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THE EFFECT OF PENTOMINO ON THE SPATIAL ABILITY

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Abstract

An intelligence game, Pentomino, was used to discover whether it can improve students' spatial ability or not via spatial rotation.

A 2 (gender: male and female) × 2 (group: experiment group and control group) × 2 (cognitive style: field dependent and field independent) experiment was designed to conduct this research, where gender, group and cognitive styles were all between-subjects variables. After one month training, the data collected from both groups was analysed and then the results were as follows: For the spatial ability, Pentomino had some effects. In particular, the main effect of group was significant. Comparing the mean score of two groups, the performance of spatial rotation of experiment group was higher than that of control group, therefore, Pentomino had positive effect on students' spatial ability. In addition, the interaction effect of gender × group × cognitive style was marginally significant when analysing the performance of spatial rotation.

Keywords: Pentomino, cognitive style, groups, gender, spatial mental rotation.

1 Backgrounds and Questions

Pentomino is similar to the Tetris, each part of it is constructed by 5-connected cubes and one set of Pentomino has different 3D geometric shapes: cuboid, cubes and L, W shapes etc al. The rule of this game is to rotate and translate these 3D shapes to form a big 3D shapes. Therefore, the difference between Tetris and Pentomino is in that the latter one can be made into 3D shapes.

J.P.Guilford proposed the 3-dimensional model of intelligence, one dimension includes the factor of shapes, which belongs to spatial ability; in the two-dimensional model of intelligence (I.M.Schlesinger & L.Guttman), where the first dimension is language, number and shapes, obviously, "shapes" includes spatial ability; H.Gardner suggested that intelligence contained 7 factors, where spatial ability was one of them. So, from the above perspectives, spatial ability is one of the part of intelligence.

But presently, there is no exact definition about spatial ability and its analysis of its structure. Magee(1979) suggested that spatial ability contained two types: firstly, spatial imagination ability, which means that rotate, turnover the images mentally; secondly, spatial direction ability, which means that visual recognition of elements' arrangement and maintains this ability when direction changes. Bishop (1980) also mentioned two different types of spatial ability: 1. The ability of explaining information of shapes, which means that explain the used

spatial language in visual representation, geometry tasks, tables and so on; 2. Visual process ability, which contains spatial imagination and changing the imaging relationships or non-shape information into visual information, and includes the operation and transformation of visual representation and visual perceptual.

About the research of mental rotation, Marmor chose 5-8 year old children as participants and found that their reflection time and rotation angle had linear relationship, namely two groups children could represent rotation metally. 1988, Gonglin Hou, Xiaochun Miu used the rotated mickey mouse as experiment material to test 133 young children (3.5-6.5 year old) and found that children formed the rotation ability when they were 4 year old with continuous development. But when they were 5-6 year old, a negative development appeared. However, some researchers (Jane E.Platt & Sophia Cohen，1981) also used 5 year old children as subjects, and they found that non-training 5 year old children could not form that linear relationship of reflection time and rotation angle. However, Xiuhuan Liu, Wen Qian etc al (2007) did the research of 3-6 year old children and found that 3-4 year old children did not have mental rotation ability, 4-5 year old this ability formed, mostly 5-6 year old children had possessed this ability.

Specifically for the spatial mental rotation, Linn、Petersen and Voyer, Voyer and Bryden found that for the 3D mental rotation, the rotation speed was different between adults and youth. For children, speed and accurate rate both had gender differences. In addition, Maccoby and Jacklin (1974) regarded that the distinction of spatial skills happened in the early stage of adolescence, however, many opposite opinions showed that this distinction occurred at pre-school. Utall etc at (1999) found that 5-year-old boys explained spatial map better than the same age of girls, especially when this map represented rotation. For this difference, some researchers thought that partially because of the participation of activities which were relative to spatial ability (e.g. Baenninger & Newcombe, 1995; Voyer, Nolan, & Voyer, 2000), therefore, this gender difference may could be reduced via this connection. But Baenninger and Newcombe (1989) found that the spatial ability of male and female developed at the same space, so this gender difference would never be changed.

About using computer games to effectively improve primary students' spatial ability, Lisi and Wolford (2002) demonstrated that the children whose accuracy of mental rotation was low improved their this ability after playing Tetris. Similarly, Terleck、Newcombe and Little found that undergraduate also improved their mental rotation ability after playing Tetris and this ability was stable and transferable. Therefore, using compter games could improve students' spatial ability.

Questions:

According to the previous research studies, most were about Tetris which were based on computer and did not did in real classroom, and Tetris is one 2D game. Therefore, there were not so many researches using intelligence game to investigate the spatial ability in classroom setting.

So based on the views above, this research will consider two potential questions:

(1) Use Pentomino which is similar to Tetris in real classroom and let students play this game by hands, what will happen? Namely, in the real teaching condition, whether this game

will also improve students' mental rotation ability?

(2) As Pentomino is 3D game, therefore compared to Tetris, whether this game will have positive effect on students' spatial ability?

Research purpose and hypotheses:

The main research purpose was to investigate that whether Pentomino would have positive effects on secondary students' spatial ability, especially the spatial mental rotation ability.

Therefore, the hypothesis of this research was:

(1) Pentomino will have positive effects on students' spatial ability, especially the spatial mental rotation ability;

(2) In the real teaching condition, the spatial ability will also be improved.

2 Experiment Research

2.1 Subjects

Two year 8 classes students were chosen as subjects, totally 68, and were divided into experiment and control group. All of them took the pre-test and post-test, where valid data were 60 (boys 27, girls 33). In control group, two students' mistake rate was 80%, showing that they did not understand the test, so were deleted. The other 6 student' scores were deleted as they did not both took pre-test and post-test, so their data were not complete. Finally, the cognitive style was judged by the pre-test scores of Mosaic pattern (field dependent: 1-7 out of 10; field independent: 7-9 out of 10).

2.2 Variables

2.2.1 independent variables:

Cognitive style (field independent and field dependent), Gender (male and female), Group (experiment group and control group), co-variable: pre-test.

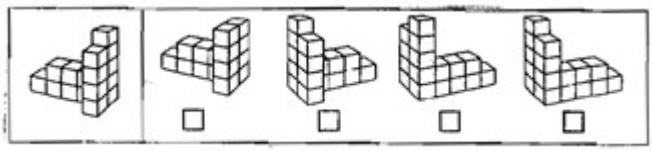
2.2.2 dependent variables:

Spatial mental rotation performance.

2.3 Experiment material and tests

The experiment material was Pentomino and two tests: pre-test and post-test, where these test items were adapted from SOI test（CR）and the 1981 Mosaic pattern test of Beijing Normal University. Test materials contained two parts: metal rotation test and figure recognition test. The first part was mental rotation test, totally 13 items, the first 5 questions were not scored, but used for judging whether students understood this test. This part required students to do this test mentally. The second part test tested students to pick simple shapes from complex one and was used to test filed-independent and field-depend ability.

One example of test item:



2.3 Procedures

(1) The time of this experiment was one month. Each week, experiment group practiced

with Pentomino half an hour;

(2) Experiment group (with Pentomino) and control group (without Pentomino): Control group did regular math study according to school time table; experiment group was given the Penomino by experimenter, and then practiced it in half an hour each week: the first two study sessions were about how Penomino came and forming some familiar shapes: according to PPT, students in experiment group learned that each part of Pentonimo consisted of 5 small cubes, and experimenter gave some conditions to ask students to rearrange the 5 small cubes on paper to make different possible shapes, and then students were required to cancel the same shapes through rotation, translation, finally they got 12 different shapes, which was the Pentomino. The experimenter then pointed some parts of Pentomino and let students form differently regularly rectangles (the number of required parts increased from 3 to 6, so did the difficulty). When they were familiar with forming the rectangle, some letter tasks (W shape, L shape etc al) were represented, these tasks required students to fill in the incomplete outline of letter shapes. When designed these letter shapes, they were physically rotated by 45°、90°、135°、180° . After first 2 sessions, students were required to form 3D shapes in last two sessions: firstly, students were required to watch the pictures about to-be-formed 3D shaps and then students were required to form this by themselves, if they found that was difficult to finish by themselves, the instructions of each floor of this 3D shape were given and then required students to form this 3D shape according to these instructions. At the end of learning phase, students were required to form one 3D shape and drew its instructions of each floor, then asked other students to form this shape based on these instructions.

(3) Score: the original score was 0 (wrong) and 1(correct), but in order to reflect different levels of students' ability, difficulty coefficient of each item was considered. The score was finally processed according to the item analysis theory.

2.4 Results

2.4.1 Descriptive results and analysis

SPSS 19.0 was used to analyse data, where gender (male and female), group (experiment and control) and cognitive style (field independent and field dependent) were all between-subject variables.

Table 1 was the descriptive analysis of spatial mental rotation:

Table 1 descriptive analysis of spatial mental rotation

gender	cognitive style	group	mean	SD	N
male	Field dependent	control	**.0725**	**.05751**	**6**
		experiment	**.1250**	**.00000**	**5**
	Field independent	control	**.1250**	**.00000**	**11**
		experiment	**.1040**	**.04696**	**5**
female	Field dependent	control	**.0810**	**.05285**	**10**
		experiment	**.1094**	**.04419**	**8**
	Field	control	**.0950**	**.05123**	**7**

independent	experiment	**.1250**	**.00000**	**8**

From the table above, for field-dependent male, mean score of spatial rotation for experiment group (M=0.1250 SD=0.0000) was higher than that of control group (M=0.0725 SD=0.05751), but the opposite result occurred for field-independent male. For female, no matter the field dependent or field independent, the performance of experiment group was higher than that of control group, specifically, field-dependent female, experiment group's mean (MS=0.1094 SD=0.04419), but control group's (MS=0.0810 SD=0.05285); field-independent female, experiment group's mean (MS=0.1250 SD=0.00000) and control group's (MS=0.0950 SD=0.05123), therefore, study in experiment group did happen and it showed that this intelligence game for female, no matter which kind of cognitive style, had positive effects on their spatial rotation ability, the same as field-dependent male.

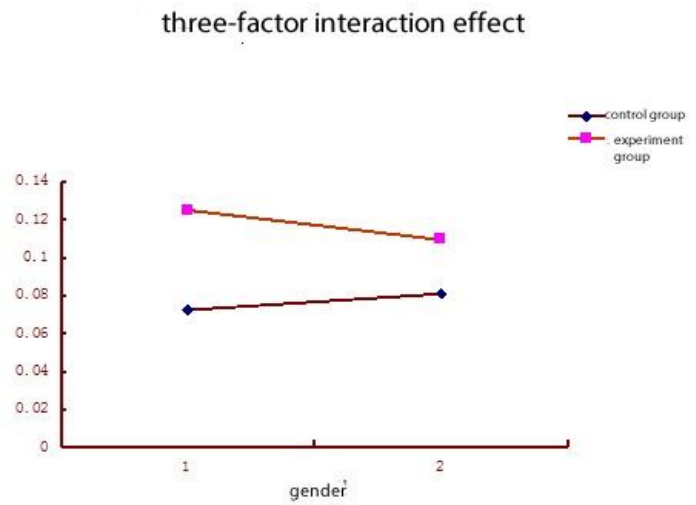
The ANOVA analysis was used (table 2)

Table 2 ANOVA analysis of spatial ability

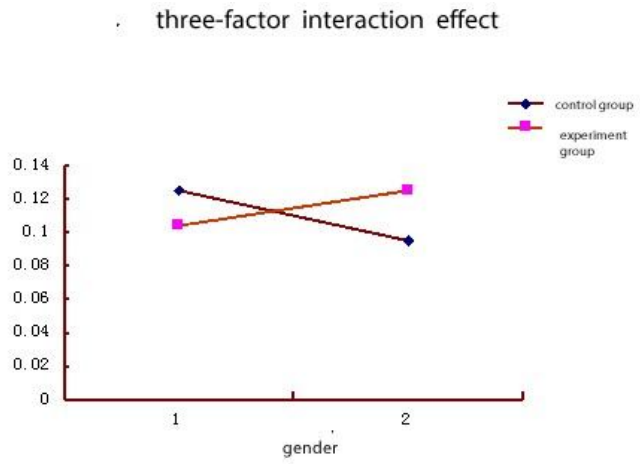
resources	**df**	**MS**	**SD**	**F**	**Sig.**
Pre-test	**1**	**.000**	**.05751**	**.199**	**.658**
gender	**1**	**.000**	**.00000**	**.134**	**.716**
cognitive style	**1**	**.003**	**.00000**	**2.241**	**.141**
group	**1**	**.007**	**.04696**	**4.477**	**.039**
gender × cognitive style	**1**	**6.724E-7**	**.05285**	**.000**	**.984**
gender × group	**1**	**.001**	**.04419**	**.429**	**.515**
cognitive style × group	**1**	**.004**	**.05123**	**2.647**	**.110**
gender × cognitive style × group	**1**	**.005**	**.00000**	**3.295**	**.075**

From this table, main effect of group was significant (F=4.477，p=0.039), it meant that group had effect on performance of spatial mental rotation, more specifically, experiment group's performance (MS=0.1162 SD=0.03138) was higher than that of control group's (MS=0.0966 SD=0.04679), therefore, Pentomino had positive effect on students' spatial mental rotation. The other main effects were not significant. In addition, unfortunately, all of the two-factor interactions were not significant.

But the interaction of gender × cognitive style× group was closely significant (F=3.295，p=0.075). So next step, simple effect analysis was used.



(figure 1. Field-dependent, 1 male, 2 female)



(figure 2. Field-independent, 1 male, 2 female)

From figure 1 and figure 2, performance of field-dependent students in experiment group had the tendency of deceasing, but generally, their performance was better than control group's; After experiment, the performance of field-independent students increased and was higher than that of control group as expected. Therefore, this intelligence game gave some interference to field-dependent students to make their performance appear the tendency of decreasing. But for field-independent students, this intelligence game gave positive effects on their spatial ability. And from the first figure, for field-dependent students who were in experiment group, no matter genders, performance was better than that of control group's. But from the second figure, for field-independent students, female in experiment group had better performance than that of control group's, the opposite result was found for male. So, Pentonimo had obviously positive effects on field-independent female, but for male and field-dependent students, this effect was

not significant.

From the simple effect analysis, some results were obtained:

(1) the main effect of group was closely to significant ($F=4.135$， $p=0.076$) for field-dependent male. It showed that group had effect on the performance of field-dependent male, specifically, experiment group (MS=0.1250 SD=0.05751) had better performance than that of control group's (MS=0.0725 SD=0.0000), it suggested further that Pentomino did improve students' spatial ability.

(2) Cognitive styles were significant ($F=9.447$， $p=0.008$) for male in control group, but this factor was not significant in experiment group ($F=1.109$ $p=0.327>0.05$). It showed that in experiment group field-independent and field-dependent students did not have significant distinction of cognitive styles, this seemed to show that the distinction of cognitive styles maybe was reduced because of playing Pentomino in experiment group and this verified the previous result that the gender distinction could be reduced if students participated in some activities relative to spatial ability.

3 General discussion:

According to this research, the most exciting result was the three-factor interaction effect. From the simple effect analysis, the main effect of group was significant and comparing the means of two groups, experiment group was better than control group, so Pentomino had positive effect on spatial ability, which was consistent with our hypothesis 1. In addition, this point also confirmed the view of Clurg and Chaille (1987) of game could improve children's spatial ability. Another interesting result was the effect of cognitive styles, in experiment group, field-independent and field-dependent male students did not have significant distinction of cognitive style, this seemed to show that the distinction of cognitive style maybe was reduced because of playing Pentomino in experiment group.

Another interesting result was that Pentonimo had obviously positive effects on field-independent female, but for male and field-dependent students, this effect was not significant. It maybe could be one method to reduce the gender differences of spatial ability.

What's more, considering the experiment design, the improvement of spatial ability was reasonable:

(1) The Pentomino itself. Traditional Tetris is 2D, students can only form 2D shapes which can only give students 2D trainings. But, each part of Pentomimo is 3D, students can get trainings in 3D space and spatial ability.

(2) The materials' design was wise. When designed the 3D materials, we represented the 3D shapes through 2D pictures (the instruction of each floor), therefore, students could image and construct the whole space of this 3D shape when they watched 2D instructions, and finally trained their spatial ability. From the self-explanation theory which is considered under Cognitive load theory, instructions of each floor could induce students to make more

self-explanation. For 3D shapes, each shape at least had three 2D instructions, students therefore had 3 times more self-explanation than that of 2D shapes' tasks to construct their spatial schema. Meanwhile, the results of this research seemed to answer one question proposed by Siqing Lian and Hui Zeng. When they did the research of self-explanation with number sequence, they found that teachers' lecture would have positive effects on far transfer, but they were not sure that whether induced self-explanation would also have positive effects on far transfer? From this research, students formed the 3D shapes which were far transfer compared to 2D tasks all by themselves and no teachers' instructions, the whole process just had 2D instructions which induced students to occur self-explanation and finally students got better performance. So, the result seemed to have answered that previous question. In addition, from the Cognitive load theory and instructional design, this research maybe verified one Ayres' idea. He used Polynomials to investigate how to reduce intrinsic load. In that experiment, he made the whole task into simply and easily single tasks for students solving, finally found this method could reduce intrinsic load and improved performance. In my research, as each 3D shape at least had 3 floors, we showed pictures of each floor to students to think how to form this 3D shape, namely we changed the whole 3D shape into some single 2D tasks. This way we did was similar to Ayres' idea, and finally we got better performance and it seemed to verify Ayres' idea.

In addition, 3D tasks were new to every students, and it seemed that students were novices for these tasks, but why they had better performance? The reason may be as follows: according to the experiment design, 3D tasks were based on 2D instructions or tasks which students had had good practices and knowledge about 2D before, so they had formed good schemas about 2D shapes, namely they were not in fact novices for 2D tasks. So when students were finishing 3D tasks, they used their 2D knowledge and self-explanation (it did not pose more load on work memory, as this satisfied the environmental organising and linking principal). Therefore, students could finish 3D tasks and this also justified Sweller's one result: self-explanation for high-expertise students will cause good performance.

From the results, Pentomino did improve and practice students' spatial ability, meanwhile, in the real teaching condition, it also had obviously positive effects which was consistent with our hypothesis 2. So, these results supported previous purposes and hypotheses.

4 Results

(1) Pentomino could improve secondary students' spatial ability;

(2) In real classroom, Pentomino did also improve spatial ability;

(3) Pentomino had positive effect on field-independent females, but not obvious for the males.

(4) Pentomino to some extend reduced the gender differences in spatial ability.

5 Highlight and creativities

(1) Previous researches on Tetris more focus on students' 2D mental rotation (2D ability), but this research used the intelligence game-Pentomino, one 3D game, to investigate students' spatial ability, which was creative in the experiment material.

(2) This research found that this game could improve females' spatial ability, especially for filed-independent female, namely, this game maybe can be used as one method to reduce the distinction of spatial ability within genders. This is one highlight.

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