EXAMINING THE EDUCATIONAL EFFECTS OF COOPERATIVE LEARNING USING A GIANT MAZE IN VIRTUAL REALITY

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Abstract

In this study, I compared VR/HMD and VR/desktop conditions in a cooperative learning situation using a giant maze and examined the differences in educational effects. The participants were 24 female university students. Participants formed pairs and attempted to reach the goal by attempting to complete a giant maze in the VR collaborative learning material "ayalab Shall we walk?" Group cohesion, interpersonal reactivity (perspective-taking, fantasy, empathic concerns, and personal pain), and critical thinking attitude (awareness of logical thinking, inquisitiveness, objectivity, and emphasis on evidence) before and after cooperative learning in this maze were measured using Microsoft Forms. For these scales, I conducted an analysis of variance on three factors: survey timing (pre-test, post-test), conditions (VR/HMD, VR/desktop), and task achievement level (completed, incomplete). Results showed that group cohesion was high in the post-test. Perspective-taking increased in the VR/desktop/task-completed group, VR/desktop/task-incompleted group, and VR/HMD/task-incompleted group but did not change in the VR/HMD/task-completed group. The empathic concerns score was higher for the task-completed groups in the VR/desktop and VR/HMD conditions The awareness of logical thinking score was higher in the task-completed group than in the task-incompleted group. The objectivity score decreased in the VR/desktop group and increased in the VR/HMD group.

Keywords: *Virtual reality cooperative learning, giant maze, VR/HMD, VR/desktop, educational effect.*

1. Introduction

Various educational materials have been recently developed using virtual reality (VR) technology (Thompson et al., 2018) that have multiple advantages; those relevant to this study include gaining perspective-taking by wearing an avatar, influencing empathy without needing real-life experience (Cotton, 2021), increasing intrinsic motivation (Bailenson, 2017), enabling interactive learning (Graham, 2023), and benefiting collaboration (Ademola, 2023). In this study, I developed a giant virtual maze and clarified the abilities that can be fostered in VR cooperative learning in pairs.

The three main types of VR technology applications are CAVEs, VR/HMD, and VR/desktop. VR/desktop is the most familiar and functional method for using VR technology with a PC, iPad, or iPhone. Previous studies have generally been conducted using one of these methods. As CAVEs are rarely used in VR cooperative learning situations, this study focused on VR/HMD and VR/desktop. If the results demonstrate educational effects, they could encourage the use of VR materials in the classroom.

Generally, cooperative learning is considered an active learning method in which students participate actively in learning. Cooperative learning in this study involves wearing avatars in a virtual space and conducting cooperative work (VR cooperative learning); it can include such processes as interactivity and collaboration (Ademola, 2023; Graham, 2023), which are a strength of VR technology. To date, few educational benefits of cooperative learning using VR technology have been demonstrated. However, high-functioning autistic children aged 10–14 years (Ke & Moon, 2018) and native English-speaking children aged 7–11 years (Craig, Brown, Upright, & DeRosier, 2016) have been shown to increase their social skills by playing cooperative VR games. Furthermore, although not using VR technology, Ilten-Gee and Hilliard (2021) also analyzed students' transactions in paired game situations, suggesting the effectiveness of manipulative transactions. In other words, cooperative games significantly generate discussion that influence each player's thinking.

In the VR research domain, wearing an avatar in a virtual space is believed to allow one to adopt another perspective. This is called virtual reality perspective-taking (VRPT), and several studies have confirmed this phenomenon (Herrera, Bailenson, Weisz, & Zaki, 2018; Van Loon, Bailenson, Zaki, Bostick, & Willer, 2018; Fujisawa, 2023a). In addition, perspective-taking is enhanced (Fujisawa, 2023b) and heart rate is increased (predicting a non-utilitarian response; Francis et al., 2016) in VR moral dilemma discussions, in which avatars are worn and moral dilemmas are discussed. Thus, although this study, in which avatars are worn in a virtual space and cooperative learning is conducted, does not directly address morality, it includes moral actions, such as helping and cooperating with each other in learning, and may be related to some aspects of morality.

In this study, I developed a giant maze, “ayalab Shall we walk?” and compared VR/HMD and VR/desktop in a VR cooperative learning situation to clarify what kinds of abilities are fostered depending on the device used in the same cooperative learning situation.

2. Methods

2.1. Participants

The participants were 24 female university students (age range 19–26 years; five had never used VR, eight had used VR two or three times, and 11 had used VR multiple times). They participated in pairs with a friend.

2.2. Procedure

The participants participated in the experiment in pairs of friends and were randomly assigned to the VR/HMD condition (MetaQuest 2) or the VR/desktop condition (iPad 9th generation). Both pair types were informed of the rules of VR maze learning: (1) enter the maze from the entrance, (2) reach the maze goal together as a pair, and (3) reach the goal as quickly as possible. Each pair had 10 minutes to complete the maze in the virtual space. Participants in the VR/HMD condition then entered individual small experimental rooms and, assisted by the experimenter, were fitted with a VR headset and handles and it was confirmed that they knew how to operate the handles. Participants in the VR/desktop condition entered individual small experimental rooms to confirm they knew how to operate the iPad. Participants in both conditions were alone in the small laboratory; however, they had online access and could converse in their pair and with the experimenter. During the VR maze learning, the experimenter followed each pair without interfering. During this process, the experimenter took notes on the pair’s discussion and recorded the avatar’s behavior. The virtual space used in this study was a giant maze set up in the VR walk, “ayalab Shall we walk?” Before and after this experiment, participants were asked to answer a questionnaire using Microsoft Forms.

2.3. Development of the virtual space

Prior to the implementation of this study, the VR walk, “ayalab Shall we walk?” (Figure 1) was developed using cluster, a metaverse platform. This virtual space allows visitors to stroll through a vast site that changes with the four seasons and is designed to be universally accessible. Originally, this virtual space was developed to allow truant children and their teachers or counselors to enjoy conversations while taking a slow walk in VR (VR walk) and the ease of expressing one’s feelings in the form of an avatar (Fujisawa, 2023b). This study was conducted only in the winter area. There was a steel tower on the upper floor of the entrance to the maze (Figure 1) that participants could climb to observe the maze from above. Whether to climb the tower and observe the maze from above was up to the participating pairs. However, the observation time was included in the maze time limit (10 minutes). During the maze challenge, participants could determine their current position and whether it was the first time they had passed through the maze by looking at the view above the maze corridor and at various items placed irregularly along the maze (Figure 2).

2.4. Survey contents

2.4.1. Group cohesiveness. I used the same items as Arai (2004), who adopted eight items from the Attitude toward Groups scale (Evans & Jarvis, 1986) to measure group attractiveness. It employs a 5-point scale, with 1 point assigned for “not applicable” and 5 points for “applicable.” Cronbach’s alpha coefficient was 0.96.

2.4.2. Short version of the Critical Thinking Attitude Scale. This scale (Kusumi & Hirayama, 2013) measures critical thinking attitudes and consists of four subscales: awareness of logical thinking, inquisitiveness, objectivity, and emphasis on evidence. Each subscale has three items. It employs a 5-point scale, with 1 point assigned for “not applicable” and 5 points for “applicable”.

2.4.3. Interpersonal Reactivity Index. This index (Davis, 1983) measures empathy using four subscales: perspective-taking (PT), fantasy (FA), empathic concerns (EC), and personal distress (PD). Each subscale has seven items. The index employs a 4-point scale with 1 point assigned for "not applicable" and 4 points for "applicable." This scale is commonly used in previous VRPT studies (e.g., Herrera et al., 2018; Van Loon et al., 2018; Fujisawa, 2023a).

2.5. Scoring

The time from the start of the maze to the goal was measured.

2.6. Categorization

Pairs of participants who climbed the tower at the start of the maze and observed the maze from above were assigned as observed, and those who did not observe the maze were assigned as not observed. Those who were able to reach the goal within the time limit were assigned as "task-completed," and those who were unable to reach the goal were assigned as "task-incompleted."

3. Results and discussion

Six participants completed the task in the VR/HMD condition, and six participants did not complete the task. Eight participants completed the task in the VR/desktop condition, and four participants did not complete the task. In the VR/HMD condition, four participants climbed the steel tower above the entrance at the start of the maze and observed the maze from above, and eight participants did not. In the VR/desktop condition, four participants observed and eight did not. The results of the direct probability computation method for condition (VR/HMD, VR/desktop) and task (completed/incompleted) showed no significant difference. The time to reach the goal was 511.0 (0.0) seconds in the completed VR/HMD condition, 425.8 (45.7) seconds without observation in the completed VR/HMD condition, 369.0 (0.0) seconds with observation in the completed VR/desktop condition, and 450.0 (9.2) seconds without observation in the completed VR/desktop condition.

The basic statistics for the measures adopted in the pre- and post-tests are presented in Table 1. A three-factor analysis of variance was conducted for the subscales of group cohesiveness and the IRI as well as the critical thinking attitude scale: time of survey (pre-test, post-test), condition (VR/HMD, VR/desktop) and task (completed/incompleted). The results showed a significant main effect of survey timing on group cohesiveness ($F(1, 20)=5.0$, $p<.05$, $\eta2=.20$). Regardless of the device used, the results indicate that group cohesiveness was enhanced in the post-test compared with the pre-test. These results suggest that, even in VR cooperative learning without direct face-to-face contact, the participants felt more attracted to the pair after VR cooperative learning.

For IRI, perspective-taking had a significant difference on the interaction between the time, condition, and task ($F(1, 20)=9.3$, $p<.01$, $\eta2=.32$). Perspective-taking scores were higher in the post-test than in the pre-test for VR/desktop-task-completed, VR/desktop-task-incompleted, and VR/HMD-task-incompleted. However, there was no change in perspective-taking between the pre- and post-tests for VR/HMD-task-completed. It has been suggested that VR/desktops may make it easier to acquire perspective-taking skills. After the VRPT was confirmed in previous studies, perspective-taking using VR technology has been used in moral education and drama classes, and the results of this study support that research. However, cooperative VR learning with VR materials involving movement in a virtual space, as in this study, may be easier to operate with a tablet than with a VR/HMD. For empathic concerns, the interaction of condition and task was significant ($F(1, 20)=4.9$, $p<.10$, $\eta2=.13$). Empathic concern scores were higher in the post-test than in the pre-test for VR/desktop/task-completed, VR/HMD/task-completed, and VR/HMD-task-incompleted. However, there was no change in the empathic concern scores in the VR/desktop-task-completed test before and after the experiment. Empathic concerns may be enhanced in patients with VR/HMDs. Because VR/HMDs are three-dimensional (3D) in 360°, they are considered more immersive and sympathetic than VR/desktop 3D.

For the critical thinking attitude scale, logical thinking had a significant main effect on the task ($F(1, 20)=9.7$, $p<.01$, $\eta2=.33$). The post-test scores were lower after not completing the task than after completing it. This finding suggests that the transformation of logical thinking was related to whether the learning task was completed, not to which device the participants used. For objectivity, there was a significant difference in the interaction of time of survey and condition ($F(1, 20)=4.8$, $p<.05$, $\eta2=.20$). The learning task in this study was a maze learning task, and it might have been easier to grasp 360° and view the learning task (maze) objectively with VR/HMD than with VR/desktop. Although a learning task such as the present one, which involves movement using VR space, may be affected by participants' spatial cognitive ability, this is not clear from the results of the present study.

4. Conclusion

In this study, I compared VR/HMD and VR/desktop in a VR cooperative learning situation and examined the abilities fostered by the devices used in the same cooperative learning task. The results showed no difference in the completion of learning using either device with respect to task accomplishment (arrival at the goal within the time limit). However, social abilities, such as empathy and objectivity, which were the focus of this study, were enhanced in the VR/HMD condition. These abilities may be more enhanced in cooperative learning with a 360-degree immersive device than in the other conditions. Furthermore, the abilities learned may differ depending not only on the device used but also on whether the task was completed. Therefore, it makes sense to change the type of device according to the ability that one wants to develop in the learning situation. At the same time, it was also suggested that it is necessary to consider the ability to be developed and whether or not the task can be completed.

Figure 1. Maze entrance and steel tower above the entrance to allow observation of the maze passageways from above

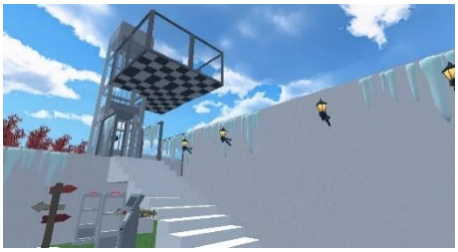

Figure 2. Examples of clues in the sky visible from the passageway of the maze (left side) and items placed in the passageway of the maze (right side)

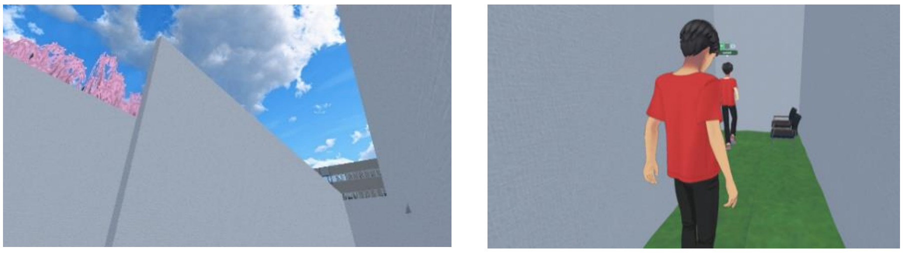

Table 1. Basic statistics for group cohesion and subscales of IRI

			awareness of logical thinking		inquisitiveness		objectivity		emphasis on evidence	
Pre test	VRdesktop	complete	12.8	1.7	13.0	3.2	12.2	2.0	11.8	3.4
		not complete	11.5	2.2	12.8	1.9	11.5	1.9	9.2	3.3
	VRHMD	complete	12.1	1.2	12.6	1.3	12.3	2.1	9.6	2.8
		not complete	11.0	1.2	12.3	1.0	11.5	3.0	10.8	1.7
Post test	VRdesktop	complete	13.2	1.5	12.7	3.6	12.2	2.1	11.0	3.8
		not complete	9.3	3.3	13.8	1.0	11.2	1.8	8.0	3.9
	VRHMD	complete	11.6	1.8	13.0	1.5	12.5	1.9	9.8	2.8
		not complete	9.8	2.9	12.8	2.6	13.8	1.3	10.0	1.6

Table 2. Basic statistics for critical thinking attitudes.

					IRI							
			Group cohesion		PT		FA		EC		PP	
			M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Pre test	VRdesktop	complete	34.0	6.7	21.7	1.6	21.8	3.3	22.5	3.7	19.5	5.5
		not complete	34.2	4.6	19.0	2.3	23.3	3.3	18.2	5.1	15.3	5.0
	VRHMD	complete	36.8	2.7	21.8	1.5	24.0	3.1	21.1	1.8	18.6	5.9
		not complete	38.5	0.6	21.0	0.8	21.5	4.5	22.8	1.5	17.3	4.2
Post test	VRdesktop	complete	37.0	3.1	24.2	2.7	22.0	4.6	23.5	3.9	19.0	5.9
		not complete	37.5	2.9	19.8	2.3	24.0	2.9	18.0	5.1	14.8	5.2
	VRHMD	complete	38.4	1.6	22.0	1.7	23.6	2.6	21.5	3.3	18.9	5.4
		not complete	38.0	3.4	23.8	1.3	20.5	4.1	23.3	2.4	16.3	3.4

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