) aimed to detect the ability of mental rotation among children, and the impact of age on it. The sample was drawn from schools in Los Anglees ages (5-11). The researchers used eight shapes as stimulus rotated into (0˚, 90˚, 120˚, 180˚, 270˚, 360˚) degrees. The shape is presented to the students and they were asked to response if the part seen of the shape is rotated left or right and to give signs with their hands (up, down and stop). There were significant differences in mental rotation abilities among the students in favour of higher educational levels.

Oliver (2000) discovered the impact of mental rotation on visual recognition tasks. One hundred participants from different age groups (children, adolescents and old aged) in North America completed a mental rotation task, it included (15) stimuli each of which is rotated into (65˚, 70˚, 90˚, 120˚, 220˚ and 270˚). Participants were asked to choose the only shape that matches the stimuli in a predetermined period of time. Mental rotation was faster among the adolescents compared with children and old aged.

1.5.3. Mental Rotation and Rotation Angle

Nunez *et al.* (1998) examined the relationship between age and reaction time and rotation angle. The sample included (151) child divided into (72) student into male and female equal groups their ages range between (9-13) years from Abidjan city and (79) student divided into (38) males and (41) females, their ages range between (8-12) from Switzerland. Stimuli were rotated into (30˚, 60˚, 120˚, 150˚, 180˚, 210˚, 240˚, 270˚, 330˚, 330˚) degrees. The students responded to the stimuli identicality or mirror-imaging as fast as possible and with the least number of errors. The results showed the existence of a linear correlation between reaction time and rotation angle in both groups. Results also indicated that there is a linear correlation between rotation angle and the number of the correct answers.

Curny and Graham (2004) study aimed at examining students' mental rotation ability in oxford high schools. The sample include (80) male student and (106) female student. Stimulus ranged (9-12) in the subject of art rotated into (35˚, 45˚, 80˚, 90˚, 154˚, 250˚) degrees. Results indicated that the greater the rotation angle is the more mental activity is exerted.

According to the literature review mentioned above, it may be said that all studies agree on gender differences in mental rotation ability in favour of males. It is noticed that there is a linear correlation between rotation angle and reaction time and between rotation angle and precision. There is also a positive correlation between mental rotation and achievement level.

2. METHODOLOGY

The study utilized the descriptive approach for its appropriateness of the study.

2.1. Population of the Study

The population consisted of all students in the department of mathematics in the Arts and Science College at Rass / al-Qassim University for the academic year 2014/2015.

2.2. Sample of the Study

The sample consisted of (160) randomly chosen postgraduate students (level 1-4) in the department of mathematics at Arts and Science College at Rass / al-Qassim University. All the students have the ability to use computers. Table (1) shows the sample distribution according to gender and educational level.

Table-1. Repetition and percentage based on the study variables.

	categories	repetition	Percentage
gender	males	80	50
	females	80	50
academic year	1st	40	25
	2st	40	25
	3rd	40	25
	4th	40	25
	total	160	100

2.3. Measures

The author studied mental rotation literature and developed a computerized test for mental rotation ability. The test items are presented to the students through the classmarker site as follows; The software includes three icons; test icons includes instructions to explain the way the test is carried out and the test itself, university academic year icon and gender icon. The procedure is explained to the students and they are given illustrative examples. Test stimuli developed were 3-Dimentional shapes (No. 6), rotated into (30˚, 60˚, 90˚, 120˚, 150˚, 180˚), each stimulus is rotated (24) times twelve of which identical and twelve non identical according to the (6) rotation angles. That means each stimulus is presented twice on each rotation angle producing (12) identical shapes and (12) non identical shapes, with and counterclockwise. The stimulus is shown on the left side of the screen and the rotated shapes on the right. The Students are asked to choose the identical shape from the group of the shapes on the right side of the screen by pressing one of the two buttons (identical or non-identical). Each answer is timed by the second. If the student does not press one of the buttons the next stimulus appears and the response is counted as a wrong one. All results are saved to be analyzed.

2.4. Content Validity

Professors majoring in cognitive psychology (N.5) from Al Qassim University and King Saud University reviewed the initial version of the test, and provided some comments. The author dealt with the comments the reviewers provided. The final version of the test included six geometric colored 3-D stimuli rotated by (30˚, 60˚, 90˚, 120˚, 150˚, 180˚) with and counterclockwise which produced (144) trials that appear randomly, out of the trials (72) were identical and (72) non-identical.

2.5. Construct Validity

The test was administered on a pilot sample of (20) students to verify the construct validity. Construct validity was calculated based on Kuder-Richardson formula (KR-20) for the correct answers. Reliability coefficient reaction time calculated by Cronbach Alpha, it scored (.88) and (.90).

The test is corrected electronically, one mark was accounted for each correct answer and zero mark is accounted for the wrong answer, total score ranged between (0-144). Reaction time was also calculated.

2.6. Variables of the Study

Dependent variables. Reaction time on the mental rotation test and number of the correct answers. Independent variables. Academic year and gender (between participants), rotation angle for the individual participant.

Statistical Analysis, An ANCOVA analysis carried out, followed by least significant difference (L.S.D) for posttest comparisons.

3. RESULTS AND DISCUSSION

The main questions in the study were; Is mental rotation ability (measured by the number of correct answers) different according to academic year, gender, and angular rotation?

Table (2) presents the means and standard deviations of the student's correct answers on mental rotation test based on academic year, gender and rotation angle.

Table-2. Means and Standard Deviations of the Student's Correct Answers on Mental Rotation Test Based on Academic Year, Gender and Rotation Angel.

		Males			**Females**			**Total**		
	Year	M.	SD.	N.	M.	SD.	N.	M.	SD.	N.
answers 30˚	1st	1.25	0.639	20	1.05	0.945	20	1.15	0.802	40
	2nd	1.40	0.681	20	1.25	0.639	20	1.33	0.656	40
	3rd	1.60	0.503	20	1.40	0.681	20	1.50	0.599	40
	4th	1.80	0.410	20	1.60	0.503	20	1.70	0.464	40
	Total	1.51	0.595	80	1.33	0.725	80	1.42	0.668	160
answers 60˚	1st	1.05	0.686	20	0.95	0.686	20	1.00	0.679	40
	2nd	1.30	0.733	20	1.00	0.725	20	1.15	0.736	40
	3rd	1.40	0.681	20	1.25	0.639	20	1.33	0.656	40
	4th	1.60	0.598	20	1.40	0.503	20	1.50	0.555	40
	Total	1.34	0.693	80	1.15	0.658	80	1.24	0.680	160
answers 90˚	1st	0.95	0.605	20	0.85	0.587	20	0.90	0.591	40
	2nd	1.00	0.725	20	0.95	0.686	20	0.98	0.698	40
	3rd	1.25	0.716	20	1.00	0.725	20	1.13	0.723	40
	4th	1.40	0.598	20	1.25	0.716	20	1.33	0.656	40
	Total	1.15	0.677	80	1.01	0.684	80	1.08	0.682	160
answers 120˚	1st	0.85	0.813	20	0.75	0.716	20	0.80	0.758	40
	2nd	1.00	0.725	20	0.85	0.813	20	0.92	0.764	40
	3rd	1.00	0.795	20	0.95	0.887	20	0.98	0.832	40
	4th	1.25	0.639	20	1.00	0.858	20	1.13	0.757	40
	Total	1.03	0.746	80	0.89	0.811	80	0.96	0.78	160
answers 150˚	1st	0.75	0.851	20	0.65	0.875	20	0.70	0.853	40
	2nd	0.80	0.834	20	0.75	0.786	20	0.77	0.800	40
	3rd	0.95	0.945	20	0.80	0.768	20	0.88	0.853	40
	4th	1.00	0.918	20	0.95	0.887	20	0.98	0.891	40
	Total	0.87	0.877	80	0.79	0.822	80	0.83	0.848	160
answers 180˚	1st	0.65	0.813	20	0.55	0.826	20	0.60	0.810	40
	2nd	0.75	0.786	20	0.65	0.813	20	0.70	0.791	40
	3rd	0.75	0.786	20	0.75	0.786	20	0.75	0.776	40
	4th	0.95	0.945	20	0.80	0.768	20	0.88	0.853	40
	Total	0.78	0.826	80	0.69	0.789	80	0.73	0.807	160

Observed differences are noticed in Table (2) due to the difference in academic year, gender and rotation angle (measured by correct answers on the test). To determine the significance of these differences 3-way ANCOVA analysis was used, and the results are exhibited in Table (3).

Table-3. 3-Way ANCOVA Analysis of Academic Year, Gender and Rotation Angel Effect on Mental Rotation Ability (measured by correct answers.

Source	Sum of Squares	df	Mean S	F	Sig.
Answers Rotation Angle	52.663	1	52.663	60.920	0.000
Rotation Angel* Gender	0.366	1	0.366	0.423	0.516
Rotation Angel* Academic Year	1.580	3	0.527	0.609	0.610
Error (Rotation Angel)	133.991	155	0.864		
Gender	4.538	1	4.538	3.300	0.071
Academic Year	20.146	3	6.715	4.883	0.003
Error	213.146	155	1.375		

Table (3) shows significant differences at (α=0.05) due to Angle rotation, *F* scored (60.920) and significance scored (0.000). There were no statistical differences at (α=-0.05) due to interaction between rotation angle and gender, *F* scored (0.423) and significance scored (0.516); no statistical differences at (α=-0.05) due to interaction between rotation angle and academic year were found, *F* scored (0.609) and significance (0.610). No statistical differences at (α=-0.05) due to gender is found, *F* scored (3.300) and significance (0.071). The only statistical differences were found in the academic year effect at (α=-0.05), *F* scored (04.883) and significance (0.003). To reveal binary differences LSD posttest is used, and the results are exhibited in Table (4).

Table-4. LSD Posttest of Rotation Angel on Mental Rotation Ability (measured by correct answers)

	Mean Square	30˚	60˚	90˚	120˚	150˚	180˚
30˚	1.419						
60˚	1.244	.175*					
90˚	1.081	.338*	.163*				
120˚	0.956	.463*	.287*	0.125			
150˚	0.831	.588*	.412*	.250*	.125*		
180˚	0.731	.688*	.512*	.350*	.225*	.100*	

* significance at (α=-0.05)

Table (4) indicated to statistical differences at (α=-0.05) between; angle (30˚) and angles (60˚, 90˚, 120˚, 150˚, 180˚) in favour of angle (30˚), in favour of (60˚) compared with (90˚, 120˚, 150˚, 180˚), in favour of (90˚) compared with (150˚, 180˚), and in favour of (120˚) compared with (150˚, 180˚), and in favour of (150˚) compared with (180˚). Binary differences of rotation angle on mental rotation is also calculated and presented in Table (5).

Table-5. LSD posttest of rotation angel on mental rotation ability (measured by correct answers)

Academic Year	Mean Square	1st	2nd	3rd	4th
first year	0.858				
second year	0.975	0.117			
third year	1.092	.233*	0.117		
fourth year	1.25	.392*	.275*	0.158	

* significance at (α=-0.05)

Table (5) shows significant differences at (α=-0.05) between the first academic year with third and fourth years in favour of third and fourth, statistical differences at (α=-0.05) are also found between the second and fourth years in favour of the fourth year.

Rotation angle significant differences at (α=-0.05), i.e. increase in rotation angle decreases correct answers, may be explained by the task difficulty and complexity for the participants. If stimuli are rotated in small rotation angles, the cognitive processing, rotating, comparing and responding to them holds less mistakes compared with large rotation angles. This confirms that the cognitive process represented by mental rotation is not easy by which individuals may response to test questions without trying really to mentally rotate them to be able to answer with identicality or un-identicality. This consists with Nunez *et al.* (1998); and Curny and Graham (2004) studies confirmation of decrease of the number of correct answers with the decrease of rotation angle.

Gender differences were not significant in mental rotation test scores, due to the cognitive strategies used by both genders. The author observed that both males and females are skillful in using computer, what made mental rotation tasks seem easy and non-challengeable for both.

The current research differed from Khairul and Azniah (2006) results; they have found differences in speed and precision in favour of males. It also differed from Titze *et al.* (2009) study, they showed males outperform over females in mental rotation ability.

The results indicated significant differences at (α = -0.05) in mental rotation ability measured by the number of the correct answers according to the academic level, in favour of students in higher academic year. This may be explained by experience the student acquires by moving into a higher academic year through exposure to different training opportunities, the more training opportunities the student receives in his major the more it helps to find accurate solutions of facing problems. Intensive mental rotation ability enables students to rotate fast.

It is also attributed to the fact that higher academic year increases students mental rotation ability and precision meaning more correct answers, this means the correlation between academic year and number of correct answers is linear. The results of the current study agrees with the studies of Leone *et al.* (1993); Ferk *et al.* (2003); and Wilkenning and Brugger (2003) results, they all confirmed a linear correlation between mental rotation and academic year. But it differs from Oliver (2000) study which believes that mental rotation ability is faster among adolescents compared with old aged.

The second question about mental rotation ability (measured by reaction time) difference according to academic year, gender, and angular rotation is answered by calculating means and standard deviations of mental rotation ability (measured by reaction time according to academic level, gender and rotation angle as is shown in table (6).

Table -6. Means and Standard Deviations of Mental Rotation Ability (Measured by Reaction Time) Based on Academic Year, Gender and Rotation Angel.

		Males			**Females**			**Total**		
	Year	M.	SD.	N.	M.	SD.	N.	M.	SD.	N.
answers 30˚	1st	34.25	4.811	20	37.55	3.677	20	35.90	4.545	40
	2nd	30.00	3.853	20	31.35	3.573	20	30.67	3.731	40
	3rd	27.60	4.838	20	29.45	3.993	20	28.53	4.478	40
	4th	26.20	2.949	20	26.30	3.658	20	26.25	3.280	40

	Total	29.51	5.129	80	31.16	5.517	80	30.34	5.374	160
answers 60˚	1st	38.55	3.379	20	39.30	5.750	20	38.92	4.671	40
	2nd	33.20	2.966	20	35.15	2.834	20	34.17	3.029	40
	3rd	30.80	3.088	20	32.90	3.161	20	31.85	3.262	40
	4th	29.80	3.334	20	31.35	2.815	20	30.58	3.145	40
	Total	33.09	4.631	80	34.67	4.823	80	33.88	4.78	160
answers 90˚	1st	49.75	3.726	20	47.95	3.137	20	48.85	3.52	40
	2nd	44.40	4.248	20	44.40	3.185	20	44.40	3.706	40
	3rd	40.55	2.685	20	43.30	3.063	20	41.93	3.165	40
	4th	39.45	2.645	20	41.30	2.055	20	40.38	2.519	40
	Total	43.54	5.248	80	44.24	3.739	80	43.89	4.556	160
answers 120˚	1st	43.05	3.486	20	44.8	4.360	20	43.93	3.996	40
	2nd	39.50	5.652	20	40.45	2.946	20	39.97	4.475	40
	3rd	35.00	3.325	20	38.85	2.925	20	36.92	3.654	40
	4th	34.55	2.605	20	36.80	2.783	20	35.67	2.895	40
	Total	38.02	5.217	80	40.22	4.398	80	39.12	4.934	160
answers 150˚	1st	49.65	2.796	20	51.25	2.359	20	50.45	2.679	40
	2nd	48.35	2.925	20	48.35	2.390	20	48.35	2.637	40
	3rd	46.00	2.362	20	47.55	3.137	20	46.77	2.851	40
	4th	44.70	3.6	20	46.30	2.055	20	45.50	3.004	40
	Total	47.18	3.492	80	48.36	3.074	80	47.77	3.333	160
answers 180˚	1st	54.7	2.993	20	54.45	2.837	20	54.58	2.881	40
	2nd	51.65	2.641	20	52.40	1.847	20	52.03	2.281	40
	3rd	50.5	2.544	20	52.10	2.654	20	51.30	2.691	40
	4th	48.9	2.511	20	50.80	2.118	20	49.85	2.486	40
	Total	51.44	3.386	80	52.44	2.695	80	51.94	3.091	160

Table (6) shows apparent differences in means and standard deviations of mental rotation ability (measured by reaction time) due to difference in the academic year, rotation angle and gender. To identify the statistical significance between standard deviations a 3-way ANCOVA analysis was used as table 7 showed.

Table-7. 3-Way ANCOVA Analysis of Academic Year, Gender and Rotation Angel Effect on Mental Rotation Ability (measured by reaction time).

Source	Sum of Squares	df	Mean Square	F	Sig.
Rotation Angle (reaction time)	47990.88	1	47990.88	5758.83	0.000
Rotation Angel* Gender	4.973	1	4.973	0.597	0.441
Rotation Angel* Academic Year	416.378	3	138.793	16.655	0.000
Error (reaction time)	1291.684	155	8.333		
Gender	462.038	1	462.038	12.562	0.001
Academic Year	7399.838	3	2466.613	67.063	0.000
Error	5701.021	155	36.781		

Statistical differences at (α=-0.05) due to the rotation angle resulted, *F* scored (5758.830) and a statistical significance of (0.000). To identify Binary differences LSD posttest is used, and the results are exhibited in Table (8). Differences at (α=-0.05) due to the interaction between rotation angle and gender were not significant, *F* scored (0.597) and significance scored (0.441). Differences at (α=-0.05) due to the interaction between rotation angle and academic year is found, *F* scored (16.655) and significance scored (0.000). Means are represented graphically in Figure (2). Differences due to gender at (α = -0.05) were significant, *F* scored (12.652) and significance was (0.001) in favour of males (Mean, 242.77) compared with females (Mean, 251.10). Differences due

to the academic year at (α = -0.05) were significant, F scored (67.063) and significance was (0.000).

Table-8. LSD posttest of rotation angel on mental rotation ability (measured by reaction time)

	Mean Square	30˚	60˚	90˚	120˚	150˚	180˚
30˚	30.338						
60˚	33.881	3.544*					
90˚	43.888	13.550*	10.006*				
120˚	39.125	8.787*	5.244*	4.763*			
150˚	47.769	17.431*	13.887*	3.881*	8.644*		
180˚	51.937	21.600*	18.056*	8.050*	12.812*	4.169*	

* significance at (α=-0.05)

Table (8) reveals statistical differences at (α=-0.05) between; angle (30˚) and angles (60˚, 90˚, 120˚, 150˚, 180˚) in favour of angle (30˚), in favour of (60˚) compared with (90˚, 120˚, 150˚, 180˚), in favour of (90˚) compared with (120˚, 150˚, 180˚), and in favour of (120˚) compared with (150˚, 180˚), and in favour of (150˚) compared with (180˚), to reveal binary differences LSD posttest is used, and the results are as in Table (9).

Table -9. LSD Posttest of Rotation Angel on Mental Rotation Ability (measured by reaction time)

Academic Year	Mean Square	1st	2nd	3rd	4th
first year	45.438				
second year	41.6	3.838*			
third year	39.55	5.887*	0.117	2.050*	
fourth year	38.038	7.400*	*275.	3.562*	1.513*
* significance at (α=-0.05)					

Table (9) shows significant differences at (α=-0.05) between the first academic year with third and fourth years in favour of second, third and fourth years, statistical differences at (α=-0.05) are also found between the second year compared with the third and fourth years in favour of the third and fourth years. Statistical differences at (α=-0.05) are found between the third and fourth years in favour of the fourth year.

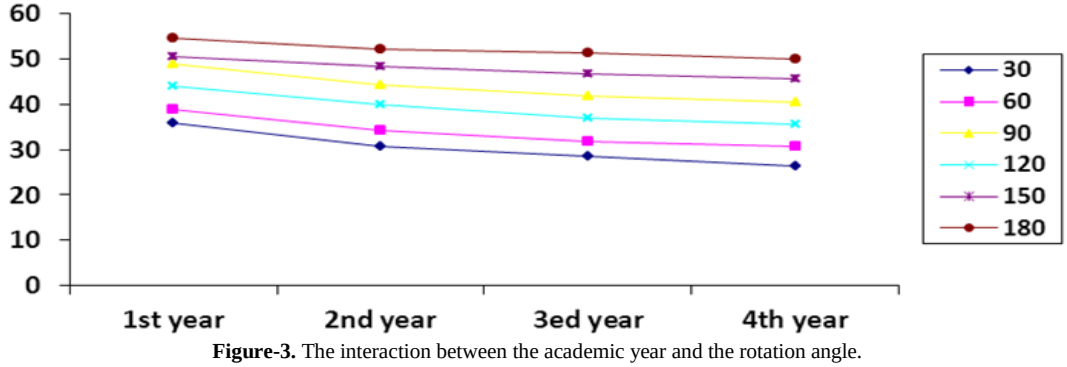

Figure-3. The interaction between the academic year and the rotation angle.

The graph shows the interaction between the academic year and the rotation angle in the ability of mental rotation (measured by the reaction time), it came in favour of (30˚) of all the academic

years. The results of no significant difference between gender and the mean of reaction time at (α = -0.05) is due to the fact that courses taught to the students are unified in subjects and involve spatial abilities skills, which means their experience is equal. The results differed from Khairul and Azniah (2006), their study revealed significant differences in responses precision and speed in mental rotation abilities among males.

Significant differences are found in reaction time at (α = -0.05) due to rotation angle, the increase in the rotation angle increases the time needed to give a response, the reaction time increase is due to the difficulty of spatial task represented in the ability of mental rotation, hence the need to encode, rotate and compare stimuli then to give a response requires more time, this resulted in a positive linear relationship. The time needed to response to a stimulus rotated by (90˚) is longer that the time needed to response to stimuli rotated by (30˚) or (60˚), this result agrees with Nunez *et al.* (1998) study, they found a positive linear relationship between rotation angle and reaction time.

4. ACKNOWLEDGEMENT

Praise be to Allah "Who creates, then makes complete, and Who makes (things) according to a measure, then guides" (Quran 87: 2, 3), and "thought man what he knew not" (Quran 96:5). Prayers and peace be on Mohammed the first teacher of mankind who guided us to the straight path.

Extended thanks, appreciation and gratitude goes to Al Qassim University for supervising this paper. I owe them a lot for motivating researchers to go forward. Sincere thanks to the people in charge of supported research represented by council of deanship of the scientific research who paid this research utmost attention and care. May Allah bless their efforts and guide their way.

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