THE USE OF COMPUTER GAMES IN TRAINING SPATIAL REASONING

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Abstract: Spatial reasoning including mental rotation ability has been seen to be linked to the ability to think scientifically and to do abstract tasks such as programming. There has been some attempt in the past to investigate ways in which navigating in hyperspace is affected by the ability to navigate in real spaces. The purpose of the current study has been to examine differences between training approaches to improve spatial ability using a video game and a block building approach. Understanding the differences of spatial performance needed to perform the training activities will eventually lead to better development of training procedure. The results show a greater relationship to gender than initial ability in the value of different types of game (computer or otherwise) but this could have been masked by lack of computer game interest in the female participants. There also would seem to be a limit to the level of improvement in skill that games can provide.

1 INTRODUCTION

The terms “spatial visualization”, “spatial thinking”, “spatial skills”, “spatial intelligence” and “spatial ability” have all been used to describe aspects of spatial reasoning. Spatial reasoning has been described by Linn and Petersen (Linn and Petersen, 1985) as “skills in representing, transforming, generating, and recalling symbolic, non-linguistic information.” Such reasoning underpins our understanding of how bodies interact with each other, where they are located relative to each other and so on. They are thus important abilities in relation to the understanding of physical sciences. Different authors have disagreed on how the different aspects of spatial reasoning interact. For instance, Linn and Petersen (Linn and Petersen, 1985)see spatial ability as consisting of spatial perception, mental rotation and spatial visualization as separate components whereas Sorby (Sorby, 1999) would promote the view that spatial visualization is made up of mental rotation and mental transformation.

A number of authors have proposed that spatial skill can be learned. Sorby (Sorby 1999) would suggest that spatial ability is innate but spatial skill can be learned through training. Interestingly while there appear to be gender differences, it has been demonstrated that the use of training has equal effect on the development of spatial skills, independent of gender (Law et al., 1993).

A relevant question then is “how can the spatial skills best be trained?” A number of computer based and non-computer based approaches have been attempted. Examples of purely non computer based approaches are: kindergarten students were taught piano keyboard lessons and the results claimed to include improved spatial memory (Zafranas, 2004); spatial reasoning was measured to be improved after listening to Mozart (Piano Sonata in D for two pianos) for 10 minutes a day for five days (Rauscher et al., 1994); block building activity was shown to improve mental rotation skill of kindergarten

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students (Casey et al., 2008). Computer based methods include the usage of a 3D design software (Dünser et al., 2006) and commercial video games including Tetris (Terlecki et al., 2008, Okagaki and Frensch, 1994) and Medal of Honor (Jing et al., 2007, Spence et al., 2009). However, this was found to produce greater improvements in spatial skills for gamers than for non-gamers (Jing et al., 2007, Boot et al., 2008).

The effect of training on spatial reasoning varies, Rauscher et al (1994) reported temporary increase in spatial reasoning after listening to Mozart for 10-minutes, whereas Terlecki et al. (2008) reported the effect lasting several month after repeated training on Tetris . The effect may depend on the duration of exposure to the training.

As a result of the diverse findings of other researchers it was decided to conduct a test on the usefulness of a computer game which would appear to require mental rotation to complete quickly, to see if exposure to this game over a prolonged period would significantly affect the player's mental rotation skill.

2 THE EXPERIMENT

The purpose of this study was then to examine the relationship among gender, video game expertise, prior mental rotation (MR) ability and mental rotation skills. It was expected that playing the video game would improve the player's mental rotation skill through repeated practice – in line with the ideas in (Sorby, 1999). To validate the approach a control group was also chosen who undertook alternative non-computer based training – involving making block models based on pictures and words. It was also expected that those with high MR ability would perform better in both training methods. That is that high mental rotation ability would give improved performance in both the computer game and the block manipulation exercise as both require the mental rotation of images in order to understand the activity. However, a counter theory would be that those with experience in game play might outperform what would be predicted because of previously acquired game play skill.

3 METHODS

3.1 Participants

A group of 98 children aged 13 years old were chosen as targets. The children were all in the same school and took part in the experiment after school voluntarily over a 4 week period. The children were allocated to the experiment and control group randomly but with even numbers of male and female participants and as far as possible an even distribution of gamers and non-gamers in both groups.

3.2 Materials

3.2.1 The Video Games Experience Survey

The survey by Terlecki and Newcombe (Terlecki and Newcombe, 2005) was used to gather participants' experiences related to video games playing. There were 14 items being questioned related to their experiences and preferences in playing video games. Additional information regarding the participants' grade in various subjects was also collected.

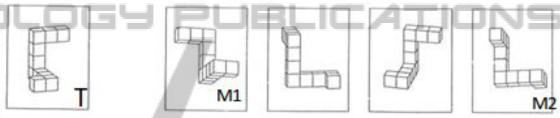

Figure 1: Example of VMRT item.

3.2.2 Vandenberg and Kuse Mental Rotation Test (VMRT)

Various standardized measures of spatial ability exist. In the area of mental rotation the Vandenberg and Kuse Mental Rotation Test (Vandenberg, 1978) is one of the most commonly used methods. The original test consists of 20 items in five sets of four items each. Each item consists of a target figure, two correct alternatives and two incorrect "distracters". Examples of the stimulus figures are given in Figure 1. T is the target figure and M1 and M2 are the "distracters". The correct alternative figures can be generated by rotating the target figure. The distracters cannot be made by rotating the target.

The redrawn VMRT (Peters et al., 1995) was used to determine the MR ability of the participants. As Voyer et al. (Voyer et al., 1995) observed most of the spatial tests were predominately created for adults and children may have some issues in completing them. As a result we reduced the number of items in the VMRT from 24 to 12.

3.2.3 Bloxorz

The video game chosen was Bloxorz. A number of versions of this game exist on line but to enable measurement of player performance during the game a version of this game was developed using Microsoft XNA. This version allowed each action of a player to be recorded to allow a measure of how many mistakes were made, how quickly the player completed each level, how many attempts were needed and so on. A typical task in the game is illustrated in Figure 2. The player has to navigate the block (shown in blue) around a maze by flipping it horizontally and vertically. Different sections of the board will appear or break if the player lands on them in the right or wrong way. The objective is to get from the start position to the exit in a minimum number of moves. The game starts relatively easily and steadily increases in complexity as the player progresses in the game. There are 10 levels; players have to complete each level in order to finish all

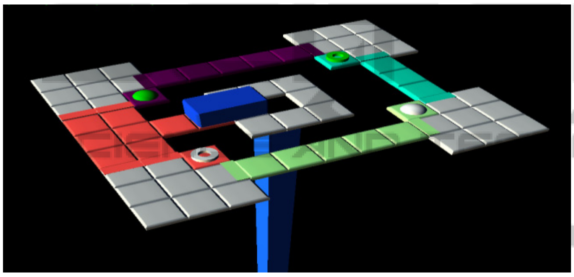

Figure 2: Typical level in the game used in Bloxorz training module

levels. The progress of players was also recorded after each play so that players can continue at the point where they last played in every session. Each student was given a designated computer where they played throughout the experiment. Bloxorz was chosen for three reason, it is analogous to the act of mental rotation, similarity of stimuli with VMRT and also girls preferred puzzle game more than action games (Lucas and Sherry, 2004, Quaiser-Pohl et al., 2006) and thus they should have lower bias against such a game.

3.2.4 Block Building

A structured block building task was developed for this study. In the block building play, structured activity was preferred to free play because it is more challenging and participants would be more focused as a result of having a defined goal (Caldera et al., 1999). For every session participants were given different sets of objects to build. For the first two sessions the participants were given an image of 10 everyday objects, and for the last two sessions, the participants were given a list of 10 object names. Participants were instructed to build the objects as realistically as they could. Marks were given based on the complexity of what was built and how closely the construction resembled the objects being modeled. The points, quantity of objects built and the quantity of blocks used were recorded and this data was used in the final analysis.

4 DESIGN AND PROCEDURE

The VMRT was given one week before the treatment as a pre-test and one week after the treatment as a post-test. Before the VMRT was administered, the children were instructed on how to answer the VMRT. The children were shown three examples of the questions to familiarize themselves with the test format. They were asked to take time in answering the test correctly and there were no penalties if they didn't finish the task. Correctness was stressed more than the completion of the tasks.

The sessions were scheduled over a 3 week period and each student participated in four sessions and one training session. In each session the experimental group played with Bloxorz for 25 minutes and control group played with blocks also for 25 minutes. According to Baeninggen and Newcombe (Baenninger and Newcombe, 1989), this could be considered as a medium duration study and training intervention should have some impact.

5 RESULTS

5.1 Survey

Out of the 98 children only 2 girls had not previously played a video game. Out of the other 96 children only 36 (27 boys and 9 girls) considered themselves to be actively playing video games. The majority of those who do not actively play video game gave the reason of "Not enough time". Unlike the majority of the boys more than half of the girls rated themselves as not good at playing video games.

5.2 Training

The relationship between VMRT pre-test score and gender was examined using the analysis of variance (ANOVAs) and yielded a significant effect, $F(1, 97) = 20.877$, $p = 0.000$. According to the mean score, the boys had significantly higher scores ($M = 8.98$) than girls ($M = 6.38$). Based on the mean of the pre-

VMRT score which was 8, those below the mean were put in the group Low MR and those above the median were put into the group High MR. There were a larger number of girls in the low MR group compared to the number of boys in that group.

To determine the effects of video games practice and block building practice with respect to gender, VMRT scores and MR skills, an analysis of covariance (ANCOVA) was used. Post VMRT scores were used as the dependent variable and pre VMRT scores were used as the covariance variable. A significant main effect of gender was observed $F(1,89) = 4.104$, $p = 0.046$ favouring boys ($M = 8.719$) over girls ($M = 7.693$). The main effect of the training condition was found to be not statistically significant, $F(1,1,89) = 0.450$, $p = 0.504$, suggesting that training in different methods doesn't effect VMRT performance.

There was also a two way interaction that was statistically significant. Gender and group interaction was significant, $F(1,1,89) = 4.176$, $p = 0.044$; suggesting that training in different methods depends on gender. Girls that trained with blocks showed more improvement in VMRT scores than boys in the same group. However boys that trained with Bloxorz improved more in VMRT score than girls as shown in Figure 3.

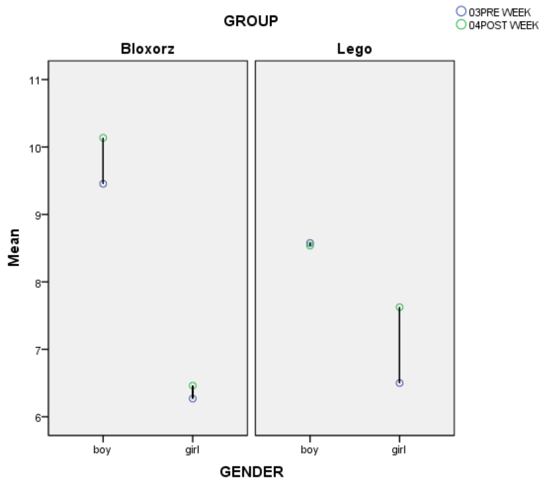

Figure 3: Means of Pre and Post VMRT scores.

5.3 Block Building

A two way Factorial (2 X 2 Factorial) was used to determine the effects of gender on block building completion (boys and girl) and MR ability (low and high). The main effect of gender was not significant, $F(1,46) = 0.143$, $p = 0.707$. But the main effect of prior MR ability was significant, $F(1,46) = 7.036$, $p = 0.011$, it can be seen that subjects with high MR ability ($M = 18.93$) built more structures than those with low MR ability ($M = 14.09$). There was no two way significant interaction.

A two way Factorial (2 X 2 Factorial) was used to determine the effects block points per construction on gender and prior MR ability. The main effect of gender was significant, $F(1,46)= 0.119$, $p < 0.05$, Girls ($M = 6.6673$) on average gained more points per construction than boys ($M = 5.9342$).

There was a two way interaction between gender and prior MR ability suggesting that boys and girls points per construction depended on the level of prior MR ability. Girls that have high MR ability gained more points per construction than boys with the same MR level; however boys with low MR ability gained more points per construction than girls with the same level of MR, as shown in Table 1.

Table 1: Means points per construct.

Gender	MR Ability	Mean	Std. Deviation
boy	low	5.6	0.4
	high	6.1	0.7
girl	low	7.2	0.9
	high	6.0	0.8

5.4 Bloxorz

A two way Factorial (2 X 2 Factorial) was used to determine the effects of Bloxor level completion on gender and MR background. The number of completed level was used as the independent variable. Gender and prior MR ability were used as the dependent variables. The main effect of gender was significant, $F(1,44) = 4.068$, $p = 0.05$, from the Estimated Marginal Means, boys ($M = 7.1364$) completed more levels than girls ($M = 5.1538$). There was no significant two way interaction.

A two way Factorial (2 X 2 Factorial) was used to determine the effects on moves per second of gender and prior MR skill. The main effect of gender was significant, $F(1,44) = 9.884$, $p < 0.00$, from the Estimated Marginal Means, it can be seen that boys ($M = 1.1069$) took significantly longer time to move than girls ($M = 0.930$). The main effect of prior MR skill was also significant, $F = 4.342$, $p < 0.05$, from the Estimated Marginal Means, it can be seen that subjects with high MR ability ($M = 1.0802$) took significantly more time to move than those with low MR ability ($M = 0.8573$). There was no two way significant interaction.

6 CONCLUSIONS

As expected boys outperformed girls on the VMRT score, which is in line with previous studies (Linn and Petersen, 1985, Peters et al., 1995). Evidence from this experiment showing the relationship between mental rotation training and gender to be as illustrated in Figure 4. Girls with low mental rotation ability did not show improvement in mental rotation skill when exposed to the computer game but did when exposed to the block building task. This was strongly influenced by the alternate observation (found from the survey) that the girls in general did not consider themselves good at playing video games. They generally were less enthusiastic for the computer game activity – even though Bloxorz would generally be thought of as a gender neutral game. The low mental rotation ability boys, however, improved far more strongly when they played the video game. These results thus confirm some findings (Cherney, 2008, Yang and Chen, 2010) but are less conclusive about the usefulness of computer games per se in training mental rotation skill. The result relating to the speed of play of children with high mental rotation ability is interesting. The number of levels completed was higher than others but the speed with which they completed the tasks was less. This could be indicating that they are using their mental rotation ability to solve the problem before moving. This is reinforced by the number of errors made in completing the levels.

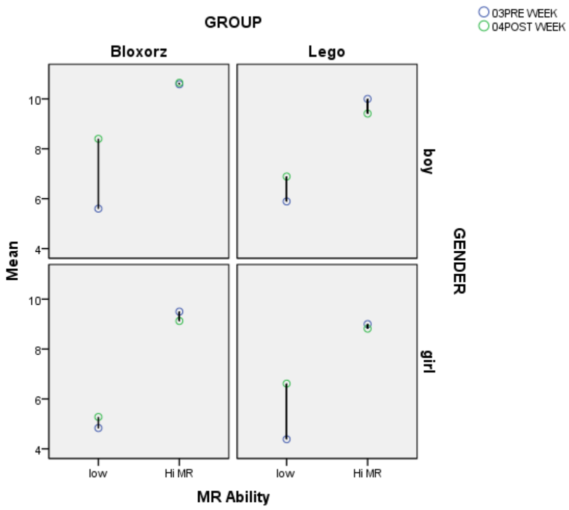

Figure 4: Illustrating the changes in VMRT scores over the period of the experiment.

There may be some confusion between the level of game play experience and effect of gender in relation to the skill building and competence in the tasks. This is because of the much lower level of female participants who considered themselves to be gamers. Further experiments will be necessary.

Clearly the value of the training activity in improving mental rotation skill is dependent on the individual. Males in this age group were more likely to be motivated by the idea of computer game play than playing with Lego. Their perception of not being good game players may have limited the low MR girls' interest in and satisfaction with the computer game intervention – and not with the block manipulation.

Mental rotation skill as part of the range of spatial skills has value in developing an understanding of science, mathematics and engineering. It is thus important for better ways to be found of improving the skill levels of children. The Bloxorz game is typical of puzzle games involving mental rotation tasks for their solution. There was a significant improvement in measured mental rotation score of male players with previously low scores over the period of the experiment and thus it should be expected that encouraging them to play will improve their skills in this area in the long term. However, the reaction of the girls to this – especially relative to their performance after using the block manipulation – indicates that the right approach for such training is strongly dependant on the person.

It is also noticeable that those with previously high mental rotations skills are not significantly affected by the game play (of either sort). This may have been limited by the measurement tool and further work should be done to test this.

Our experiment brings further light to the debate on whether computer games can enhance educational aims for all students. Clearly from our study, those who find computer games engaging will engage with the game and if it contains the right mechanic to learn the subject they will learn. However, computer games will not be the right approach for all students and for those who find a given game mechanic less engaging it is unlikely that they will learn. In our case most of the boys who began the experiment with low mental rotation skill were gamers and learned through the process – improving their mental rotation skill as a result. Most of the girls who began the experiment with low mental rotation skill were not gamers and did not improve their mental rotation skill as a result of the experiment.

REFERENCES

Baenninger, M. & Newcombe, N. 1989. The Role Of

Experience In Spatial Test Performance: A Meta-Analysis. Sex Roles, 20, 327-344.
Boot, W. R., Kramer, A. F., Simons, D. J., Fabiani, M. & Gratton, G. 2008. The Effects Of Video Game Playing On Attention, Memory, And Executive Control. Acta Psychologica, 129, 387-398.
Caldera, Y. M., Culp, A. M., O'brien, M., Truglio, R. T., Alvarez, M. & Huston, A. C. 1999. Children's Play Preferences, Construction Play With Blocks, And Visual-Spatial Skills: Are They Related? International Journal Of Behavioral Development, 23, 855-872.
Casey, B. M., Andrews, N., Schindler, H., Kersh, J. E., Samper, A. & Copley, J. 2008. The Development Of Spatial Skills Through Interventions Involving Block Building Activities. Cognition And Instruction, 26, 269-309.
Cherney, I. D. 2008. Mom, Let Me Play More Computer Games: They Improve My Mental Rotation Skills. Sex Roles, 59, 776-778.
Dünser, A., Steinbügll, K., Kaufmann, H. & Glück, J. 2006. Virtual And Augmented Reality As Spatial Ability Training Tools. Proceedings Of The 7th Acm Sigchi New Zealand Chapter's International Conference On Computer-Human Interaction: Design Centered Hci. Christchurch, New Zealand: Acm.
Jing, F., Spence, I. & Pratt, J. 2007. Playing An Action Video Game Reduces Gender Differences In Spatial Cognition. Psychological Science (Wiley-Blackwell), 18, 850-855.
Law, D. J., Pellegrino, J. W. & Hunt, E. B. 1993. Comparing The Tortoise And The Hare: Gender Differences And Experiences In Dynamic Spatial Reasoning Tasks. Psychological Science (Wiley-Blackwell), 4, 35-40.
Linn, M. C. & Petersen, A. C. 1985. Emergence And Characterization Of Sex Differences In Spatial Ability: A Meta-Analysis. Child Development, 56, 1479-1498.
Lucas, K. & Sherry, J. L. 2004. Sex Differences In Video Game Play: A Communication-Based Explanation. Communication Research, 31, 499.
Okagaki, L. & Frensch, P. A. 1994. Effects Of Video Game Playing On Measures Of Spatial Performance: Gender Effects In Late Adolescence. Journal Of Applied Developmental Psychology, 15, 33-58.
Peters, M., Laeng, B., Latham, K., Jackson, M., Zaiyouna, R. & Richardson, C. 1995. A Redrawn Vandenberg And Kuse Mental Rotations Test - Different Versions And Factors That Affect Performance. Brain And Cognition, 28, 39-58.
Quaiser-Pohl, C., Geiser, C. & Lehmann, W. 2006. The Relationship Between Computer-Game Preference, Gender, And Mental-Rotation Ability. Personality And Individual Differences, 40, 609-619.
Rauscher, F. H., Shaw, G. L., Levine, L. J., Ky, K. N. & Wright, E. L. 1994. Music And Spatial Task Performance: A Causal Relationship.
Sorby, S. A. 1999. Developing 3-D Spatial Visualization Skills. Engineering Design Graphics Journal, 63, 21-32.
Spence, I., Yu, J. J., Feng, J. & Marshman, J. 2009. Women Match Men When Learning A Spatial Skill. Journal Of Experimental Psychology: Learning, Memory, And Cognition, 35, 1097-1103.
Terlecki, M. & Newcombe, N. 2005. How Important Is The Digital Divide? The Relation Of Computer And Videogame Usage To Gender Differences In Mental Rotation Ability. Sex Roles, 53, 433-441.
Terlecki, M. S., Newcombe, N. S. & Little, M. 2008. Durable And Generalized Effects Of Spatial Experience On Mental Rotation: Gender Differences In Growth Patterns. Applied Cognitive Psychology, 22, 996-1013.
Vandenberg, S. G. K., Allan R. 1978. Mental Rotations, A Group Test Of Three-Dimensional Spatial Visualization. Perceptual And Motor Skills, 47, 599-604.
Voyer, D., Voyer, S. & Bryden, M. P. 1995. Magnitude Of Sex Differences In Spatial Abilities: A Meta-Analysis And Consideration Of Critical Variables. Psychological Bulletin, 117, 250-270.
Yang, J. C. & Chen, S. Y. 2010. Effects Of Gender Differences And Spatial Abilities Within A Digital Pentominoes Game. Computers And Education, 55, 1220-1233.
Zafranas, N. 2004. Piano Keyboard Training And The Spatial-Temporal Development Of Young Children Attending Kindergarten Classes In Greece. Early Child Development And Care, 174, 199-211.