Applied & Educational Psychology (2025)
Clausius Scientific Press, Canada

DOI: 10.23977/appep.2025.060107
ISSN 2523-5842 Vol. 6 Num. 1

An intervention study of mental rotation skills in older children

Li Min[1], Tian Jing[1]

[1]*College of Education, Chengdu University, Chengdu, China*

Keywords: Gamified instruction; mental rotation skills; older children

Abstract: Mental rotation is important for individual development and is "teachable", but there is a scarcity of research on intervention programs for preschool children that are tailored to the daily work of kindergartens. In this study, we used a 2 (time: pre-test/post-test) × 2 (group: experimental/control) experimental design, and based on the concept of "teaching for fun", we conducted 8 play-based teaching activities for 4 weeks with 20 children in the experimental group. The study found that: (1) the development of children's mental rotation ability is limited under the state of "letting nature take its course", and its enhancement needs to be improved through the intervention of educational activities; (2) game-based teaching can effectively improve children's mental rotation ability; (3) the development of children's mental rotation ability has the difference of rotation direction and rotation angle.

1. Presentation of the issue

Mental rotation, also known as "mental rotation" or "imagery rotation", is a cognitive psychology term that refers to the ability of a person to make a flat or three-dimensional movement of the image of a visual stimulus in his/her mind. [1]In the process of exploring mental rotation, many studies have attempted to intervene in children's mental rotation ability and achieved certain results. Those studies give us an important message: mental rotation is important for individua development and is "teachable", which warrants attention in the field of education.[2] However, from the overall viewpoint of the existing research results, there are few empirical studies from the perspective of educational interventions, especially the scarcity of research results that target preschool children and use intervention programs that are in line with the reality of kindergarten's daily work. Therefore, it is worthwhile to further validate the effects of interventions through experiment a studies and to develop educational intervention programs that can be modeled on the age-appropriate characteristics of children.

2. Study design

2.1 Measurement tools

The Peter 1995 version of the mental rotation experiment material is a more common measurement tool. [3]The present study enriched the measurement materials based on Peter's version

by adding four stimuli each of number, fruit, and icon stimuli. Thus, the measurement task of the present study contained a total of five categories of stimulus images, with four task cards for each category, including clockwise and counterclockwise rotations of four 5 °, 90 °, 135 °, and 180 ° angles (Fig. 1 as an example). On the left side of each task card was at arget stimulus, and on the right side there were a total of four images, two of which were images of the target stimulus after counterclockwise and clockwise same-angle rotations, and the other two were images of rotations of mirror images of the target stimulus.

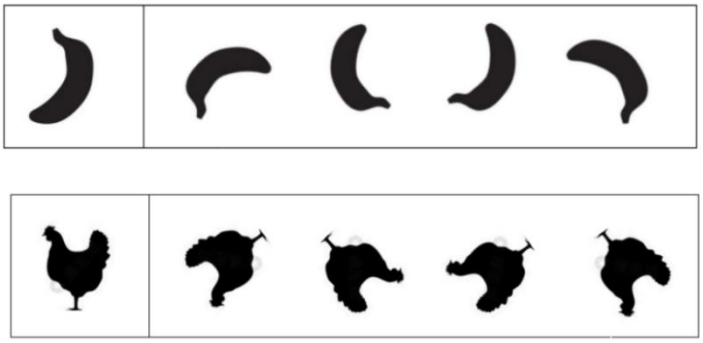

Figure 1 Measurement tools used in this study (animal and fruit examples)

2.2 Study subjects

A township kindergarten in a county in Ankang City, Shaanxi Province was selected as the research base for this study. The kindergarten had a total of three large classes, and since it was not possible to readjust the division of classes, the first and third large classes were identified to participate in this study upon the recommendation of the kindergarten. The researcher used a numbered lottery method to select 10 male and female children each from each class, totaling 40 children to participate in the study, and obtained the consent of the children's guardians.

2.3 Intervention programs

This study focuses on the goal of cultivating the mental rotation ability of kindergarten children, and designs two preparatory activities and eight Game-based Teaching activity programs. The design of the teaching activities focuses on "internalizing the spirit of play in the teaching context", and the process of the activities emphasizes the "organic combination of play and learning.

2.4 Research process

This study utilized a 2 (time: pre-test/post-test) x 2 (grouping: experimental/control) experimental design, where time was the within-subjects variable and grouping was the between-subjects variable. The whole study was implemented in a total of several steps:

In the first step, the researchers worked with the teacher of Class 3, Grade 1, to carry out two preparatory activities for the classes one week before the pretest. The two preparatory activities were "Magic Mirror" and "Knowing the Clock". The purpose of these activities was to ensure that children could understand and distinguish the concepts of mirror image and rotation before the test.

In the second step, 40 children were pre-tested on the mental rotation task and the results were analyzed for the third and first classes. Considering that the third class was significantly lower than the first class, the third class was set up as the experimental group and the first class as the control group.

In the third step, the experimental group was given eight sessions of mental rotation play-based

instruction in the third class for four weeks. Each activity lasted 15-20 minutes and was implemented by the researcher in collaboration with the class teacher.

In the fourth step, the posttest of the mental rotation task was administered to the 40 children again the following week after the intervention program was completed, and the between-group and pre- and posttest differences were statistically analyzed. Both the pre-test and post-test were administered individually by the researcher to each kindergarten at the same location, on a one-to-one basis.

3. Findings

3.1 Difference in scores between pre- and post-tests of the experimental grouptest

3.1.1 Overall variances

See the Table 1, according to the criteria for grouping score bands in the pre-test, the number of toddlers whose mental rotation ability was at a low, intermediate, and high level was 1, 9, and 10, respectively. It can be seen that the mental rotation ability of the children in the experimental group was mostly at the medium level in the pre-test and transformed to mostly at the high level in the post-test. The paired samples t-test showed that there was a highly significant difference between the pre and post-test scores of the experimental group. The level of the posttest was significantly higher than the level of the pretest, indicating that the gamification instruction achieved a good intervention effect.

Table 1 Mental rotation ability in the experimental group

	M	**SD**	**Max.**	**Min**	**P**
pre-testing	22.40	9.65	38	8	.000 ***
post-test	31.25	8.45	40	9	

Note: * denotes p < 0.05; ** denotes p < 0.01; *** denotes p < 0.001, and the same below.

3.1.2 Variations by dimension

By examining the differences in children's performance in different dimensions of the mental rotation task in the experimental group, the results showed that: All significant differences except for the numeric category (see Table 2).

Table 2 The dimension of mental rotation ability in the experimental group

different dimension		**Pre-test**	**Post-test**	**P**
direction of rotation	counterclockwise	10.10±5.57	14.75±4.71	.000***
	counterclockwise	12.30±4.81	16.5±4.16	.000 ***
angle of rotation	45 °	5.45±3.24	7.90±5.27	.001***
	90 °	4.75±2.32	6.90±2.99	.011*
	135 °	7.40±2.28	9.40±0.94	.001***
	180 °	4.80±2.59	7.15±2.98	.000***
stimulus category	alphanumeric	4.20±1.99	6.70±1.84	.000***
	animals	4.75±2.30	6.35±1.60	.003**
	numeric category	5.15±2.28	6.00±2.10	.108
	fruit	4.05±2.33	6.35±1.60	.000***
	icon class	4.25±2.51	6.00±2.10	.002**

3.2 Difference between pre- and post-test scores in the control group test

See the Table 3, the 20 children in the control group had a mean pre-test score of 30.4, a maximum score of 40 and a minimum score of 17.The results showed that 3 children had low level of mental rotation ability (total score less than 24), 5 children had high level of rotation ability (total score greater than 38), and the other 12 children had moderate level of mental rotation ability. In the posttest, the mean score was 30.25, the maximum score was 40, and the minimum score was 15; according to the criteria for grouping score bands in the pre-test, the number of toddlers with low, medium, and high levels of psycho-rotational ability was 5, 9, and 6, respectively. Paired samples t-tests indicated that there was no significant difference in the pre and post-test scores of the control group.

Table 3 Mental rotation ability in the control group

	M	**SD**	**Max.**	**Min**	**P**
pre-testing	30.40	6.39	40	17	.940
post-test	30.25	8.12	40	15	

3.3 Test of differences in scores between the experimental and control groups

By comparing the overall scores of the pre- and post-tests of the mental rotation ability of the children in the experimental and control groups, it was found that the difference between the two groups from the pre-test, which was highly significant [F=4.941, P=0.004**], became non-significant [F=0.001, P=0.705] in the post-test (see Table4). The experimental group went from being significantly weaker than the control group before the intervention to catching up with the control group after the intervention, which means that the experimental group effectively improved the level of mental rotation ability after receiving the intervention of game-based instruction.

Table 4 Mental rotation ability in the experimental and control groups

	experimental group	**control subjects**	**F**	**p**
pre-testing	22.40±9.65	30.40±6.39	4.941	.004**
post-test	31.25±8.45	30.25±8.12	.001	.705

4. Analysis and discussion

4.1 Possible large differences in the level of development between administrative kindergarten classes

Significant differences in mental rotation ability were found in parallel kindergarten placement in the pre-test task, specifically the mean pre-test score of the experimental group was significantly lower than the mean pre-test score of the control group. Through non-participant observation of the two classes and interviews with teachers, the researcher analyzed that the reason for this may lie in the fact that different main classroom teachers bring different reserves of prior experiences to the children. Differences between the two teachers arose during the implementation of specific math activities, with Ms. L stating, "We usually have some training related to rotation, orientation, and directional movement in our activities, and I intentionally give out some instructions when we play down there "on the playground." Teacher W, on the other hand, stated, "Usually the children are brought to the unified specialized activity area for learning and these are talked about during class." Overall, Ms. L used a more intuitive, manipulative and experiential approach to infuse experiences about rotations and orientations in her activities, providing children with a greater reserve of prior

experiences. This reveals the importance of emphasizing the differences between children's developmental levels that may occur in different classes due to teacher literacy and style.

4.2 Game-based teaching can effectively enhance the mental rotation ability of kindergarten children

In the pre-test task, the control group's total score of 608 was much higher than the experimental group's 448; however, in the post-test task, the experimental group overtook the control group's 605 with a total score of 625. At the same time, the experimental group's posttest scores were significantly higher than the pretest scores, and the experimental group was significantly weaker than the control group from the pretest to the posttest where there was no significant difference. All these data indicate that the gamification teaching intervention used in this study effectively improved the mental rotation ability of the older children.

4.3 Characteristics of the development of mental rotation in older children

In the study, it was found that the development of young children's mental rotation ability has dimensional differences. First of all, in terms of rotation direction, the present study is consistent with Liu Qi's findings, and the data showed that children performed better in counterclockwise rotation direction than clockwise, which may be influenced by the position of card arrangement. The significant difference between the two groups of children in the counterclockwise direction in the pre-test disappeared in the post-test, suggesting that the effect of gamification teaching on enhancing children's mental rotation ability in the counterclockwise direction was significant.

5. Conclusions and reflections

5.1 Conclusions of the study

Based on the above findings and discussions, the present study has four conclusions: first, the development of children's mental rotation ability is limited in the state of "letting nature take its course", and the enhancement of children's mental rotation ability needs to rely on the intervention power of educational activities. Second, the teaching activities of game-based teaching can effectively improve children's mental rotation ability, and can achieve more obvious results in a shorter period of time. Third, teacher quality is a crucial influence on the overall level of development of kindergarten classes, and it is important to be alert to the significant developmental differences that may exist between different parallel classes in the same kindergarten, in order to effectively safeguard the learning development of each class and each child.

5.2 Reflections on the way forward

In this study, only 20 older children aged 5-6 years old in the experimental group were provided with a gamified instructional intervention, so the validity of generalizing the achieved milestones to a larger group needs to be further tested. In addition, this study only focused on the mental rotation ability itself and did not explore the transfer effect of mental rotation ability. Looking ahead, related studies could expand the sample size and age range of subjects, more strictly control the effects of extraneous variables, and conduct long-term follow-up to further explore the process of change in the development of individual mental rotation ability.

References

[1] Pazzaglia F, Mo è A. Cognitive styles and mental rotationability in map learning [J]. Cognitive Processing. 2013, 14(4):391-399.
[2] Levine S C, Ratliff K R, Huttenlocher J, Canon J, Early puzzle piay: A predlictor of preschooler spatia transformation skill [J]. Development Psychology, 2012, 48(2):42-53.
[3] Jasen P, Schmelter A, Quasier pohl C, et al. Mentai rotation performance in primary school age children: Are there gender different in chronometric [J]. Cognitive Development, 2013, 28(1):51-62.