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EXPLORING COOPERATIVE LEARNING: A COMPARISON OF SCENE IMAGINATION AND VIRTUAL REALITY

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Abstract

This study developed virtual reality cooperative learning material titled "ayalab Save ayami!" in which participants navigated a Western-style floating house in nocturnal darkness to rescue the main character. The study involved 30 female university students who participated in pairs, with each pair assigned either a "university student" or "detective" avatar. Within each pair, one participant was designated as the leader and the other as the non-leader. In the scene imagination experiment, participants viewed a Western-style house displayed on a tablet and engaged in cooperative learning, by deciphering codes associated with the seven treasures needed to save the main character and identifying the locations of each of the seven treasures hidden in the house (time limit: 10 minutes). In the virtual space experiment, participants used a 9th-generation iPad to enter the virtual environment, wore designated avatars, and searched for the seven treasures in the virtual space (time limit: 10 minutes). The leader was tasked with taking pictures of the pair and each treasure and identifying each of the seven treasures, which were combined with cipher numbers. Questionnaires measuring group cohesion, critical thinking attitude (CTAS), the Interpersonal Reactivity Index (IRI), and the short version of the Sense of Direction Questionnaire (SDQ-S) were administered before and after cooperative learning in both conditions. In the scene imagination condition, inquisitiveness regarding CTAS increased among non-leaders using the university student avatar. Regarding the IRI, the perspective-taking score increased for participants using the university student avatar, suggesting that these avatars may provide learning effects similar to those of real-life experiences. In the virtual space condition, the inquisitiveness of CTAS also increased for university students. Additionally, IRI scores for perspective-taking and fantasy scores increased for the university student leaders and detective non-leaders but decreased for university student non-leaders, detective leaders, and detective non-leaders. Group cohesion and SDQ-S scores remained unchanged. These findings suggest that there are differences in cooperative learning outcomes between scene imagination and virtual space conditions.

Keywords: *Cooperative learning, scene imagination, critical thinking attitude, sense of direction, avatar.*

1. Introduction

Recent advancements in virtual reality (VR) technology have enabled the application of scene imagination methods used in psychological research to virtual spaces, but findings in this area remain limited. This study compared cooperative learning outcomes in scene imagination with those in virtual spaces, aiming to elucidate the unique characteristics of each.

The scene imagination method involves envisioning oneself in a specific scenario, estimating cognition, emotion, and behavior, and is often employed when it is difficult to implement the method in a laboratory. For example, participants may imagine being in a different place, a manipulated social situation, or as a person unlike themselves. While this method is meaningful, and knowledge gained has yielded significant insights, VR technology now enables the recreation of experimental scenarios in virtual environments. Through body transference by wearing avatars, participants can virtually experience the target scene rather than merely imagining it. Previous research has explored VR simulations and compared them with watching video recordings (e.g., Richter et al., 2022; Huang et al., 2023). However, comparisons of scene imagination and VR-based cooperative learning remain scarce.

Research on cooperative learning using VR indicates positive outcomes. For instance, VR cooperative games enhance social skills among children with autism aged 10–14 years (Ke & Moon, 2018) and among native English-speaking children aged 7–11 years (Craig et al., 2016). Studies have also shown that even partial moral skills and high task achievement performance are enhanced in cooperative learning in VR environments, such as paired classroom tidying tasks (Fujisawa, 2024a) and VR giant maze navigation (Fujisawa, 2024b), which can improve moral skills and task performance. Moreover, VR facilitates perspective-taking, a phenomenon confirmed by several studies (Herrera et al., 2018; van Loon et al., 2018), and enhances perspective-taking scores in moral dilemma discussions (Fujisawa, 2023c).

VR environments offer advantages beyond replicating real-world experiences, such as three-dimensional interactions influenced by spatial cognitive abilities. These abilities, emphasized in Science, Technology, Engineering, and Arts education, exhibit gender and individual differences (Lyons et al., 2018) and are related to perspective-taking (Lyons, et al., 2018; Desme et al., 2024). Although spatial cognitive abilities have been reliably self-reported (Hegarty et al., 2002), their role in VR performance remains underexplored. Experiencing a manipulated social situation in VR through avatars could enable participants to engage more concretely than in scene imagination, with potential effects varying based on individual characteristics.

This study had two objectives: (1) to determine whether cooperative learning outcomes in scene imagination differ from those in VR and (2) to examine whether VR cooperative learning, involving free movement, impacts participants' spatial cognitive abilities.

2. Methods

2.1. Participants

Thirty female undergraduate university students participated in the study in pairs.

2.2. Procedure

Development of the virtual space: Before the experiment, the VR cooperative learning material "ayalab Save ayami!" was developed. The virtual space consisted of a Western-style house with two floors above ground, a basement, and a garden. The house included several rooms, underground passages, and secret entrances, and could be accessed through multiple routes. The design ensured that the entire house could not be viewed from any single location. Seven treasures (four crystals and three beckoning cats) were hidden in difficult-to-locate spots within the house.

2.3. Experimental procedure

Participants completed the experiment in pairs and were administered a pre-test. The pairs were then randomly assigned to one of two conditions: the University Student Condition (USD) or the Detective Condition (DC). Each condition was introduced using explanatory text, accompanied by an illustration of the avatars. The text for the DC (with "detective" replaced by "university student" in the USD condition) read as follows: "You are a detective who has solved many difficult problems and helped many people. Now you heard of a problem in a large Western-style house that appeared in the dark. The only way to save the main character, ayami is to find seven treasures (four crystals and three beckoning cats). As detectives, your team must decipher the message from Thief X and find the seven treasures he has hidden."

In the scene imagination experiment, a tablet displaying the exterior of the Western-style house and seven ciphers indicating the treasures' hiding places was presented to the pairs (Figure 1). Participants were tasked with discussing potential treasure locations based on the ciphers, working collaboratively without physically interacting with the tablet. They were permitted to take notes. This phase lasted 10 minutes, followed by Post-Test 1, in which participants answered the same questions as in the pre-test.

After completing Post-Test 1, one participant in each pair designated as the leader was tasked with taking photographs of each treasure and of the pair in the virtual space upon finding them. Participants were then instructed on how to operate the tablet and avatar, check and verify their avatars, and review the rules (e.g., always searching as a pair).

In the virtual space experiment, participants searched for treasures within a 10-minute time limit. The experiment concluded either when all seven treasures were located or when the time limit expired. Post-Test 2 was then administered.

Figure 1. A tablet displaying the exterior of the Western-style house.

2.4. Measurements

The Sense of Direction Questionnaire-Simplified (SDQ-S) was used to assess the sense of direction (Yanagihara & Mihoshi, 2005). It is a five-point scale measuring the sense of direction, with a Cronbach's alpha coefficient of .92.

Group cohesion was measured using eight items from the Attitudes Towards Groups Scale (Evans & Jarvis, 1986). These items were scored on a five-point scale, with a Cronbach's alpha coefficient of .94.

The short version of the Critical Thinking Attitude Scale (CTAS) was used to measure critical thinking attitudes (Kusumi & Hirayama, 2013). It consists of four subscales: awareness of logical thinking, inquisitiveness, objectivity, and emphasis on evidence, each with three items scored on a five-point scale. Cronbach's alpha coefficients for these subscales were .68, .65, .80, and .60, respectively.

Empathy was measured using the Interpersonal Reactivity Index (IRI) (Davis, 1983), which comprises four subscales: perspective-taking (PT), fantasy (FT), empathic concerns (EC), and personal distress (PD). Each subscale consists of seven items scored on a four-point scale. Cronbach's alpha coefficients for these subscales were .66, .76, .62, and .80, respectively.

Participants were coded based on their initial SDQ-S scores. Those with scores at or above the average (58.1) and higher SDQ-S measured for the first time were assigned to the upper group, while those with lower scores were assigned to the lower group.

3. Results and discussion

3.1. Are scene imagination cooperative learning and virtual reality cooperative learning the same?

The basic statistics are presented in Table 1. To examine cooperative learning in scene imagination, an analysis of variance (ANOVA) was conducted with each subscale score as the dependent variable and survey timing (pre-test, post-test 1), condition (USC, DC), and attributes (leader, non-leader) as independent variables for the SDQ-S, CTAS, IRI, and group cohesion. The results showed that there were no significant differences for the SDQ-S and group cohesion. For the CTAS, there was a significant tendency for an interaction between survey timing and the attribute of inquisitiveness (F (1, 26) = 3.7, $p = .07$, $\eta^2 = .13$), which increased for non-leaders in the USC condition. Regarding objectivity, a significant trend was observed for the interaction between survey timing and condition ($F(1, 26) = 3.2$, $p = .09$, $\eta^2 = .11$) and between survey timing and attribute ($F(1, 26) = 3.4$, $p = .08$, $\eta^2 = .12$), with both increasing in the USC condition. For the IRI, the interaction between condition and attribute showed a significant trend for PT (F (1, 26) = 3.9, $p = .06$, $\eta^2 = .13$), which increased in the USC group.

Table 1. Basic statistics for each subscale by attribute and condition.

	condition	attribute	GC		awareness of logical thinking		inquisitiveness		objectivity		emphasis on evidence		PT		FT		EC		PD		Space	
			M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Pretest	University student	leader	34.7	4.5	11.3	2.4	14.0	1.2	12.0	3.8	11.9	2.9	22.0	3.6	22.6	3.6	20.7	2.8	20.6	3.9	63.7	11.4
		no leader	32.4	9.9	11.0	2.9	12.3	1.9	10.4	2.4	10.6	2.3	20.0	2.0	23.1	2.5	22.7	3.1	19.9	5.8	54.0	18.4
	detective	leader	33.4	6.6	11.0	2.2	12.8	2.0	11.5	1.5	11.1	1.6	20.4	3.0	24.1	4.7	21.3	3.5	22.0	5.6	49.9	13.3
		no leader	33.7	7.0	10.1	2.4	12.0	2.0	13.3	1.8	10.5	2.2	22.6	3.0	22.0	5.3	21.6	1.9	21.5	3.7	66.3	11.8
Posttest1	University student	leader	35.3	5.1	11.4	3.2	13.7	1.4	12.9	2.7	11.9	2.7	23.0	3.3	23.4	3.9	20.3	3.2	19.6	5.2	62.6	14.8
		no leader	35.1	5.1	11.4	2.9	13.6	1.9	11.9	2.5	10.6	2.9	21.1	4.5	23.1	3.3	22.4	3.9	19.3	4.8	53.6	19.8
	detective	leader	35.0	4.7	10.9	3.1	12.8	1.8	11.5	2.7	11.6	1.8	20.5	2.3	25.3	4.9	21.0	4.1	20.5	7.0	50.9	15.0
		no leader	33.4	7.7	11.8	1.8	12.1	2.1	13.4	1.8	10.6	2.7	22.4	2.4	21.1	4.7	21.5	2.1	21.6	4.5	66.3	11.9
Posttest2	University student	leader	35.6	4.4	11.6	2.6	14.0	1.4	12.6	3.2	12.4	2.2	22.9	3.8	24.1	4.2	20.1	2.9	18.4	4.3	61.7	16.9
		no leader	37.6	3.3	11.7	2.8	13.3	2.0	11.9	3.0	11.9	3.2	20.9	4.2	22.9	3.4	23.0	3.4	19.3	5.0	53.6	19.6
	detective	leader	35.4	4.0	11.8	2.6	12.9	1.9	12.0	2.7	11.8	2.0	20.9	2.5	25.0	5.0	21.8	3.2	20.8	7.1	51.1	14.3
		no leader	35.0	7.3	11.4	2.3	12.3	2.2	13.1	1.9	11.1	2.1	23.0	2.7	22.4	4.7	20.9	1.8	21.8	4.3	65.0	11.9

To examine cooperative learning in the virtual space, an ANOVA was conducted with each subscale score (SDQ-S, CTAS, IRI, and group cohesion) as the dependent variable and survey timing (post-test 1, post-test 2), condition (USC, DC), and attribute (leader, non-leader) as independent variables. The results showed no significant differences for the SDQ-S and group cohesion. For the CTAS, the main effect of the condition on inquisitiveness tended to be significant ($F(1, 26) = 2.9$, $p = .10$, $\eta^2 = .10$), with higher scores in the USC condition. Regarding emphasis on evidence, the main effect of survey timing was significant ($F(1, 26) = 9.3$, $p = .01$, $\eta^2 = .26$), with higher scores in the post-test. For the IRI, the interaction between condition and attribute showed a significant trend for PT ($F(1, 26) = 2.8$, $p = .10$, $\eta^2 = .10$), which increased for leaders in the USC condition and non-leaders in the DC condition, while decreasing for non-leaders in the USC condition and leaders in the DC condition. For FT, there was a significant interaction between survey timing and attribute ($F(1, 26) = 7.7$, $p = .01$, $\eta^2 = .24$), which increased for leaders in the USC condition and non-leaders in the DC condition, while decreasing for non-leaders in the USC condition. The interaction between survey timing, condition, and attribute for EC showed a significant trend ($F(1, 26) = 3.0$, $p = .10$, $\eta^2 = .10$), increasing for non-leaders in the USC condition and for leaders in the DC condition, while decreasing for non-leaders in the DC condition.

3.2. Is virtual reality cooperative learning influenced by spatial cognitive ability?

The basic statistics before the analysis are listed in Table 2. To clarify the influence of the participants' spatial cognitive ability on virtual spatial cooperative learning, an ANOVA was conducted on the SDQ-S, CTAS, IRI, and group cohesion, with each subscale score as the dependent variable, survey timing (post-test 1, post-test 2), and condition (USC, DC). The results showed no significant differences in group cohesion. For logical thinking in the CTAS, a significant interaction between survey timing, condition, and spatial cognitive ability was observed ($F(1, 26) = 3.0$, $p = .10$, $\eta^2 = .10$). Scores increased in the upper USC and lower DC groups but decreased in the upper DC group. For inquisitiveness, a significant interaction between survey timing and spatial cognitive ability was found ($F(1, 26) = 3.8$, $p = .06$, $\eta^2 = .13$), with scores decreasing in the upper group and increasing in the lower group. Regarding objectivity, the main effect of spatial cognitive ability tended to be significant ($F(1, 26) = 3.3$, $p = .08$, $\eta^2 = .11$), with higher scores in the upper group .For the IRI, EC showed a significant interaction between condition and spatial cognitive ability ($F(1, 26) = 7.0$, $p = .01$, $\eta^2 = .21$), with scores increasing in the upper group of the DC group. A significant interaction between survey timing, condition, and spatial cognitive ability was observed for PD ($F(1, 26) = 3.3$, $p = .08$, $\eta^2 = .11$), with scores decreasing in the upper USC group, increasing in the lower USC group, and increasing in the upper DC group. For the SDQ-S, the main effect of spatial cognitive ability was significant ($F(1, 26) = 39.8$, $p = .01$, $\eta^2 = .60$), indicating an increase in scores in the upper group. These results suggest that it may be meaningful to conduct virtual reality cooperatives for participants with lower spatial cognitive ability. Additionally, EC, essential for morality, was higher in the upper group, suggesting that high spatial cognitive ability may promote moral development in virtual spaces.

Table 2. Basic statistics for each subscale by spatial cognitive ability.

	condition	space ability	GC		awareness of logical thinking		inquisitiveness		objectivity		emphasis on evidence		PT		FT		EC		PD		Space	
			M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Prosttest 1	University student	upper	34.7	4.5	10.9	2.7	13.0	1.8	12.9	2.3	11.4	2.4	22.7	2.7	22.0	3.1	19.6	2.9	19.9	4.9	71.3	8.2
		lower	35.7	5.6	12.0	3.3	14.3	1.1	11.9	2.9	11.0	3.4	21.4	4.9	24.6	3.6	23.1	3.4	19.0	5.0	44.9	13.5
	detective	upper	36.4	6.9	12.1	1.6	12.4	2.1	13.6	1.6	11.3	3.0	22.6	2.6	22.2	5.8	22.7	2.3	21.4	4.6	70.4	8.6
		lower	32.9	5.5	10.7	3.0	12.4	1.9	11.6	2.6	11.0	1.7	20.6	2.2	24.1	4.7	20.1	3.4	20.8	6.7	48.0	10.6
Posttest 2	University student	upper	35.4	4.3	11.3	2.2	13.3	2.0	13.1	2.5	12.4	1.9	22.0	3.7	22.1	3.4	19.7	3.0	18.0	3.7	71.3	8.3
		lower	37.7	3.3	12.0	3.1	14.0	1.4	11.3	3.3	11.9	3.4	21.7	4.5	24.9	3.8	23.4	2.6	19.7	5.4	44.0	14.4
	detective	upper	36.7	6.2	11.3	2.4	12.9	2.2	13.4	1.4	11.6	2.2	23.1	2.9	23.5	5.4	21.9	2.5	21.9	4.6	70.1	8.6
		lower	33.9	5.5	11.8	2.4	12.3	1.9	11.9	2.7	11.3	1.9	21.0	2.4	24.0	4.8	20.9	2.6	20.8	6.7	48.7	10.7

3.3. Differences in task achievement in cooperative learning in virtual reality: Are there differences in learning achievement between university student avatars and detective avatars?

Task achievement in the virtual space was examined by evaluating the success of finding and photographing the seven treasures across the two conditions (USC and DC). Three pairs (USC = 1, DC = 2) successfully located and photographed all seven treasures within the time limit. Two pairs (USC = 1, DC = 1) located and photographed up to six treasures, four pairs (USC = 1, DC = 3) located and photographed up to five treasures, and six pairs (USC = 4, DC = 2) located and photographed up to four treasures. There were no significant differences between the conditions or in task achievement. These findings suggest that the type of avatar does not affect task achievement in virtual reality cooperative learning.

4. Conclusions

In the scene imagination method, inquisitiveness, objectivity, and PT partially increased in the USC group. In the virtual space, inquisitiveness, emphasis on evidence, PT, FA, and EC partially increased. The effects of the avatars (university student and detective) differed between the scene imagination method and the virtual space. In the scene imagination method, ability increased in the USC group, consistent with the participants' own attributes. In the virtual space, however, the attributes of leader and non-leader were more strongly associated with changes in abilities than with the type of avatar. Regarding the SDQ-S, the CTAS scores increased in the lower groups for both conditions. This suggests that virtual space cooperative learning may be especially beneficial for participants with lower spatial cognitive abilities. However, EC, critical for morality, was higher in the upper group, indicating that virtual spaces may promote moral development when spatial cognitive ability is high.

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