A Study on the Differences Among M3D, S3D and HMD for Students with Different Degrees of Spatial Ability in Design Education

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Abstract. In the curriculum of product design education, some teaching materials for demonstrating and discussing case studies are always presented in images with monocular depth cues. However, using this approach to train students with different spatial abilities is a great challenge. It was reported that stereoscopic 3D (S3D) displays were helpful for the performance of depth-related tasks. Some research groups had tried to use stereoscopic visualization for teaching Descriptive Geometry, and some research reported that the effect of stereoscopic displays on science learning was related to the spatial ability of the viewer. In product design education, identifying proportion and manipulating proportional relationships were important practices of form-giving training. Whether the correctness of proportion judgement would be influenced by different displays remained an open question. Therefore, this study aimed to explore the performances of students with different background across three display modes, i.e. M3D, S3D, and head-mounted display (HMD). In the experiments, physical chairs and the corresponding digital models with different proportions were used as the stimuli. The participants were asked to identify the correct digital models of chairs. The results indicated that HMD approach could facilitate the reflection and adaptation of dimensions and proportions, compensating the differences of spatial abilities, and therefore enhancing the learning effects significantly.

Keywords: Design education · Spatial ability · Stereoscopic 3D · Head-mounted display

1 Introduction

In the field of design education, students learn how to estimate proportion and to manipulate proportional relationships of an object is a very important training. However, using conventional 2D displays with monocular depth cues, namely the so-called monocular 3D (M3D) images, to train students with different spatial abilities is a great challenge. Although, some literature has indicated that stereoscopic 3D (S3D) displays are helpful for depth-related tasks, whether S3D is helpful for proportion estimation is an open question. Therefore, the objective of this research is to study whether using

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S3D for design department students could assist them in improving their ability to interpret the proportions of product shapes.

In our daily life, the display technique has been developed from monocular 3D (M3D) to stereoscopic 3D (S3D) technology with binocular depth cues. With the S3D technology, the system could display not only colorful and high-resolution images, but also process the depth of space. Furthermore, head-mounted display (HMD) with virtual reality (VR) even makes it easier to immerse the viewer in the proposed reality environment. Stereoscopic 3D displays have been used by some research groups to present learning contents for medical, geological research, entertainment, games and education. This project hopes to explore the benefits of research on the students with different spatial abilities for design education through S3D or HMD devices.

2 Literature Review

Stereoscopic images were used not only in audiovisual entertainment and the game industry, but also in medicine, geology, education, and other research fields. Unlike a monocular 3D (M3D) display, an S3D display increased the composite of visual depth cues. Existing S3D display technologies comprised two types, i.e., stereoscopic with glasses and autostereoscopic without glasses [1, 2]. In addition, the head mounted Virtual Reality system offered an alternative stereoscopic display without wearing glasses [3]. Although these systems differed in the technologies of facilitating depth perception [4], overall, stereoscopic 3D displays were helpful for the performance of depth-related tasks. For example, the comprehension, memorization, and recall of 3D scenes and objects could be enhanced [5, 6]. The estimation of depth was more accurate compared to M3D display [7]. In the processes of product design education, the teaching materials and sample cases for demonstration, explanation, and discussion were always presented using images with monocular depth cues [8]. The depth cues of these graphics were identified based on the relative attributes of objects and heavily relied on the experiences and complicated cognition processes of the observers. For freshman and sophomore students of universities, their capabilities of drawing, observation, and spatial imagination are still under construction, design educators need to consider the impact of stereoscopic technologies on traditional design education [9], and try to reduce the gap between communication methods and learning performances [10, 11].

3 Experiment

The stimuli of experiments were drawn from five masterpiece chairs that students in the Department of Industrial Design were familiar with (Fig. 1). The digital models of these chairs were then imported into Unity 3D to construct the experimental system (Fig. 2).

At the beginning of experiments, participants were asked to observe the physical chairs and tried to memorize the proportions of each chair (Fig. 3). After the stage of

Fig. 1. Five masterpiece chairs

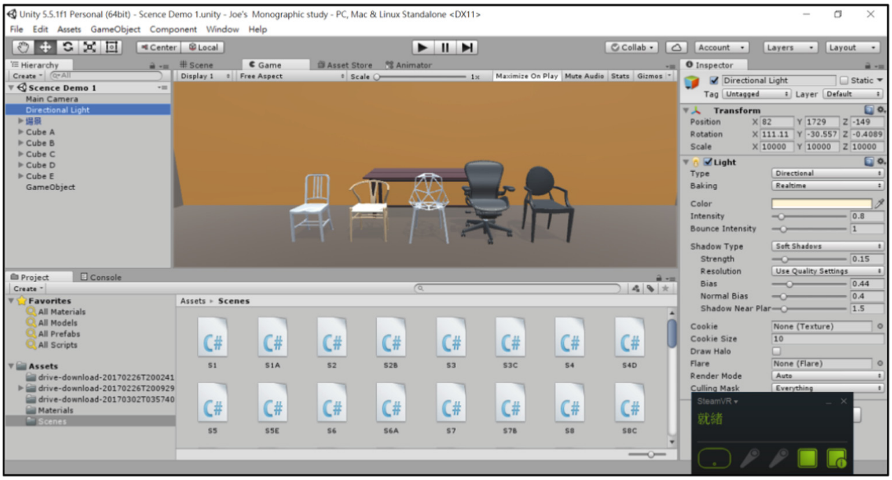

Fig. 2. 3D digital models in the Unity 3D system

Fig. 3. Participants observing the physical chairs

observations, these physical chairs were removed before the digital models of chairs were displayed on the screen, so that no physical chairs were available for reference.

Each computer experiment started with displaying a 3D digital chair with correct proportion. The model rotated with respect to the vertical axis to enhance the

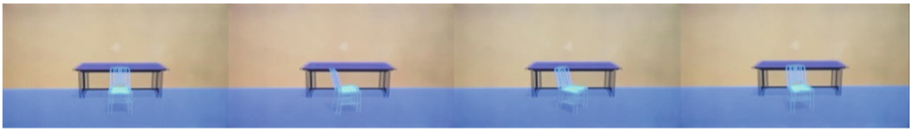

Fig. 4. A 3D digital chair with correct proportion and rotating animation

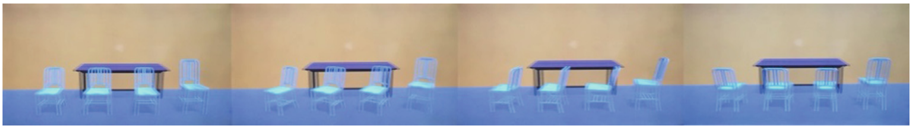

Fig. 5. Four digital chairs, with one in correct proportion and three in different proportion

Fig. 6. M3D, S3D, and HMD experiment conditions

impression of the masterpiece (Fig. 4). Then four digital chairs, with one in correct proportion and three with the adjustment of width, height, and depth, were put together (Fig. 5). The participants were asked to identify the correct chair within designated time.

There were three experiment conditions, i.e., M3D, S3D, and HMD (Fig. 6). An LG Cinema 3D TV was used for M3D and S3D. While in in S3D, the display mode was switched to stereoscopic and viewed with polarized 3D glasses. An HTC VIVE was used for HMD. The experiments were conducted in a room with illumination controls.

4 Results and Discussions

Ten students, 6 female and 4 male, were invited to participate in the experiments. Among them, five students majored in industrial design, and five students were from other departments. Each participant was asked to identify the correct digital models of five masterpiece chairs, with three deformation rates (20%, 10%, and 5%) in three viewing conditions. The scores were counted based on the correctness of judgement for each task. The results were shown in Table 1.

Table 1. Descriptive statistics for computer-based test with different deformation rates

Deformation rate			20%		10%		5%	
Conditions	Groups	N	Mean	SD	Mean	SD	Mean	SD
M3D	Design	5	4.0	0.71	3.2	1.10	1.6	1.14
	Non-design	5	3.4	1.82	1.6	1.52	1.2	0.84
S3D	Design	5	3.6	1.52	3.6	1.67	2.2	0.84
	Non-design	5	3.8	0.84	2.0	0.71	1.0	1.22
HMD	Design	5	3.8	1.10	3.2	1.48	2.6	0.55
	Non-design	5	2.6	0.55	2.8	0.84	2.0	0.71

The results indicated that the scores decreased with the increase of task difficulty levels. However, the HMD condition yielded less performance drops in both user groups compared to M3D and S3D conditions. HMD was more helpful for proportion judgements.

In M3D and S3D conditions, the performance drops from 20% to 5% deformation rates were consistent. The threshold for students from design department was the deformation changes from 10% to 5%. The threshold for students from other departments was the changes from 20% to 10%. However, in the HMD condition, the performance drop from 20% to 5% was less than the performance drops of M3D and S3D conditions (Fig. 7).

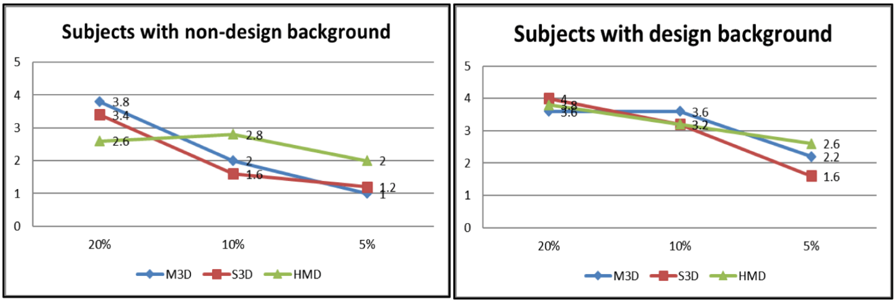

Fig. 7. The performance line charts for participants with design and non-design background

In the M3D condition, the performance gaps between two student groups increased as the level of difficulty increased (Fig. 8). However, in the HMD condition, the gaps between two student groups did not increase significantly. This result indicated that 3D displays with disparity depth cue, a binocular depth cue, could compensate the performance gaps for students with different education background and different spatial abilities.

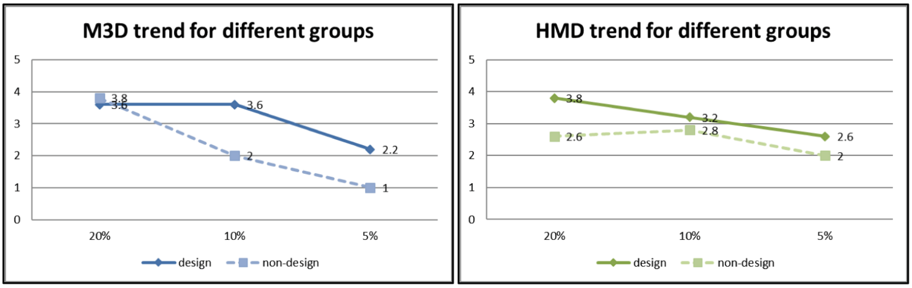

Fig. 8. The performance line charts for M3D and HMD

5 Conclusion

The result of experiment indicated that the advance of technologies could provide with new solutions for traditional design education. Compared to traditional M3D teaching methods with two-dimensional displays, S3D or HMD teaching methods offer the experiences of the third dimension, i.e. perceived depth. This approach could facilitate the reflection and adaptation of dimensions and proportions, compensating the differences of spatial abilities, and therefore enhancing the learning effects significantly. Although the outcome of preliminary experiment had revealed the opportunities, the number of participants was limited. In the future, more participants will be invited to consolidate the results.

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