The Effect of Stereoscopic to Different Spatial Ability College Students

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Abstract: Spatial ability refers to a group of cognitive functions to spatial tasks, which is considered as an important factor in human intelligence. Several studies report that low spatial learners must devote many cognitive resources to hold the images in working memory, but high spatial ability learners can hold images in working memory without expending many cognitive resources. We researched the effect of 2D or 3D display mode to the mental rotation test performance of different spatial ability subjects. Although the result revealed that 3D display mode would not affect the accuracy of MRT performance, Three D display mode might decrease the response time of low spatial ability subjects. After expending the number of subjects, the result would support the ability-as-compensator hypothesis.

Keywords: spatial ability, mental rotation, 3D display, ability-as-compensator hypothesis

Introduction

Spatial ability refers to a group of cognitive functions performing spatial tasks, which is considered as an important factor in human intelligence, one which is essential to several scientific and engineering activities. Extent studies have shown that high correlation between spatial ability and learners' achievement in various domains, such as chemistry (Bodner & Guay, 1997), engineering drawing (Potter & Merwe, 2001), and medical surgery (Eyal & Tendick, 2001).Spatial ability has long been identified as an individual ability, partially independent of general intelligence. In the 1980s, McGee, Linn and Lohman were all dedicated to doing research on spatial ability. Therefore, there are numerous different definitions of spatial ability or visual abilities. Till the 1990s, Carroll identified five factors of spatial ability in a large factor analytic survey. These five factors of spatial ability are: spatial visualization; spatial relations; closure speed; flexibility of closure; and perceptual speed. Carroll's definition of spatial ability is wider than McGee(1979) and Lohman (1979). For spatial visualization, it involves the processes of mental operation, and mental flipping, rotating figures. For spatial relation is the individual use of mental transformations to rotate the 2-D object in a short period of time to overcome the problem. Flexibility of closure is that the subject knows in advance what the pattern is. Therefore, the subject needs to hold the pattern in working memory. However, in contrast to flexibility of closure, for closure speed, the subject does not have to do so. He needs to access information from long-term memory. Perceptual speed, finally, relates to the speed in identifying perceived objects (Jonassen and Grabowski 1993).

Shepard and Metzsler (1971) present a way to assess the ability of subjects to visualize and mentally manipulate graphical, 3-D objects. They presented subjects with pairs of perspective drawings of 3-D objects comprised of blocks. Subjects were asked to determine whether the stimuli were of different object or different angular orientations of the same object. By recording and comparing the accuracy and response time of the mental rotation test (MRT), we can measure the subject's mental rotation ability. Steven G. Vandenberg and Allan R. Kuse conducted a similar experiment in 1978 that was based on Shepard and Metzler's original study. Different from Shepard and Metzsler's MRT, Vandenberg and Kuse's MRT increased the comparison from one object to four objects.

Besides the MRT, Purdue visualization and rotation test is another valid spatial ability test (PVRT), which is considered to be more difficult and challenging. PVRT is composed with five irregular objects. Subjects have to recognize the rotated angle of the target first, rotate the target in the same way, then find the correct answer in five comparisons. Although the developed history of PVRT was not as long as MRT, it still has high reliability and validity (Branoff, 2009).

Traditional mental rotation tasks (MRT), such as those developed by Shepard and Metzler (1971) and Vandenberg and Kuse (1978), are paper-and-pencil tests, so participants had to image the 2D object to represent a 3D object. In contrast, Parson, Larson, Kratz, Thiebaux, Bluestein, Buckwalter & Rizzo (2004) developed a virtual reality spatial rotation (VRSR) task using stimuli from the MRT. Through stereo glasses, the stimuli appear as "hologram-like" three-dimensional objects floating above the projection screen. Their results showed that sex differences traditionally seen on paper-and-pencil measures could no longer be observed in the virtual environment. One possible explanation for such discrepancy is the difference of working memory loading between traditional 2D and vivid 3D versions of MRTs. In 3D task, the requirement of imagining the 3D object lessens so that working memory loading is also reduced.

Nevertheless, Parson et al.(2004) totally focused on sex differences rather than another important factor that more directly affects the performance in the MRT—spatial ability (for example, spatial visualization—the ability to mentally rotate objects in two or three dimension)—that plays a crucial role in managing and rotating the object in a learner's mind. Several studies report different effects for high and low spatial ability learners (e.g., Hays, 1996; Höffler& Leutner, 2011; Huk, 2006; Lee, 2007; Mayer & Sims, 1994; Moreno & Mayer, 1999). According to Moreno and Mayer (1999), low spatial learners must devote many cognitive resources to hold the images in working memory, but high spatial ability learners can hold images in working memory without expending many cognitive resources.

Therefore, this article is primarily concerned with the relation between spatial ability and stimuli presentation formation (2D/3D), specifically, examining the benefit of decreasing working memory load from 3D version of the MRT between learners with high and low spatial ability. As the prediction from ability-as-compensator hypothesis (Hay, 1996; Mayer& Sims,1994), learners with low spatial abilities should be supported by some form of visual assistance more than those with higher spatial abilities who can more easily form some type of spatial representation (Hay, 1996). But this special visual assistance is not indispensable for learners with higher spatial abilities, that is, whether in 2D or 3D MRT, there is no difference in their performances.

Method

This study aims at investigating the effects of different stimuli presentation formation and learns spatial ability on their performances in the mental rotation task. An experimental, 2×2 between-subjects factorial, pretest-posttest design was employed. So, the two independent variables were presentation formation (2D / 3D) and learns' spatial ability. The dependent variable was the score and reaction time recorded on the mental rotation task.

Participant

Forty undergraduate students in Taiwan took part in this experiment. They were randomly assigned to one of two experimental conditions (2D: 20 participants, 3D: 20 participants). Demographic information about sex, age, academic background and game-playing experience was collected.

Materials

A Purdue Spatial Visualization test (Guay, 1977) and an adapted version of mental rotation task from the study of Vandenberg and Kuse (1978) were used in pretest and posttest respectively. For the sake of recording both performance and task completion time, we use computerized version instead of paper-and-pencil test for both tasks.

According to the stimuli presentation formation, there are two versions of mental rotation tasks for posttests: 2D version vs. 3D version. In the 2D mental rotation task, the 2D figures were just present on the computer screen. However, participants of the 3D version would be assisted with 3D virtual technology: they wore stereo glasses and could actually perceive the hologram of the 3D object. Additionally, the original version of Vandenberg and Kruse's (1978) mental rotation task was modified. In their initial task, a target stimulus and 4 other choice figure stimuli were presented to the participants. Two stimuli among the 4-choice stimuli were identical but the rotated version of the target stimulus and the participants have to select the identical items out of the two distracters (mirror or different stimulus). In this experiment, to simplify the task and track the reaction time for 4-choice stimuli separately, one multiple-choice question was split into four yes-no questions, the target stimulus was paired with one choice stimulus. Participants had to judge whether these two stimuli were the same or not (congruent / incongruent trial).

Procedure

In the beginning, spatial ability was measured using a Purdue Spatial Visualization test (Guay, 1977). According to the scores in this pretest, learners were divided into two groups: high spatial ability group (higher than average) and low spatial ability group (lower than average). Within each group, they were randomly assigned to one of the two versions of the posttest (2D/3D) mental rotation task. Participants had to decide whether the two figures are identical (congruent trial), or one of the figures is the mirror image of the other figure (incongruent trial) in the posttest.

Result

The correlations show a medium relationship between the scores of pretest and posttest ($r = .545$, $p < .001$), indicating that the abilities measured by Purdue Spatial Visualization test and our adapted version of MRT from the study of Vandenberg and Kuse (1978) were similar. In addition, no significant correlation was uncovered between the task scores and reaction time in both pretest (p = .94) and posttest (p = .89).Two types of data were collected: the response time (RT), and the accuracy of two tasks. An analysis of variance (ANOVA) was performed on the RTs and accuracy with following factors: spatial ability (high and low spatial ability) × display mode (2D and 3D).

In accuracy, the analysis of variance (ANOVA) indicates a significant main effect only for spatial ability, ($F_{(1,36)} = 16.104$, $p < .01$), and there was no statistically significant interaction effect. It means that regardless of the 2D or 3D display mode, the accuracy of the high spatial ability subject was higher than the low one (Table 1).

Table 1. Accuracy of post-test

	2D		3D	
	M	*SEM*	*M*	*SEM*
High spatial ability	.96	± .019	.95	± .020
Low spatial ability	.86	± .021	.88	± .020

In response time, there was a statistically significant interaction effect between spatial ability and display mode, ($F_{(1, 36)} = 4.90$, $p < .05$). In the 2D display mode, there is a main effect of spatial ability. High spatial ability subjects spend less time than low spatial ability subjects, ($F_{(1, 36)} = 4.77$, $p < .05$). However, in the 3D display mode, there is no significant difference between different spatial ability subjects. Interestingly, analysis of variance (ANOVA) revealed the trend of main effect of the display mode to low spatial ability group, ($F_{(1, 36)} = 3.07$, $p = .088$). The average response time of low spatial ability group was decreased from 10.42 s (in 2D display mode) to 7.97s (in 3D display mode) (Table 2).

Table 2. Response time (sec) of post-test

	2D		3D	
	M	*SEM*	*M*	*SEM*
High spatial ability	7.46	± .898	9.20	± .942
Low spatial ability	10.41	± .993	7.97	± .942

Conclusion

We found the following effects, first of all, there is a medium relationship between scores of pretest and posttest, revealing that the Purdue Spatial Visualization test and the adapted version of MRT were similar. Second, the 3D display mode could not affect the accuracy of high or low spatial ability groups. Third, it seems a trend that 3D display mode could decreased the response time of low spatial ability. Although the result could not directly support our prediction, the ability-as-compensator hypothesis, by the help of 3D display mode, low spatial ability subjects might not elevate the accuracy of performance directly, but it did decreased the response time. Therefore, the result showed that there was a possible trend of ability-as-compensator hypothesis in the response time. One possible reason for there being no statistical significance may lie in the small size of two spatial ability groups.

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