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Training effects on mental rotation, spatial orientation and spatial visualisation depending on the initial level of spatial abilities

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Abstract

The aim of the study is to identify who benefits more from the training of spatial abilities, those who have initial good levels of ability or those who are weak in this matter. The participants were split in 3 groups on the basis of their initial level of abilities and the differences between pre and post training scores were compared. ANOVA showed significant differences for scores in all tests, with students low in spatial abilities gaining the most benefits from training.

Keywords: mental rotation, spatial orientation, spatial visualisation, training, computer games

1. Introduction

Spatial abilities are considered important for everyday tasks and also in many of the school subjects that require graphs, figures, sketches, and comprehension of visual stimuli. Their level of development results from an interaction between biological and environmental factors and many studies showed that spatial abilities can be improved by training (Baenninger, & Newcombe, 1989, 1995).

Computer games are a very popular activity among young people and exposure to screen, digitelised information proved to have an impact on users (Barlett, Anderson, & Swing, 2009). Extensive studies on computer games consider the educational role of this activity and present both enthusiastic views on the influence digital media has on learning and also precaution in unconditioned embrasing of new

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technologies (Connelly, Stansfield, & Boyle, 2009). Computer games can't be narrowly perceived as entertaining means but also as partners in learning and tools to overcome technology anxiety and skills inequality. One of the characteristics that makes them suitable for training spatial abilities is the visual presentation of information and spatial processing involved in computer tasks. Spatial processing lays on the activation of spatial abilities, a domain where knowledge is dynamic and expanding. The specialists in cognitive abilities are inclined to accept one classification of spatial abilities, which resulted from a meta-analysis conducted in 1985 by Linn and Peterson. There were identified three categories as follows:

- mental rotation, defined as the ability to mental rotate two or three-dimensional figure rapidly and accurately and to imagine the aspect of the figure after it was rotated around an axes with a certain number o degrees
- spatial relation, involved in determining spatial relationships with respect to the orientation of your own body
- visualization which requires multiple and complex manipulation of spatially presented information and flexible activation of different operational strategies.

2. Objectives

Immersion of technology in professional and everyday tasks requires increased level of spatial functioning in order to effective analyze information and keep the pace with the changes. The interest of the study is the investigation of the gains obtained by students after playing computer games. We supposed that computer games help those with law spatial abilities to improve their performance. If this will be the case, then computer games may became a useful instrument for narrowing the gap between people with respect to spatial abilities.

3. Method

3.1. Participants

178 students (mean age = 14,8 years, 50,6% males, 49,4% females) were tested before and after training using video games. They were instructed to play for at least six hours with games that involved mental rotation of bi-dimensional or three dimensional figures, spatial visualisation, anticipation of consequences for mental transformations, pattern analysis and strategic planning of spatial relations. The participants were split in 3 groups on the basis of their initial level of abilities for each of the psychological tests used.

3.2. Instruments

The computer games selected for playing, namely: *Shapes*, *Block-out*, *3D Blocks, Cram jam, Cyclanoid, and Kiki the nano bot,* require visual-spatial processing. They all fit in a category of puzzle games, combining educational features (logical thinking and planning) with hand/ eye coordination, short reaction time and all range of spatial abilities. The participants received CDs with games, instructions and rules and were asked to keep a journal of playing activity.

There were used four spatial ability tests, pre and post training:

- Mental rotation test: it measures the ability of a person to transform mental imagines especially through rotation.

- Spatial orientation task: subjects are shown three dimensional figures placed on a target position and are required to indicate from a changed perspective which two of four images are identical with the target one.
- Image generation test: measures visualization ability and consists in two series of 15 cardboards depicting black squares in certain positions.

Mental rotation test, spatial orientation test and Image generation test are all component of BTPAC (ASCR, 2003).

- Blocks test - Clinciu version (Clinciu, 2004) adapted after Block design subtest from Wechsler Intelligence Scale for Children-Revised requires spatial visualization, gestalt comprehension and manual action, combining nonverbal intelligence and spatial conceptualization. The test showed a satisfying internal consistency in the present research (Chronbachs α = .78 to .82).

4. Results

Multifactorial ANOVA analysis was used with initial level of spatial ability and sex as independent variables and the difference in raw scores from post and pre-intervention for mental rotation, spatial orientation, image generation and blocks as dependent variables. Variance analysis for mental rotation was significant with $F_{(5,\ 172)}$=12.22 p<.001, η^2= .26 (tab.1). The result is due to the main effect of initial level of mental rotation and not to gender or the interaction of the two independent variables. The variance explained by the level of the abilities is moderate, as eta squared has revealed.

Table 1. Differences in mental rotation' scores after training

Initial level of ability	Males Mean (σ)	Females Mean (σ)	F	p	Eta squared
low	4.10 (3.09)	3.67 (2.63)	12.22	.000	.26
medium	2.20 (2.15)	2.62 (2.49)			
high	.76(2.28)	-.88 (2.36)			

Levene's test for equality of variance was not significant, so Bonferroni post hoc analysis was performed. The results showed differences in gains among all three groups, with those low in spatial abilities gaining significant more from those with medium level of ability, and those from the middle group gaining significant more points in mental rotation tests after playing games than those with higher initial level of mental rotation skill.

Similar results were found for spatial orientation ability. ANOVA was significant only for the corrected model $F_{(5,\ 172)}$=11.78 p<.001, η^2= .25 (tab.2) due to the main effect of spatial orientation's initial level. Gender effect and combined interaction of the two independent variables were not statistical significant. Levene's test result allowed considering equality of variance, so Bonferroni post hoc was performed. No significant difference was identified between those with low and medium initial performance, but there were significant differences between low and high skilled participants and medium and high skilled participants.

Table 2. Differences in spatial orientation' scores after training

Initial level of ability	Males Mean (σ)	Females Mean (σ)	F	p	Eta squared
low	4.68 (3.05)	3.31 (2.28)	11.78	.000	.25
medium	3.13 (2.71)	2.63 (2.14)			
high	.63(2.70)	.39 (1.92)			

Spatial visualisation was measured using two tests: image generation and blocks. In image generation test ANOVA showed significant result for the main effect of pre-intervention level of ability F(5, 172)=9.54 p<.001, η2= .21 (tab.3). Once again, no males or females group has increased their capability in spatial visualisation and Bonferroni post hoc test revealed disparity in benefits only between those low and medium in initial skills compared with those equipped before training has started.

Table 3. Differences in image generation' scores after training

Initial level of ability	Males Mean (σ)	Females Mean (σ)	F	p	Eta squared
low	1.53 (1.39)	1.92 (1.99)	9.54	.000	.21
medium	1.82 (2.01)	1.22 (1.92)			
high	-.41 (1.88)	-.30 (2.13)			

In blocks test, total variance in scores explained by the initial level of ability is higher, η2= .38, and F(5,172)=21.15 p<.001(tab.4). Gender didn't contribute to the general effect, or the combination of gender with the initial scores in blocks test. Games-Howell post hoc tests uncovered that all three groups' improvements were significant different from one another, with students less able before training gaining the most points after playing computer games. The least improvement was present in the group of high skilled participants.

Table 4. Differences in blocks' scores after training

Initial level of ability	Males Mean (σ)	Females Mean (σ)	F	p	Eta squared
low	28.26 (18.70)	23.92 (16.23)	21.15	.000	.38
medium	9.65 (11.17)	13.53 (8.80)			
high	2.63 (4.00)	4.27 (4.27)			

Because in all tests, participants with lower initial scores improved more consequently of playing computer games, we were interested to check if their post intervention performance was good enough to reach the level of those who were already outfitted and didn't improved their performance much after playing computer games. Student *t* test was performed for all tests to analyze the differences in scores at the post-intervention evaluation and proved significant and in favour of participants high in spatial abilities prior intervention.

5. Discussion

Results presented above confirmed the hypothesis that claimed that students with low spatial abilities gain more after using computer games then those with better initial skills. Training sessions through simple computer games have proved to be useful in participants with reduced spatial skills, the lower the initial level the higher is the improvement. Both genders have gained from training without differences, meaning that girls are not specially advantaged by computer games' practice, their initial level of abilities being more significant than gender. A somehow different result was found by Feng, Spence and Pratt (2007) who noticed more improvements in girls compared with boys after playing computer games, but their group numbered only 20 participants.

Training contributes to increase in spatial abilities scores, but do not cover the gap between people who posses high spatial skills and those low in this matter. These findings support both nature and nurture implication in modelling spatial skills in a person, opinion that has been advocated by many researches (Potter, Kaufman, Delacour, & Mokone, 2008; Terlecki, Newcombe, & Little, 2008).

The present research opens a possible way of helping students with low spatial abilities to increase their performance and therefore to improve their skills in activities that require such competences, including school topics. It still remains as unanswered questions the time needed for further improvement, until the participants reach a ceiling, the transferability of the skills trained through computer games, the best approach in selecting the procedure of training, and a better control of confounding variables that contributed to scores improvement.

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