A review of using virtual reality for learning: influences on gender differences in spatial abilities

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ABSTRACT
The major concern of educators is how to enhance the quality of teaching and learning in education. Virtual reality learning environment has been identified as one of them. Many studied have agreed that virtual reality approach could help to improve performance and conceptual understanding on a specific range of task in learning. On the other hand, gender differences in spatial abilities, favoring male, are well established issues. Biological, psychological, cultural and political factors in many research reports are considered to influence and shape gender differences in cognitions, emotions, language and human behavior. Studies using standardized test have found support for the notion that men have strengths in the spatial domain, sometimes quite distinct strength. As a remedy, this paper reviews the effects of virtual reality learning environment explanation with particular reference toward gender differences in spatial abilities. Finally, this paper will discuss the issues of virtual reality learning environment on gender differences in spatial abilities.

Keywords: virtual reality, gender differences, spatial abilities
INTRODUCTION

Virtual reality (VR) is a new class human-computer interfaces. VR is an emerging computer-based technology that offers promise as a learning tool for diverse learners. It is a mechanism for communication and creative expression. VR permits people to enter, manipulate, and travel through computer-generated, interactive, three-dimensional (3-D) worlds that exist only in computer. VR’s approach has been used as learning tools for some time in applied fields such as aviation and medical imaging, and it has also been used in schools and colleges in the recent years. Use of VR in education and training is to support the high interactivity and the ability to provide a virtual environment that resembles the real world. With this technology, learners can explore and manipulate 3-D interactive environment. In suitable application areas, VR learning environment can provide an effective mechanism for enhancing spatial skills. For example, it can effectively coordinating sensory-motor skills, training in design skills, and gaining situation awareness through the use of simulations. Recent literature reviews of published research (c.f., Ausburn & Ausburn, 2004, 2008a, 2008b; Ausburn, et al., 2007; Ausburn, et al., 2006) have proved the effectiveness of virtual reality (VR) as a learning medium in a variety of settings. The research has proved that many educational institutions, industries, and society are now turning to VR technology to provide effective and cost-efficient ways of teaching and career development.

In parallel with this matter, in the other hand, we have seen the increasing understanding of the factors that affect the male advantage in spatial tasks where is not only a question of scientific interest, but it is also relevant in enhancing the academic achievement of students in meeting the workforce demands of today's technological society. Studies spanning the last half century have shown a male lead on spatial tests, with three-dimensional mental rotation yielding the largest and most reliable differences (Kimura, 1999; Voyer, Voyer & Bryden, 1995). These differences are typically described in linear terms, with male occupying a higher place on the extent of general spatial abilities. Male and female are believed to be equally intelligent in terms of overall general cognitive abilities (Jensen 1998). Unfortunately, they tend to perform unequally on some spatial tests which are relevant to spatial transformation skills (Halpern 2000) where involving mental rotation (Linn and Petersen 1985; Voyer et al. 1995). A substantial body of research shows that male performs better than female in spatial task, especially those involving mental rotation (eg, Hyde, 1981; Linn & Peterson, 1985; Voyer, Voyer & Bryden, 1995). Research has identified several theoretical and conceptual areas that suggest reasons for differential effects of virtual environments across genders (Lynna et al, 2009). The effects include spatial functioning, human navigation, socially- and culturally-influenced and experiences with computer technology.

These factors come with self-efficacy theory, where each influences come from the formation of an individual’s technological self-efficacy, which determines an
individual’s performance and perception of that performance in a technology learning environment such as VR (Lynna et al, 2009).

VIRTUAL REALITY ENVIRONMENT AND SPATIAL ABILITY

Virtual reality environment is the most promising development in learning, which allows for an immersion learning experience in simulated environments that span into 3D. This environment can be implemented to support instruction in spatial visualization and geometric reasoning. In the literature, several studies have reported on training materials designed to enhance spatial abilities in general and spatial visualization in particular. Recently, most of the programs have focused on the manipulation of physical objects. VR is certainly one of the ranges of more modern computer based technologies that may increase the possibilities for interactivity (Shim, et al., 2007).

On the other hand, spatial ability is a psychometric structure with two main factors: spatial orientation and spatial visualization (Michael, Guilford, & Fruchter, 1957). McGee (1979) defines spatial abilities as a measure of the ability to restructure mentally or manipulate the components of the visual stimulus which involves identifying, maintaining and recalling configurations when the figure or part of the figure moved. Spatial abilities are the ability to describe and manipulate the information received in the learning and problem solving (Clements, et al., 1992). Spatial Abilities also are prominent in many intellectual fields, such as solving problems in engineering, design, physics and mathematics (Smith, 1964; Pellegrino, et al., 1984). According to Olkun (2003), spatial ability is crucial and can be enhanced through appropriate activities. According to Terlecki and Newcombe (2005), facilitation of computer experience through training may have differential effects on males and females spatial abilities, and males not only perform at higher levels than females on tests of spatial and mental rotation abilities but also tend to have more spatial experiences.

According to Gardner (1993), spatial ability related to deal with sharp observation, visual thinking, mental images, and sensitivity to nature and so on. Students with this capability will typically use the right brain in process information to manipulate the visual objects to obtain information. High degree of spatial ability is often linked to creativity, not only in the arts, but also in science and mathematics (Shepard, 1978; West, 1991). The students who have skills in drawing techniques will engage with games such as jigsaw puzzles, maze, game LEGO and so on to stimulate their minds and most of them are exclusive with high imagination and intensely creative (Sorby, 1998). Not only that, the students who can understand a concept will enable to classify the object and distinguish it from other objects. They will able to connect the concept with other concepts. Unfortunately, student faced a problem in order to get a good results in examinations is often associated with weaknesses in the formation of a good
visualization. According to Lord (1985), the spatial ability is the ability to engage the mind to manipulate and rotate an object and creating structures in mind from instructions written or oral. Therefore, the skills required to develop a spatial ability is through programs or activities related to engineering or sketches (Olkun, 2003). There are many studies done and found that the skills of spatial abilities have a positive relationship with the level of mathematical performance (Battista, 1978; Hogson, 1996; Tarte, 1990).

Voyer, Voyer and Bryden (1995) found that, there are three types of spatial ability. There is space perception, spatial orientation, and spatial visualization. Kimura (1996) also classifies the six factors of spatial ability, namely spatial orientation, spatial location memory, targeting, Spatial Visualization, disembedding and spatial perception.

**IS VIRTUAL REALITY RELEVANT TO SPATIAL ABILITIES?**

Many researchers and educators believe that VR technology offers a powerful advantage that can support and improve the quality of education. VR is becoming increasingly popular for a variety of applications in today’s society. It has become well suited and a powerful media for use in school, especially for science, mathematics, engineering and design which involve the study of natural phenomena and abstract concepts. Chen, Czerwinski, and Macredie (2000) studied shows an overview of some approaches used and major findings of various research studies where concerning on the effects of gender differences on the use of this new technology. VR is the use of advanced computer device that increased strength to scientific spatial abilities. Spatial ability is perhaps the most obvious area where virtual reality offers potential as a tool for learning and understanding. According to Jacobson (1993),

> Virtual reality helps us to solve problems because it helps us visualize information- it lets us view things spatially. When we can look at data in space as a whole or in detail, we see its elements in association with each other or individually. It’s easier to solve a problem when it’s presented spatially instead of on paper or computer screen. As a result, we make judgment faster than if we viewed the data in numeric or written form. (p.27)

He suggests that the spatial abilities or virtual reality can support logical-mathematical understanding as well as spatial intelligence. VR also can be used to model complex phenomena. Students can use VR to explore perspective, spatial relationships, and other types of relationship between variables in a variety of fields. Benjamin Woolley (1992) had identified a connection between virtual reality and the notion of memory palace, a technique for aiding the memory that was highly influential in ancient Greece before a written language was available.
The memory palace technique used spatial intelligences to support linguistic intelligences.

However, most of these studies focus specifically on the interaction between human and computer aspect. Salzman, Dede, Loftin, and Chen (1999) also point out the need to be carried out in-depth study of the interaction of individual characteristics with the characteristics of VR. The key to increase spatial abilities is in representing information in ways that can involve any of human sensory systems and then, draw on our extensive experience in organizing and interpreting sensory input (Erickson, 1993). Visualization techniques also can assist people in using and interpreting particular emphasis data, transformation and contextualization in order to improve spatial abilities skills. All of these applications can be used in education as well as in professional practice, taking advantage of, and developing, spatial intelligence (McLellan, 1994).

RELATIONSHIP BETWEEN GENDER DIFFERENCES IN SPATIAL ABILITIES

There is a great deal of evidence to suggest that the spatial skills of female lag significantly behind those of their male counterparts. Theories for the cause of these differences include the assertions that spatial ability related to a male sex hormone (Hier & Crowley, 1982) or that environmental factor is the main reasons for male-female differences in spatial skill levels (Fennema & Sherman, 1977). Debate on the issue of gender differences in spatial abilities started since 1980 when Stanley and Benhow printed one science review. In this report, they found that the male student is better than female student in mathematical problem solving ability. This article also proves that the boys were exceedingly ability to solve problems involving space. Furthermore, the factors which influenced spatial ability development occur in a few psychology studies such as sex, age and experience (Miller, 1996). Besides that, Vandenberg and Kuse (1978) and Hamilton (1992) found that male showed greater ability than females in spatial mental rotation task.

Two studies were published in memory and cognition, to determine the gender gap through Mental Rotation Test achievement (MRT). Based on this test, students asked to look at an object of 3-dimension. Then, they are given four answers (two rotation is the original object) to identify two appropriate alternative with the original object. These studies use the ratio of performance to conclude that gender differences for mental rotation skills are significantly reduced when the effect of performance factors such as length of time and strategy to guess the answers eliminated. The first study focused only on the MRT, while the second study provides an analysis of fifteen skills assessment and the study area, proved that there are gender differences only in tasks that require mental rotation. In addition, several studies in spatial abilities conducted and the researcher found that there are differences between the gender differences where the male students who enter the technology field have higher spatial ability compared to male students in
Social Sciences while the female students in the technology field has the spatial ability higher than female students in Social science but lower than male students in the Social Sciences (Nordvik, 1998). However, Feingold (1993) and McGee (1979) found that there is no significant difference in the spatial ability between male and female students.

Levine et al (1999) states on average male exceed woman in spatial ability in the fourth stage. This is because; males tend to look for a technique or method by using space and direction or orientation strategy while females prefer to use sign and route directions (Lawton, 1994 and Geary, 1998). This study is consistent with the findings Koenig et al (1990) found that women's advantage is in relation to absolute space (location of the object) while the male advantage is in the space coordinate relations (distance and direction). Based on spatial tests, gender differences in strategy use has not been adopted widely, but at least one (Gluck & Fitting, 2003) form that male more commonly used holistic strategies than female, and female more often used analytic and mixed strategies than male in two different spatial tests. The holistic strategy relies on visualizing the whole object, and the analytic strategy uses a structured, stepwise approach. The holistic strategy has found to be most effective (i.e. less time consuming) in timed tests. Linn & Peterson have, therefore, concluded that “spatial strategy selection” is a factor in gender differences in mental rotation tasks. However, Hsi et al (1997) determined that spatial strategies can be acquired through training.

ADVANTAGES OF VIRTUAL REALITY LEARNING ENVIRONMENT ON GENDER DIFFERENCES IN SPATIAL ABILITIES

The literature search shows only one model that has been developed to understand how VR influences the learning process and learning outcomes in a VR learning environment. Although designers and evaluators of VR systems know that this technology has significant potential to facilitate and enhance learning, but little known about the aspects of this technology that are best leveraged for enhancing understanding. In other words, we need to know when and how to use VR’s features to support different learning tasks and various learners’ needs to maximize the benefits of employing this technology in learning in order to reduce gender differences on spatial skill.

According to the model of Salzman et al. (1999) in figure 1, before designing and developing an immersive VR learning environment, it is necessary to analyze the concepts to be mastered for the appropriate use of VR’s features because VR’s features can support the study of one concept, and at the same time constrain the understanding of another. The three features afforded by the VR technology in this model are immersive 3-D representations, multiple frames of references and multisensory cues. The model shows that the relationships between the VR’s features and information may be moderated by the learner characteristics such as gender differences, domain experience, spatial ability, computer experience,
motion sickness history and immersive tendencies. Besides that, these learner characteristics may also affect the teaching and interaction experience in a learning environment. Finally, the VR’s features also affect the quality of the interaction and learning experiences which, in turn, affect the learning and also may reduce the gender differences issues.

The model by Salzman et al. (1999) can be a practical guide in designing, developing and evaluating VR learning environment. For instance, the concept is applied to address the problem, and how interfaces should be designed to support usability. This model might have shed some light on what type of students might gain benefits through VR learning and how VR enhances learning by looking into the interaction and learning experience.

![Figure 1: Model describing how VR’s features, the concept one is being asked, learner characteristics, and the interaction and learning experiences work together to influence the learning outcomes in VR learning environments (Salzma et al., 1999).](image)

CONCLUSION
Evidence that spatial abilities can be improved is less valuable than the answer to the question of whether improvements are also significant for women than for men, so that women can hold up to men and beat their deficit and cognitive ability. In the reality, individual that have high spatial ability will be taking the whole concept before solve the problem in their approach. Those who have high spatial skill level are suitable with career in the engineering field, architect, designer, mechanical and mathematics (Baum, 1994). Furthermore, this paper has given an overview of the VR used for learning in helping reducing gender differences issue on spatial abilities. From the literature search, it can be observed that there are already some applications of VR for learning that have been implemented. Key factors related to learning effectiveness in a VR based learning environment and the impact of VR technology on psychological learning process should not be ignored. VR offers a promising environment for teaching people about the spatial characteristics of places and situations regarding to its present spatial nature. Indeed, there are still many compelling issues to be investigated regarding the interaction of gender differences on spatial abilities with the characteristics of VR in the effort to reconstruct the nature of VR-based instruction to assist individuals of different spatial abilities. Further investigation on the role of individual characteristics in VR learning environment is also needed to respond to those implementation questions.

REFERENCES


