The role of spatial experience in mental rotation

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Abstract. Mental rotation is one of spatial reasoning ability. It is the ability of a person to imagine how objects of a two- or three-dimensions look like when rotated in a specific degree. Not only due to curriculum demand, mental rotation is also essential for Mathematics itself, such as in geometry. In addition, it also helps students for their future career, such as architects, computer programmers, and graphic designers. This study aims to describe the mental rotation of female and male students who have spatial experiences with those who do not have spatial experience. The data were collected using Mental Rotation test and interview and were analysed qualitatively. A total of 10 post-graduate students were interviewed in a semi-structural way. The results showed that spatial experience has an important role in improving one's mental rotation.

1. Introduction

Mathematics is one of the subjects that must be studied by students at every level of education [1]. The importance of mathematics is not only learned in the classroom, but mathematics is close to daily life activities. Geometry is one of the important branches in mathematics and is heavily associated to the daily life [2] . It is the key to understand the nature with all its forms in the world. Geometry bridges daily events and mathematical concepts so that geometry has very important role in studying mathematics [3]. Geometry is one of the basic methods that people use to understand and to explain the physical environment by measuring length, surface area and volume [4]. In the pimary level, children learn about shape and use shapes to learn. In learning the geometry of shapes, they development through increasingly strong levels of thinking about shapes. Spatial reasoning complements geometric knowledge. Spatial reasoning is the process of forming ideas through spatial relationships between objects. It is a form of mental activity that allows one to make spatial figures and manipulate them in solving practical and theoretical problems.

Spatial reasoning or spatial thinking consists of several types, including building and manipulating two or three-dimensional objects, perceiving objects from different perspectives, and using images, diagrams, graphics, models or other concrete objects to explore, investigate, and understand abstract concepts like algebraic formulas or physical world models. [5]. Geometry is a tangible example of spatial reasoning in mathematics. most of the required thingking skills in higher mathematics is spatial. Spatial ability is known to be a predictor of mathematics achievement at all grade levels [6]. There are

eight types of spatial ability, such as: Spasial Visualization (Vz), Spatial Relations (SR), Flexibility of Closure/ Field Independence (CF), Environtmental Ability (EA), Spatial Orientation (SO), Closur Speed (CS), Perceptual Speed (P) dan Spatiomeporal Ability (SA) or Dynamic Spatial Ability (DSA) [7]. However, this paper discussed a small section on Spatial Relations (SR). SR is the ability to identify objects in rotated or mirrored state. One of these abilities is called mental rotation ability (MR).

1.1. Definition and importance of mental rotation

Some researchers identified several components of spatial ability [8], include spatial perception, spatial visualization, and mental rotation [9]. one can usually establish that two-dimensional object represents the same three-dimensional object although the object is depicted in a different orientation. One type of spatial reasoning is the ability of mental rotation. Mental rotation ability involves a cognitive process to mentally rotate or transform two- or three-dimensional objects to any direction showed through Spatial Visualization [10]. This ability implicates moving two- or three-dimensional objects around one or more axes in the mind's eye [11], and is indicated by the ability to recognize images of shapes presented in different orientations, decomposition and rotation. (See Figure 1).

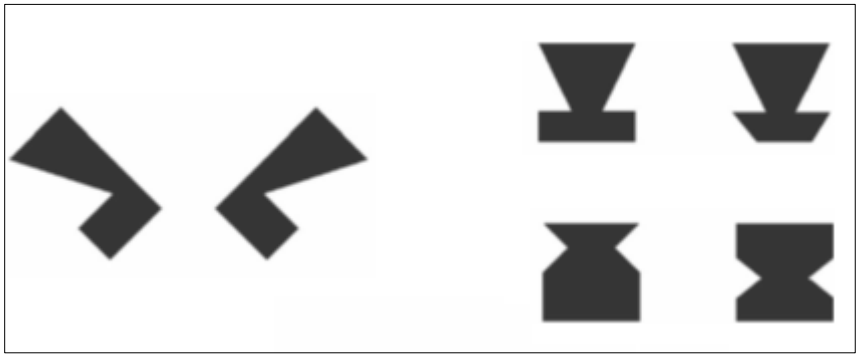

Figure 1. When we mentally rotate the two shapes on the left so that they are joined a centre y-axis. Which figure is formed (of the four on the right)? [12].

Mental rotation skills and geometry are mutually revealed to each other. we must also know that it is also a process of cognitive that is learned by cognitive scientists and neurologists [12]. Mental rotation ability can be used as a proper strategy for understanding area measurement task, composing and decomposing two- or three-dimensional object, proving symmetriy, and finding missing part of an object. [13]. These ability is also very much needed in everyday life, for example when driving a car, organizing objects effectively into limited space, and sports activities. Mental rotation ability are closely related to skills such as map reading [14] , orientating and navigating [8], verbal and visual-spatial working memory [15] and to overall problem solving too [16]. These abilities are used in daily life but three-dimensional mental rotation abilities are also clearly related to mathematics in the curriculum including school geometry [17], algebra [18], and mental mathematics [17].

1.2 Factors influencing mental rotation

There are several factors that can affect one’s mental rotation ability. Mohler reviewed that mental rotation of a person is influenced by age, brain physiology, gender, socio-cultural factors [19]. the ability of a person's mental rotation improves as the person grow older. The findings of Newcombe confirm this conclusion, that people of all ages can show an increase in mental rotation ability [20].

All of studies that try to see the correlation between brain physiology and mental rotation ability have gained a general agreement: individuals who use their right brain dominantly will have better mental rotation abilities than those who are more dominant using the left brain [21].

Many researches have found that men have better spatial abilities than women, especially in terms of mental rotation and Spatial Relations [8][9]. This study strengthens the 1974 study conducted by

Maccoby and Jacklin, which states that boys show better spatial performance than girls, especially when they have passed childhood phase [22].

The next factor that can affect a person's mental ability is socio-cultural factors where the dilemma includes games, gender roles, social expectations and parents, and other experiences that influence the development of children's abilities. In the selection of games, boys tend to play with toy cars and blocks, which requires spatial ability, while girls tend to play with dolls, which will have an impact on the development of their social abilities [6]. Gymnastic exercise [23] and struggle [24] can also affect their mental rotation ability.

Spatial enhancement skills can also be done with spatial training which is more common than just task-specific practice. For example computer and videogame usage are linked to improvements in mental rotation and other related spatial tasks [25] [26] [27]. Another Example, mental rotation can be developed through task-spatial, such as tetris, Card Rotation, paper folding and Form Board tasks. Activities in game can be called spatial experience. With regard to the factors that affect the mental ability of rotation, in this research will focus more on the role of spatial experience on the person's mental rotation ability.

2. Method

This study was a descriptive qualitative. 10 post-graduate students were recruited as participants. The participants are selected based on their spatial experience. By experience, it is that they've encountered spatial problems in aptitude test, such as in the university admission test. The instruments used were tests and interviews. The test is used as an instrument to obtain data about mental rotation ability consisting of 4 multiple choice questions and six questions interviews related to spatial experience.

The three items in the test instrument are about the rotation of a 3D shapes and one question is about the nets of 3D shape. Interview questions consist of the level of experience participants had working on related questions, the level of difficulty of the problem, and the game played in relation to two- or three-dimensional shapes. Each item was scored 1 when both correct alternatives were chosen, and individual items scores were summed in a total score. Participants who answered correctly all items of mental rotation ability test were categorized as respondents who had high mental rotation ability and students weith less than two correct answers were categorized as low mental rotation ability. The results of the test instrument analysis will be matched with the results of the interview.

3. Result and Discussion

The distribution of correct and wrong answers to each item is presented in Table 1.

Tabel 1. Frequency and percentage of correct and wrong answers for each item

Item		**1**	**2**	**3**	**4**
Correct	**Frequency**	6	8	8	7
	Percentage	60%	80%	80%	70%
Wrong	**Frequency**	4	2	2	3
	Percentage	40%	20%	20%	30%

Based on the data presented in Table 1, it is observable that 40% of students get low score in item 1 : Rotating cubes with distinct attributes on each side. Meanwhile 80% students were able to answer second and third questions correctly.

Based on the results of the mental rotation ability test, it was found that 6 participants (S1, S2, S3, S5, S6, and S9) correctly answered the whole test of mental rotation ability. While the rest (S4, S7, S8, S10) only answered correctly 1 number out of all the test questions given.

Further questionnaire were conducted on all respondents. From the results of the student interview analysis were obtained:

a. Experience of working on the problems that are similar to a given test.

90% of students answered having worked on the similar problems before, 10% said never. Most of the respondents stated that they worked on the questions in admission test for universities. There was also respondent said that he is a private tutor focusing on aptitude test and makes him frequently deal with spatial questions.

b. Level of difficulty items.
20% of students felt that the mental ability test given was easy. 70% of students said the test was medium, and 10% of students say it's difficult. In relation with spatial ability, every students have different spatial ability [26]. Gender difference is the most popular area for research. Several studies stated that there is a notable difference of spacial ability between men and women [28]. However, there is no difference between males and females in term of spatial reasoning ability[4] .

c. Spatial experience.
Spatial experience obtained from respondents is very diverse. But it is more dominated by the experience of playing computer games. Respondents who have high mental rotation ability, some said that they often practice working on spatial ability questions, there are also respondents who said that they like and often play 2d-3d computer games and real games such as Lego and Rubics, some said they have designing as a hobby. While respondents with low mental rotation ability said that they were not playing games related to two or three-dimensional shapes.

From point (c) above, it is shown that computer games affect a person's mental rotation skill. This is supported by the results of Sims and Mayer's study which found that task-specific improvement in spatial performance following tetris and videogame playing [29]. The two respondents who said that they often practice working on spatial ability questions also affect their mental rotation. This is in accordance with the law of exercise theory proposed by Thorndike. It is said that the more often a response or behavior is done, the better a person's ability in that matter [30]. This theory is in line with the findings of Sternberg et al. which states that a person's cognitive abilities can be more accurate and fast through practice [31].

Female participants who were active in art, music, or athletic activities had experience in more spatial activities and obtained higher score in mental rotation test compared to those who do not take part in such activities. This shows that practice is essential factor that cause the gender difference in term of spatial skill [32]. Moreover, the gap in spatial ability due to the gender difference can be narrowed with practice.

4. Conclusion

Based on the results above it can be concluded that spatial experience has an important role in the mental ability of a person's rotation. This research ensures the notable impact of long-term training or repeated testing, and the potential for training in improving mental rotation performance despite both mental rotation training and videogame training reduces gender differences in spatial skills. This might be a recommendation for teachers to pay a closer attention in character of female students and male students and the difference it makes in learning geometry and spatial ability. By doing this, teachers are expected to be able to find the best fit and efficient learning method to apply in the classroom.

References

[1] Utami R W and Wutsqa D U 2017 *Jurnal Riset Pendidikan Matematika.* **4** 166–75
[2] Retnawati H 2017 *Int. J. New Trends Educ. their Implic.* **34** 390–403
[3] Biber C, Tuna A and Korkmaz S 2013 *Eur. J. Sci. Math. Educ.* **1** 50–9
[4] Hwang W Y, Su J H, Huang Y M and Dong J J 2009 *Educ. Technol. Soc.* **12** 229–47
[5] Kinach B M 2012 *Math. Teach.* **105** 534–40
[6] Clements D H and Battista M T 1992 Geometry and spatial reasoning *Handbook of Research on Mathematics Teaching and Learning* pp 420–64
[7] Yilmaz B and Yilmaz H B 2009 *Int. Electron. J. Elem. Educ.* **1** 83–96
[8] Linn M C and Petersen A C 1986 *Psychol. Gend. Adv. through meta-analysis* 67–101
[9] Voyer D, Voyer S and Bryden M P 1995 *Psychol. Bull.* **117** 250–70

[10] Carroll J B 2007 Human cognitive abilities A survey of factor-analytic studies *Cambridge Handb. Phonol.*
[11] Shepard R N and Metzler J 1971 *Science (80-.).* **171** 701–03
[12] Bruce C D and Hawes Z 2015 The role of 2D and 3D mental rotation in mathematics for young children: what is it? Why does it matter? And what can we do about it? *ZDM Math. Educ.* **47** 331–43
[13] Cheng Y L and Mix K S 2014 *J. Cogn. Dev.* **15** 2–11
[14] Pazzaglia F and Moè A 2013 *Cogn. Process.* **14** 391–9
[15] Kaufman S B 2007 S *Intelligence* **35** 211–23
[16] Geary D C, Saults S J, Liu F and Hoard M K 2000 *J. Exp. Child Psychol.* **77** 337–53
[17] Delgado A R and Prieto G 2004 *Intelligence* **32** 25–32
[18] Kyttälä M and Lehto J E 2008 *Eur. J. Psychol. Educ.* **23** 77–94
[19] Mohler J L 2008 A review of spatial ability research *Eng. Des. Graph. J.* 19–30
[20] Newcombe N S 2013 *Am. Educ.* **37** 26
[21] McGlone J 1980 *Behav. Brain Sci.* **3** 215–27
[22] Maccoby, E. E., & Jacklin C N 1978 *The psychology of sex differences*
[23] Jansen P and Lehmann J 2013 *Adv. Cogn. Psychol.* **9** 92–8
[24] Moreau D, Clerc J, Mansy-Dannay A and Guerrien A 2012 *J. Individ. Differ.* **33** 83–8
[25] De Lisi R and Wolford J L 2002 *J. Genet. Psychol.* **163** 272–82
[26] Roberts J E and Bell M A 2000 *Percept. Mot. Ski.* **91** 1027–34
[27] Asis, M., & Nurdin Arsyad A 2015 Profil kemampuan spasial dalam menyelesaikan masalah geometri siswa yang memiliki kecerdasan logis matematis tinggi ditinjau dari perbedaan gender *Daya Mat. J. Inov. Pendidik. Mat.* **3** 78–87
[28] Ganley C M and Vasilyeva M 2011 *J. Appl. Dev. Psychol.* **32** 235–42
[29] Sims V K and Mayer R E 2002 *Appl. Cogn. Psychol.* **16** 97–115
[30] Travers J F, Elliott S N and Kratochwill T R 1993 *Educational psychology: Effective teaching, effective learning*
[31] Sternberg R J, Kaufman J C and Grigorenko E L 2008 *Applied intelligence*
[32] Ginn S R and Pickens S J 2005 Relationships between spatial activities and scores on the mental rotation test as a function of sex *Percept. Mot. Skills* **100** 877–81