Utilizing HMD VR to Improve the Spatial Learning and Wayfinding Effects in the Virtual Maze

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Abstract. Human wayfinding strategy in an unfamiliar space has been an important research issue in the interface design of spatial navigation. This study aims at comparing the participants' spatial learning and wayfinding performance using two different visual displays - the regular PC screen and the head mounted display (HMD) virtual reality (VR) system. HMD VR (we used HTC vive) is the popularizing device which provides users the immersive visual experience and full body interaction with the virtual environment. We designed a target-finding experiment to examine three factors, the spatial complexity, the visual display, and the landmark type. The participants were divided into two groups and used PC screen with keyboard and VR with controller stick respectively to perform the task, namely finding a particular target in six virtual mazes in two different sizes. In each target finding trial, the participant received one of the three navigation aids, a given distant landmark, some local landmarks in every intersection, or local landmarks freely laid by the participant. We measured the complete time, the times of taking repeat routes, the times and duration of the pause, and the eye movements during target-finding in PC screen. Soon after the task, the participants were also asked to draw a maze map from memory. The preliminary results reveal the group of PC screen found target more quickly, but the VR group produced cognitive maps with higher spatial accuracy.

Keywords: Wayfinding · HMD VR · Navigation aids

1 Introduction

Human wayfinding behavior in unfamiliar virtual space had drawn researchers' attention in the interface design field of spatial navigation [1, 2]. This study aims at comparing the participants' spatial learning and wayfinding performance in two different visual displays, namely the regular PC screen and the head mounted display (HMD) virtual reality (VR) system. This study adopted a consumer VR product, HTC vive, as an experimental apparatus. HMD VR is a rapidly growing interface which provides users the immersive visual experience and full body interaction with the virtual environment [3]. HMD VR is a contemporary visual communication technology yet with room for improvements, such as imperfect user experience [4–6], high costs, and content shortage. Nevertheless, numerous VR applications for gaming, education, marketing and recreational purposes have been intensively explored in the past few years. VR

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technology was also used to investigate human wayfinding performance [7, 8], as manipulating the virtual space is much easier than manipulating a real space.

In this study, we designed a target-finding experiment which manipulates three factors, the spatial complexity, the visual display, and the landmark type. The fator of spatial complexity is varied in two sizes of Unity made virtual mazes with different numbers of intersections. The visual displays are a regular PC screen and HTC vive, while the three variations of landmark type include a given distant landmark, local landmarks in every intersection, or local landmarks laid by the participant. The influence of the three factors in spatial learning and wayfinding performance was evaluated through performance measures and the accuracy of the hand-draw cognitive map produced by the participant. Based on the theory of human navigation and motor skills [9], we hypothesize the users' spatial learning and wayfinding performance in the VR immersive environment could be better than that of in a flat display.

2 Method

2.1 Participants

The participants are undergraduates and graduate students enrolled in Chinese Culture University. There are 70 aged between 18–24 participants. The researcher recruited them in the classes and screened them with a short test of 3D sickness and illusionary motion sickness. Only the participants who are novice users of VR products and had no sickness reaction had participated in the experiment. There participants were divided into two groups: VR group and PC screen group. There are 35 participants in a group.

2.2 Stimuli

The Virtual Mazes

We created two sets of virtual mazes with different sizes and configurations, as shown in Fig. 1. It presents two bird view samples of the two different sized mazes. There are three different mazes in the small and larget set of mazes. From the start to the end of the wayfinding task, there are fixed four intersections in the small set of mazes and eight intersections in the large set of mazes.

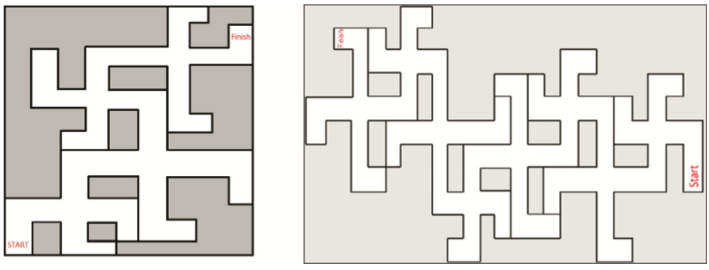

Fig. 1. Two sizes of virtual mazes represent two level of spatial complexity in the wayfinding experiment.

The Landmarks

Each participant was asked to complete the wayfinding task containing six trials, where each has to go through three small and three large mazes. In each trial, the participant would received a specific navigation aid, namely one of the three types of landmarks, a given distant landmark, local landmarks in every intersection, or local landmarks laid by the participant. Figure 2 shows these three types of landmarks from the participant's view. The distant landmark is a tree located constantly beside the maze. The local landmarks are different conspicuous objects such as a chair or a box placed in every intersection in the maze. The third type of landmarks is red disks that the participant can freely place on the floor in any route that he or she is taking.

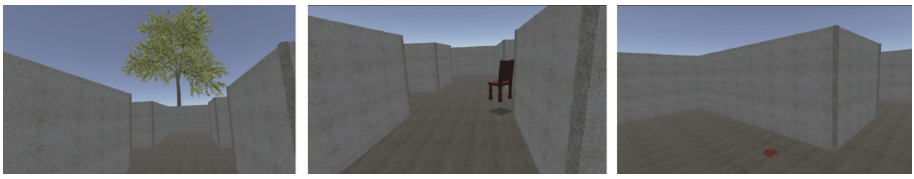

Fig. 2. Three types of landmarks: distant, local, and local landmarks laid by the participant. (Color figure online)

2.3 Apparatus

Figure 3 shows the apparatus used to display the virtual mazes and control the participants' movement within them. The participants were divided into two groups and used either PC screen with keyboard HTC vive with controller stick respectively to perform the task.

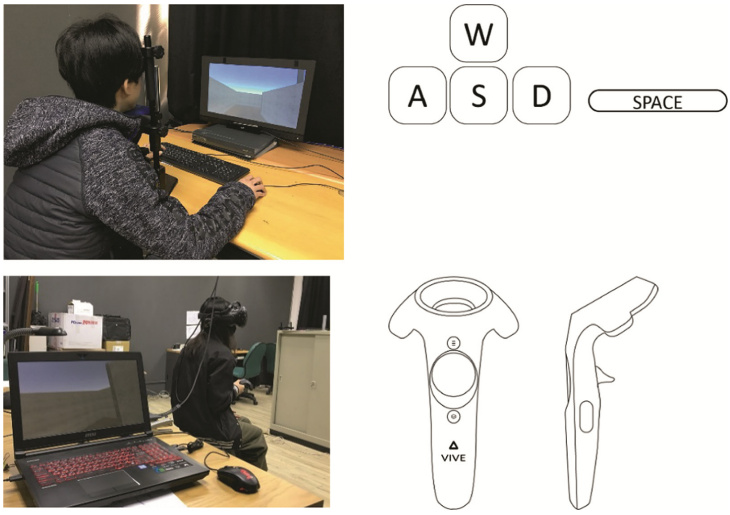

Fig. 3. Two types of interaction in the wayfinding experiment: PC screen with keyboard (upper) and HMD VR (HTC vive) with controller stick (lower)

2.4 Procedure

The participant accompanied by a research assistant have carried out the wayfinding experiment in the lab. The participant first takes a few minutes practicing the wayfinding task with either PC screen or VR interface. He or she has learned to control the movements in the mazes with the given interface, and also view three types of landmarks in the practice trial. The participants were informed that they would receive one of the navigation aids in every trial in the later experiment. During the practice, if the participant reports having difficulty with controlling the movement, then he or she will be given more time to practice.

There are two separated groups: VR group and PC screen group. There are 35 participants in a group. Each participant was asked to perform six times of wayfinding task (two sizes of mazes and three types of landmarks) using either PC screen or VR. The configuration of the mazes varies from trial to trial. The participant took around 40 to 60 min to complete all the six trials. They could have a short break if they ask. We measured the complete time, the times of taking repeat routes, the times of pause, and the eye movements during target-finding in PC screen. The participants were also asked to draw the maze map immediately after finishing the task from their fresh memory. The hand-draw cognitive maps (shown in Fig. 4) they produced would serve as a qualitative evaluation of the spatial learning. The researchers briefly interview the participant to access their experience interacting with the virtual environment.

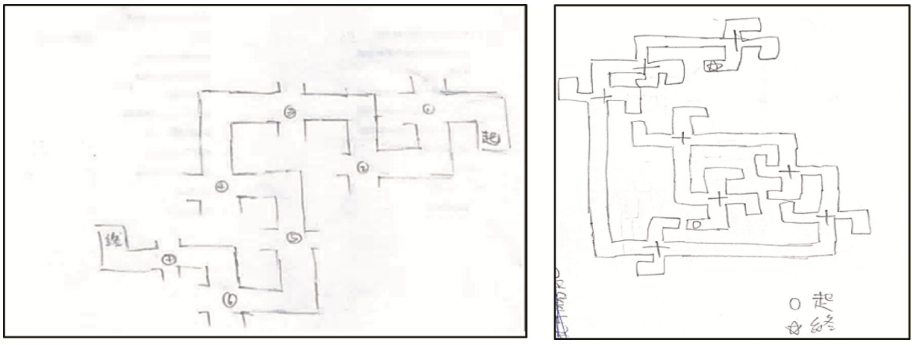

Fig. 4. Sample cognitive maps generated by two of the participants

3 Preliminary Results

Figure 5 shows the current results, where the two diagrams are mean complete time for PC and VR groups, with black, gray, and white bars to represent different conditions of navigation aids. The horizontal axis in the diagrams presents four sub-groups, male or female participants taking the large or small mazes.

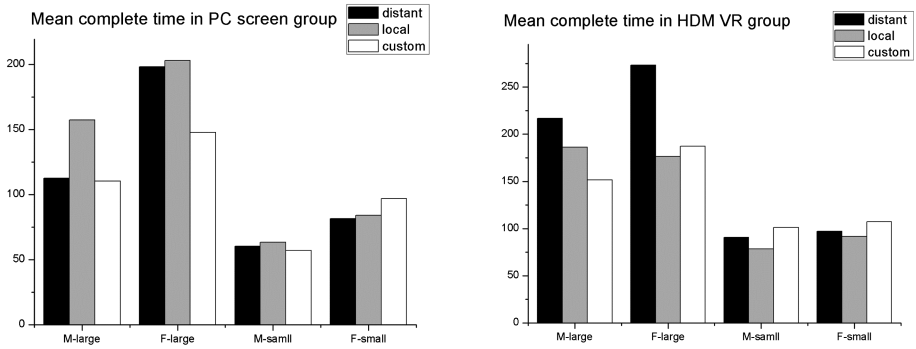

Fig. 5. Mean compele time of three types of landmarks in PC screen group and HD VR group

The primary results reveal that HMD VR group seems to require longer complete time (M = 146.47 s) than PC screen group (M = 114.30 s). However, if taking a closer look, the female participants in VR group result in shorter complete time in the condition of the small maze, and the females in VR group who were given local and custom landmarks also result in that of in screen group. Further more, based on our current collected hand-draw maps (see samples in Fig. 4), the participants of VR group are capable of generating the cognitive maps with better spatial representing of the mazes structure. Currently, we are increasing the number of the participants, analyzing the experiment datas and seeking for more evidence supporting the benefits of HMD VR system in the aspect of spatial learning.

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