Is VR Always a Better Choice? Investigating the Effects of Game Modes and Role-Playing on Fire Escape Simulation Training

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***Abstract*—In this paper, we present a multi-user fire escape simulation training system that involves an actionist in Virtual Reality (VR) and a strategist using a desktop. We implemented two game modes (collaboration and competition) and conducted a comparative study to investigate how user experiences and learning outcomes vary between the two game modes, and between the two roles in the gameplay. The learning outcomes using the simulation training were compared against a baseline condition, where participants learned the fire escape knowledge by reading paper instructions. Our results revealed that users reported higher perceived usability and lower workload in the collaboration mode than in the competition mode. In addition, actionists (VR users) reported greater performance but also greater mental workload than strategists (desktop users). In terms of learning outcomes, strategists showed greater improvement than actionists. However, the improvement in learning outcomes did not vary significantly from the baseline condition. We discussed the effects of game modes and role-playing on user experience and learning outcomes and the implications for future interactive educational systems.**

***Index Terms*—human-computer interaction, virtual reality, gameplay, role-playing**

I. Introduction

Computer-based interactive education systems have been found to be an effective way to achieve good user experience and learning efficiency in various fields, such as mathematics [1], medicine [2], and history [3]. For example, Bruzzone et al. [4] proposed a serious game on ships and off-shore platforms for training and education. The results showed that this game reduced training time, cost and risk. Using Virtual Reality (VR) for 3D anatomy training was also found appropriate to be used as an alternative to the traditional training method [5]. In addition, previous researchers also found that learning through collaborative groups could achieve higher learning efficiency and performance than learning individually, in both traditional school educations [6] and computer-supported learning systems [7]. To improve user experience and training effect, researchers tried to take advantage of the high immersion and fidelity features of Virtual Reality (VR) in the design of education systems, especially for the training related to safety-critical scenes, such as earthquakes [8] and floods [9]. In this way, users could have realistic training experiences without worrying about the risk of physical injury. However, while existing works have explored ways to develop realistic simulation systems, limited research has explored the effect of games, in particular the mode of games and the roles in multi-user gameplay, on users' learning outcomes and user experience.

To fill this research gap, we present a comparative study that investigates the differences in user experience and learning outcomes between game modes (competition mode and collaboration mode) and roles in multi-user gameplay (strategist and actionist) in a multi-user fire escape simulation game. The main contributions are three-fold. First, we designed an asymmetric interactive game for fire escape simulation. Then, we presented an empirical evaluation of the user experience of the two game modes and two roles when performing the fire escape simulation game. Meanwhile, we also show the difference in learning outcomes between the two game modes and the paper-based learning mode. Finally, we discussed the features of different game modes and roles, which have led to useful findings and design implications for future educational systems.

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II. Related work

A. Gamified Education Systems

Computer-based interactive education systems have been wildly applied and proven to affect user experience and learning efficiency [1, 10]. For example, Kebritchi et al. [1] explored the effects of using a modern mathematics computer game besides regular math instruction on student achievement. They found that students who played this game achieved significantly higher scores on their final exams than those who did not play the game. Similar results were also found by Shin et al. [11]. They found that students learning through a game system achieved better learning results than the students learning through the traditional paper method in mathematics. Except for the benefit on learning results, existing research has also shown that gamified education systems can improve student motivation in learning [10]. Therefore, gamified education system is becoming increasingly popular.

With the development of VR technology, researchers tried to develop immersive education systems to bring better user experience and alleviate education constraints [4]. In particular, VR is an ideal approach for simulation education systems that could avoid potential physical injury from real training scenarios. This includes the training of coping strategies necessitated under natural disasters and emergency circumstances, such as earthquakes [8] and floods [9]. Such systems have become an effective alternative method and add an additional layer to traditional training methods by providing immersive displays with a sense of presence and allowing participants to naturally interact with the virtual environments. While maintaining the effectiveness of training, these VR educational systems significantly reduce training costs and risks.

B. Multi-user Asymmetric Interactive Systems

In multi-user systems, asymmetric interactions allow users to view and interact with system content using different roles, abilities, or devices for collaboration [12]. Asymmetric interactive systems provide users with more options than symmetric systems from devices, interaction methods and working scenarios. For example, *Virtual Makerspaces* [13] showed a remote multi-user online collaborative system. Users can join in virtual environments based on real-time scanning of the real space, within which they could generate content and have real-time remote discussions using various devices such as PC, AR, or VR. The telemedicine guidance system developed by Strak et al. [2] allows experts using a VR HMD to remotely guide medical staff, who can then practice using AR HMDs. By allowing multiple devices to join in the collaborative tasks, these asymmetric collaboration systems expanded the systems' available environment and increased users' achievable information. Thus, users could achieve satisfying user experience and task performance by selecting devices and cooperating according to their needs and conditions. Users with different knowledge or skills also could collaborate more easily and efficiently. However, the evaluations of user experience and task performance in existing studies often took a holistic view and considered participants as a group. Some only focused on the part of users. There is still a lack of research exploring the differences in user experience and task performance between users when they use different devices and play distinct game roles. Thus, we proposed two research questions (RQs) and their hypotheses.

RQ1: Does role-playing affect user experience (engagement and workload) in a fire escape game?

RQ2: Does role-playing affect learning outcomes in a fire escape game, compared to traditional learning methods?

Hypotheses: Users will feel different engagement (**H1a**) and workload (**H1b**) when playing different roles. The learning outcomes will differ for role-playing and traditional learning methods (**H2**).

C. Game Modes in Multi-User Educational Systems

In multi-user education systems, competition and collaboration are two popular modes of forming the relationship between users. Existing research has shown that game modes could affect user experience and task performance. For example, Plass et al. [14] found the competitive mode better contributed to users' learning results than the collaborative mode. Morschheuser et al. [15] found that the group competitive mode (members of a group cooperate but compete with other groups) leads to greater enjoyment, participation, and a higher level of willingness to recommend a system than the competitive mode and collaborative mode in a crowdsourcing system. They suggested that designers should consider using cooperative mode instead of competitive mode to increase users' willingness to recommend crowdsourcing systems. However, contradictory results in the effect of game modes were found in different fields. For example, Vrugte et al. [16] found students with different knowledge levels showed opposite results in the same mathematics education system: competition mode had a positive effect on the learning of high-level students but negatively affected the learning of low-level students. Thus, how the game modes affect user experience and learning efficiency in different fields deserves further exploration. Motivated by the related work on game modes, we propose two research questions and their hypotheses.:

RQ3: Do game modes affect user experience (engagement and workload) in a fire escape game?

RQ4: Do game modes affect learning outcomes in a fire escape game, compared to traditional learning methods?

Hypotheses: Users will feel different engagement (**H3a**) and workload (**H3b**) in different game modes. The learning outcomes will differ for the two game modes (**H4**).

III. System Design

A. Apparatus and Implementation

1) Hardware and Software: The fire escape system was built using a desktop with an Intel(R) Core(TM) i9-10900K CPU, 64GB RAM, an NVIDIA GeForce GTX 2080ti graphics card. This workstation is also used to run the VR system. In addition, we used a laptop with an AMD Ryzen 7 5800H processor, 16GB RAM, and an NVIDIA GeForce RTX 3070 graphics card to host another user. The systems were built in Unity (version 2020.3.25) and *Photon Unity Networking 2* [1]. Virtual objects were built using Blender 3.0.

2) System Setup: We adopted two PCs and a VR HMD to set up the experiment. Specifically, the laptop used for the experiment has a 17.3-inch screen display (3840×2160 resolution, 120 Hz refresh rate). A Meta Quest 2 with a resolution of 1920×1832 for each eye and a refresh rate of 72 Hz was connected to the desktop and used as the VR device.

B. Experimental Environment

1) Virtual Buildings: The virtual buildings used in this game were made to refer to the real structure of two teaching buildings in a university, each building consisting of five floors. The two buildings are connected by interior corridors on the second floor and exterior corridors on the third floor.

2) Props: We provide three common types of fire-fighting equipment in this system to help users escape from the building: wet towels, fire extinguishers and ropes. In real fire scenes, covering the mouth using *wet towels* can keep people

[1]https://assetstore.unity.com/packages/tools/network/pun-2-free-119922

Fig. 1: The environment and props in the fire escape game. Yellow: wet towels used to reduce the inhalation of smoke; purple: actionists' health bar; red: ropes used to escape; blue: descriptions of fire extinguishers; and green: descriptions of the fire.

from breathing in the smoke. We thus included the strategy in the game design and required users to use wet towels to cover their mouths during the game (see Fig. 1, yellow). Otherwise, users' health bar will drain (see Fig. 1, purple). Considering the common fire types in schools, we designed four types of *fire extinguishers*: water, carbon dioxide, dry powder, and foam. Users need to select the correct fire extinguisher for the fires caused by different materials (see Fig. 1, blue). The material causing the fire is shown to users (see Fig. 1, green). *Ropes* can be used to help users reach the ground directly from the third floor or below (see Fig. 1, red).

3) Role-playing: The fire escape game involves two roles: an actionist with a first-person perspective wearing a VR HMD, who should try to escape the fire; and a strategist with a third-person perspective, who should prevent the actionist from escaping the fire by setting fires in the simulation, or help the actionist to escape. Each game lasts a maximum of 8 minutes. An actionist wins if he manages to escape the fire scene (i.e., reach the ground floor) within 8 minutes; otherwise, a strategist wins.

Actionist. The actionist wears a VR HMD and experience the fire simulation in a first-person perspective (see Fig. 2, left). Users could move and interact with props in the virtual buildings. Specifically, users could use the thumbstick of the VR controller to teleport and move, use raycasting to point and indicate an object to select, use the grip button to confirm a selection and grab props, and use the trigger button to activate items.

Strategist. The strategist plays the game with a top-down view of the virtual environment (see Fig. 2, right). During the game, users could switch floors by pressing the "2" and "3" keys on the keyboard. They could set fire at fire points on the second floor when the fire cool-down time is equal to "00:00" by clicking the fire buttons (see Fig. 2, yellow). Actionists can see the game's remaining time, fire cool-down time, and material cool-down time (see Fig. 2, red).

Fig. 2: Screenshots showing actionists' (left) and strategists' (right) views. Yellow: buttons for different types of fire; red: time information.

C. System Setting in Two Game Modes

We set up two game modes (competition mode and collaboration mode) by adjusting the system settings. The actionists have the same aim in both modes: escape the fire. The difference between them is that in the competition mode, they can obtain information about the type of fire extinguishers and fires, but they have to rely on guidance from strategists to obtain these two types of information in the collaboration mode. The details of the system setting for strategists in the two game modes have been shown in Table I.

TABLE I: The details of system setting for strategists between competition mode and collaboration mode.

	Competition mode	Collaboration mode
Aim	Prevent actionists from escaping	Help actionists to escape
Fire Ability	Yes	No
Fire (2nd floor)	Choose 2 fire points to set fire	System set fire at 4 fire points
Fire (3rd floor)	System set fire at 4 fire points	System set fire at 4 fire points
Info about fire	Available	Available
Info about fire extinguishers	Available	Available

IV. Evaluation Study

We designed a mixed study that involved two participants in each experiment. The within-group variable is the game mode (collaboration or competition), and the between-group variable is the role in gameplay (strategist or actionist). For each of the two sessions, we measured participants' engagement and workload to assess their user experience. The sequence of collaboration and competition game modes was counterbalanced in the experiments. We assessed participants' learning outcomes about fire escape knowledge only after the first session.

A. User Experience

Engagement. The short form of the User Engagement Scale (UES-SF) [17] consists of twelve questions and is used to analyse user's engagement by four dimensions: Focused attention, Perceived usability, Aesthetic appeal and Reward. Each dimension is measured with three questions rated on a 5-point Likert scale (5 = strongly agree).

Workload. The unweighted NASA Task Load Index (NASA-TLX) [18] consists of six questions and is used to analyse users' workload. The questions assess users' feelings on six dimensions: Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration. Questions were rated on a scale between 0 and 20. Each dimension has the same weight, and the average sum of these six dimensions is reported as the overall workload.

B. Learning Outcomes

A Fire Escape Knowledge Questionnaire (FEKQ) is designed to measure users' knowledge of fire equipment. In this questionnaire, two questions are about how to use wet towels and escape ropes in a fire situation. The other four questions examined which fire extinguishers should be used to deal with fires caused by combustive solids, active metals, electricity and oil (see Table. II). Each question has five options and only has one correct result. We counted the correct accuracy of pre-test (Pre) and post-test ($Post$). The learning outcomes (LO) was thus calculated by the formula: $LO = Pre - Post$.

TABLE II: The questions used in the Fire Escape Knowledge Questionnaire (FEKQ).

	Type	Question
Q1	Wet towels	What is the role of wet towels in a fire?
Q2	Escape ropes	What is the function of the escape rope in a fire?
Q3	Water-based fire extinguisher	If you are at the scene of a fire caused by flammable solids (e.g, wood, paper), which type of extinguisher should you use?
Q4	Dry powder D type fire extinguisher	If you are at the scene of a fire caused by reactive metal, which type of extinguisher should you use?
Q5	Carbon-dioxide fire extinguisher	If you are at the scene of a fire caused by electrical contact, which type of extinguisher should you use?
Q6	Foam extinguisher	If you are at the scene of a fire caused by flammable liquids (e.g., gasoline), which type of extinguisher should you use?

C. Experimental Procedure

We conducted a study that took place in a 4m×2m space in a university lab. The experimental procedure is summarised in Fig. 3. This study is approved by our University Ethics Committee.

The study began with a brief introduction, after which we collected participants' consent and asked them to fill out a pre-experiment questionnaire and the FEKQ. Then, participants were asked to familiarise themselves with the two devices used for the two roles. They were asked to adjust the device to a comfortable physical setting, including the sensitivity of the mouse and the strap fit and lens position of the VR HMD. Next, participants went through a tutorial to familiarise

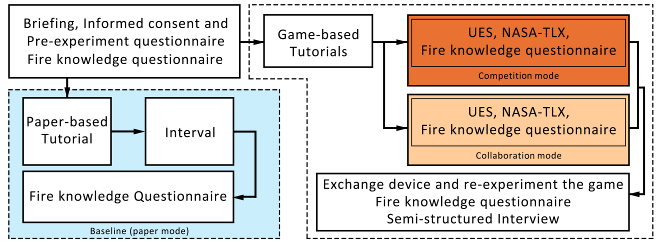

Fig. 3: An example experimental procedure and the counter-balanced sequence of sessions.

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themselves with the fire escape knowledge and the system's control methods as strategist and actionist, respectively. The tutorials for the two players were different. Strategists (PC users) were given a paper with fire escape knowledge. Meanwhile, they would also be provided a tutorial on how to play the game as a strategist. Actionists (VR users) were instructed to learn the fire escape knowledge and control methods during the VR HMD tutorials. Participants were asked to complete questionnaires measuring their engagement, workload, and knowledge after the game. Then, they were asked to exchange the roles to play the game again in the same game mode and evaluate their preferences. Finally, participants were invited to participate in a voluntary interview. The entire experiment lasted approximately 35 minutes.

We invited another group of participants to use the traditional paper-based learning mode, which we treated as the **baseline** condition. Participants were given a piece of paper, containing the fire escape knowledge we covered in the game system. They were given 8 minutes (equal to the average tutorial time in game modes) to learn and memorise the information. Then, we asked them to wait and relax for 8 minutes, which is equal to the time in game modes. Then, we asked them to answer the FEKQ again.

D. Participants

Forty participants (19 female, 21 male) voluntarily signed up for the two game modes, with an average age of 23.00 (SD = 2.35). Among them, 38 are students and 2 are company employees. Participants were asked to rate their usage frequencies and familiarity with the devices we used. On a 5-point Likert scale, participants were highly familiar with PC (3.70 ± 1.08) but moderately familiar with VR (3.30 ± 1.16). Twenty participants (9 female, 11 male) voluntarily signed up for the baseline, with an average age of 25.65 (SD = 2.41). Among them, 14 are students and 6 are company employees.

V. Results

For all ten collaboration groups, participants managed to escape the fire, whereas only three actionists (out of 10) managed to escape under the competition mode. In the following sections, we present the statistical analysis results in user experience, learning outcomes, and user preferences. We also present the interview findings.

A. User Engagement

Fig. 4 illustrates the analysis results showing the effect of game mode (Competition and Collaboration) and role-playing (Strategist and Actionist) on user engagement.

Focused Attention. A two-way repeated measures ANOVA showed no significant interaction between the effects of the game mode and role-playing on focused attention, $F(1,36) = 0.151, p = 0.70, \eta^2 = 0.004$. Further analysis showed that both game mode ($F(1,36) = 0.50, p = 0.488, \eta^2 = 0.013$) and role-playing ($F(1,36) = 1.35, p = 0.253, \eta^2 = 0.036$) had no significant effect on focused attention.

Perceived Usability. A two-way repeated measures ANOVA showed no significant interaction between the effects of the game mode and role-playing on perceived usability, $F(1,36) = 0.02, p = 0.882, \eta^2 = 0.001$. Further analysis showed that game mode ($F(1,36) = 5.13, p = 0.030, \eta^2 = 0.125$) had a significant effect on perceived usability. The role-playing had no significant effect on perceived usability, $F(1,36) = 1.11, p = 0.298, \eta^2 = 0.030$. Post hoc analysis revealed users reported significantly higher perceived usability in the collaboration mode than in the competition mode ($p = 0.03$).

Aesthetic Appeal. A two-way repeated measures ANOVA showed no significant interaction between the effects of the game mode and role-playing on aesthetic appeal, $F(1,36) = 2.85, p = 0.100, \eta^2 = 0.073$. Further analysis showed that both game mode ($F(1,36) = 3.43, p = 0.072, \eta^2 = 0.087$) and role-playing ($F(1,36) = 0.06, p = 0.809, \eta^2 = 0.002$) had no significant effect on aesthetic appeal.

Reward. A two-way repeated measures ANOVA showed no significant interaction between the effects of the game mode and role-playing on reward, $F(1,36) = 3.22, p = 0.081, \eta^2 = 0.082$. Further analysis showed that both game mode ($F(1,36) = 3.22, p = 0.081, \eta^2 = 0.082$) and role-playing ($F(1,36) = 0.46, p = 0.502, \eta^2 = 0.013$) had no significant effect on reward.

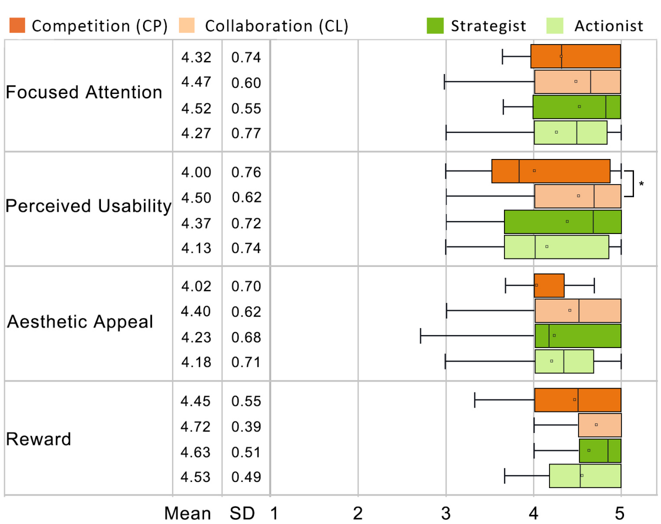

Fig. 4: The results of users' self-reported engagement in User Engagement Scale.

B. Workload

Fig. 5 illustrates the analysis results showing the effect of game mode (Competition and Collaboration) and role-playing (Strategist and Actionist) on workload.

Mental Demand. A two-way repeated measures ANOVA showed no significant interaction between the effects of the game mode and role-playing on mental workload, $F(1,36) = 2.97, p = 0.093, \eta^2 = 0.076$. Further analysis showed that both game mode ($F(1,36) = 6.56, p = 0.015, \eta^2 = 0.154$) and role-playing ($F(1,36) = 25.76, p < 0.001, \eta^2 = 0.417$) had a significant effect on mental workload. Post hoc analysis revealed that users reported significantly higher mental workload in competition than in collaboration ($p = 0.015$). For role-playing, users reported significantly higher mental workload when playing as actionists than when playing as strategists ($p < 0.001$).

Physical Demand. A two-way repeated measures ANOVA showed no significant interaction between the effects of the game mode and role-playing on physical workload, $F(1,36) = 1.05, p = 0.313, \eta^2 = 0.028$. Further analysis showed that both game mode ($F(1,36) = 1.96, p = 0.170, \eta^2 = 0.052$) and role-playing ($F(1,36) = 2.41, p = 0.129, \eta^2 = 0.063$) had no significant effect on physical workload.

Temporal Demand. A two-way repeated measures ANOVA showed no significant interaction between the effects of the game mode and role-playing on temporal workload, $F(1,36) = 0.16, p = 0.693, \eta^2 = 0.004$. Further analysis showed that both game mode ($F(1,36) = 1.42, p = 0.241, \eta^2 = 0.038$) and role-playing ($F(1,36) = 3.51, p = 0.069, \eta^2 = 0.089$) had no significant effect on temporal demand.

Performance. A two-way repeated measures ANOVA showed no significant interaction between the effects of the game mode and role-playing on performance, $F(1,36) = 0.59, p = 0.447, \eta^2 = 0.016$. Further analysis showed that role-playing ($F(1,36) = 4.59, p = 0.039, \eta^2 = 0.113$) had a significant effect on performance and game mode had no significant effect on performance, $F(1,36) = 2.37, p = 0.133, \eta^2 = 0.062$. Post hoc analysis revealed users reported significantly higher performance when playing as actionists than when playing as strategists ($p = 0.039$).

Effort. A two-way repeated measures ANOVA showed no significant interaction between the effects of the game mode and role-playing on the efforts of workload, $F(1,36) = 0.02, p = 0.890, \eta^2 = 0.001$. Further analysis showed that both game mode ($F(1,36) = 0.48, p = 0.491, \eta^2 = 0.013$) and role-playing ($F(1,36) = 2.56, p = 0.118, \eta^2 = 0.066$) had no significant effect on effort.

Frustration. A two-way repeated measures ANOVA showed no significant interaction between the effects of the game mode and role-playing on the frustration, $F(1,36) = 1.48, p = 0.232, \eta^2 = 0.039$. Further analysis showed that both game mode ($F(1,36) = 3.6, p = 0.066, \eta^2 = 0.091$) and role-playing ($F(1,36) = 0.02, p = 0.885, \eta^2 = 0.001$) had no significant effect on frustration.

Overall Workload. A two-way repeated measures ANOVA showed no significant interaction between the effects of the game mode and role-playing on overall workload, $F(1, 36) = 0.05, p = 0.821, \eta^2 = 0.001$. Further analysis showed that game mode ($F(1, 36) = 6.00, p = 0.019, \eta^2 = 0.143$) had a significant effect on overall workload. The role-playing had no significant effect on overall workload, $F(1, 36) = 1.23, p = 0.274, \eta^2 = 0.033$. Post hoc analysis revealed significant differences between competition and collaboration ($p = 0.019$). The overall workload in collaboration was significantly lower than in competition.

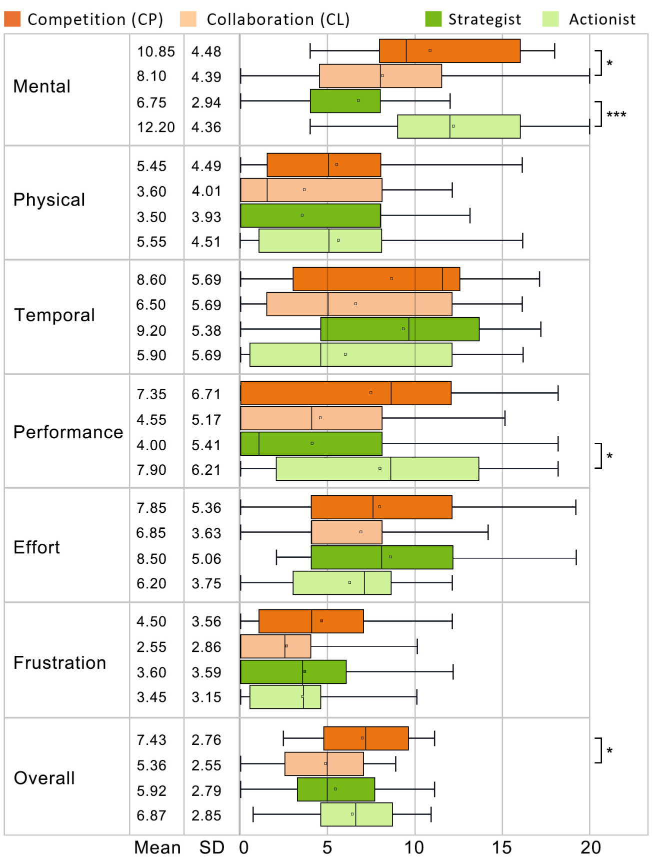

Fig. 5: The results of users' self-reported workload in NASA Task Load Index.

C. Learning Outcomes

FEKQ Pre-test. Fig. 6 (left) illustrates the results in the pre-test. A Mann-Whitney U test showed no statistically significant difference in learning outcomes between competition and collaboration, $Z = -0.78, p = 0.434$. A Kruskal-Wallis H test showed a statistically significant difference in learning outcomes between strategist, actionist and baseline, $\chi^2(2) = 11.68, p = 0.003$. Post hoc analysis revealed that strategists have significantly lower knowledge levels than actionists ($p = 0.004$) and the baseline condition ($p = 0.002$).

FEKQ Post-test. Fig. 6 (middle) illustrates the results in the post-test. A Mann-Whitney U test showed a statistically significant difference in learning outcomes between competition and collaboration, $Z = -2.974, p = 0.003$. Learning outcomes was greater in collaboration mode than in competition mode. A Kruskal-Wallis H test showed a statistically significant difference in learning outcomes between strategist, actionist and baseline, $\chi^2(2) = 23.26, p < 0.001$. Post hoc analysis revealed greater learning outcomes in the baseline condition than in the two role-playing conditions of strategists ($p < 0.001$) and actionists ($p < 0.001$).

FEKQ Improvement. Fig. 6 (right) illustrates the results in the improvement of learning outcomes. A Mann-Whitney U test showed a statistically significant difference in learning outcomes between competition and collaboration, $Z = -2.362, p = 0.018$. Improvement in learning outcomes was greater in collaboration mode than in competition mode. A Kruskal-Wallis H test showed a statistically significant difference in the improvement between strategist, actionist and baseline, $\chi^2(2) = 15.16, p = 0.001$. Post hoc analysis revealed that actionists had significantly less improvement than strategists ($p = 0.027$) and the baseline condition ($p < 0.001$).

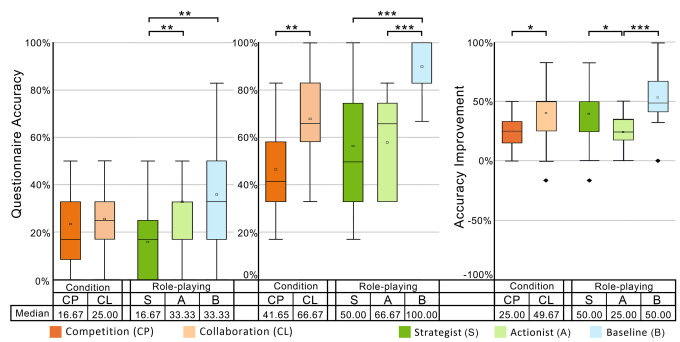

Fig. 6: The results of learning outcomes in the Fire Escape Knowledge Questionnaire (FEKQ): pre-test (left), post-test (middle), and the improvement (right).

D. User Preference

Twenty groups of participants who participated in the two game-based modes rated their preferences for the two roles in the gameplay, considering the game experience and its effect on learning. Fig. 7 shows the results. Under competition mode, 7 participants thought they had a better experience as strategists, while the other 13 participants preferred to play as actionists. To achieve good learning outcomes, there were also 7 participants who chose to play as strategists and the other 13 participants voted for actionists. Under the collaboration, only 2 participants preferred the game experience as a strategist, while the other 18 participants preferred actionists. Eight participants found that strategists better facilitated their learning, and the other 12 participants preferred to be actionists.

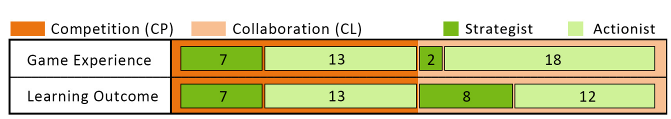

Fig. 7: The results of users' preference of role-playing.

E. Semi-structured Interview

At the end of the experiment, 17 participants volunteered to participate in the interview. About the first question: *"Which way would you prefer to learn? The game system or traditional methods?"*. All participants ($N = 17$) chose the game system. Then, about *"does role-playing affect your experience?"*, most participants ($N = 14$) mentioned that playing as an actionist was highly immersive and allowed them to better understand of the fire scene. However, some found it caused extra study load ($N = 5$) and discomfort ($N = 4$). Playing as strategists, participants found it hard for them to actually feel what the fire was really like ($N = 5$). Yet, it was also found easy to play ($N = 6$) because they were familiar with desktop devices. When asked *"does role-playing affect your learning"*, 11 participants found being an active player in VR better supported their learning because it allowed them to explore and experiment with what they needed to do in a fire. The other 6 participants found the realistic simulated environment caused some pressure for them to escape and affected their ability to concentrate on memorising the knowledge. These people prefer to be strategists, in which case they could learn from the holistic overview of the fire environment, compared to the limited first-person perspective as an actionist. When asked about suggestions, 6 participants said the differences between fire extinguishers and causes of fire should be signified. Two participants demanded a more realistic environment (e.g., with classroom furniture and other people) will further improve their user experience. Four participants indicated that the game play as actionists could be improved with more training tasks (e.g., via quiz systems) inside the scene.

VI. Discussion

A. Actionists in VR perceived better performance, but also higher mental workload.

Our results reject **H1a** (engagement) but show support to **H1b** (workload). From participants' comments, we learned that the highly immersive and realistic first-person perspective in VR has contributed to user experience and allowed users to perceive higher performance, similar to the findings in previous work [19]. As commented by P17: *"playing as actionists made me deeply understand the danger of fire and the different ways to put out the fire."* P14 also commented that *"I can experience the fire more vividly when playing as an actionist."* Regarding the mental workload, our findings resonate with previous work that VR is subject to higher mental workload [20]. In addition, the workload is likely to relate to role-playing in our study. As P12 reported: *"the feeling of being in the fire gave me a strong presence and forced me to learn quickly, but I do not have this kind of feel when playing as strategist"*. On the other hand, strategists may had less sense of urgency from fire, thus exhibiting lower mental workload.

B. Learning outcomes were greater for strategists, which was comparable to the baseline.

Our **H2** was supported - we found participants' learning outcomes varied significantly for role-playing and traditional learning methods. Given that participants demonstrated significant differences among the three conditions in the pre-test, we mainly refer to the FEKQ improvement results here. We found strategists showed greater improvement than actionists. However, it was not greater than the baseline, which was the overall highest improvement. Similar results were found in [21], where a baseline condition with paper-based learning outperformed AR approaches. P38 reported that: *"I was more immersed when I play as an actionist. In VR, I was more interested in the operations than learning about fire knowledge."* P34 also commented that *"sometimes it was hard to recall the correct fire extinguisher when I was moving from one place to another."* Makransky et al. [22] also reported that learning in VR may cause information overload and distract the learners, resulting in less construction of knowledge than using a PC in a science lab simulation system. Thus, we suggest that to the systems aim to facilitate the construction of knowledge, designers should be aware of the potential negative effects of gameplay and immersion on users' attention and learning outcomes.

C. Collaboration mode supported higher perceived usability and lower workload than competition mode.

Our results showed that participants felt higher perceived usability when they played in collaboration mode than in the competition mode. In addition, they also reported significantly lower mental workload in collaboration mode. These results supported **H3a** and **H3b**. When working in pairs to solve a problem, players exchange information and collaborate with each other. The interaction between them is likely to reduce the stress and negative effects on individual players compared to solving a problem alone, as indicated in previous work [23]. P36 supported this view: *"collaboration mode was more relaxing because we can remind each other of what we learned."* In contrast, the competition mode may have increased players' stress levels as they needed to compete with other players [24]. As P20 reported: *"Except for the pressure from the game itself (e.g., time limit), I also feel extra pressure from the other player because I need to fight against him."* Fire escape simulations have inherent sense of tension due to its safety-critical nature and the realistic display. In the meantime, the competition mode may add an additional layer of workload to participants.

D. Collaboration mode facilitated better learning outcomes.

Comparing the improvement in learning outcomes, the collaboration mode outperformed the competition mode, which supports **H4**. In competition mode, players needed to fight against each other to win the game. Thus, this may affected the time and efforts users spent on learning. On the other hand, users worked together to escape the buildings in the collaboration mode. Therefore, they were able to fully commit their attention to fire knowledge. During the process, we also observed a greater communication frequency between them, which may have eased the memory load and strengthened their memory. As P14 reflected, *"I think collaboration is better because it allows me to focus on putting out the fire with additional help. In competition, I just want to run and win the game."* While this shows a difference in game mode, the results also implicate the potential negative effect of action-based and experiential learning in VR, where the actions and experience themselves may overpower the original intention of learning activities.

E. Limitations and Future Work

Our study has some limitations that need to be addressed. First, we would point out that the two roles (strategist and actionist) involve more than the difference in gameplay, but also their perspectives (first-person and third-person) and the use of devices (VR and PC). The perspectives and devices are the premises of the two roles and are needed for the comparison of the two roles. Yet, these should be taken into account when interpreting our results. Second, our sample showed some limitations. The pretest of the fire escape knowledge questionnaire showed a significant difference. This was unexpected as we adopted a random sampling technique. Still, this was a limitation of our data. We thus calculated the differences in learning outcomes between the pre-test and post-test rather than directly comparing the post-test results. In addition, our results were drawn from the participants aged between 20 and 30 years old. Thus, our findings should be generalised to other age groups with caution. Another limitation of this study is the lack of knowledge retention assessment for long-term memory. How well participants retained the newly grasped knowledge through different game modes over time is uncertain. In addition, the current knowledge test about the types of fire extinguishers favoured traditional learning methods, perhaps because they were mainly memory tasks. We did not assess users' acquisition of behavioural knowledge, such as the appropriate body postures (e.g., staying low to the ground) at a fire scene. It is likely that learning outcomes as actionists in VR will outperform other conditions for these behavioural tasks.

VII. Conclusion

In this study, we present a comparative analysis that explores the distinctions between game modes (collaboration and competition) and role-playing (strategists and actionists) in an asymmetric co-located fire escape game. Through our empirical evaluations, we found significantly different user experiences and learning outcomes among users employing game modes and role-playing. Specifically, actionists reported better perceived performance but also higher mental workload than strategists. For learning outcomes specifically, the greatest learning outcomes and improvement in learning was observed in the baseline condition: learning with a piece of paper. The results showed the potential negative effects of VR on mental workload and the limited improvement in learning outcomes compared to traditional learning methods, indicating that VR is perhaps not always a better choice. However, our study also showed significant user engagement in the game simulation, which should not be overlooked. As shown in the user preferences results, most users prefer to play as actionists (in VR). Regarding the game modes, the collaboration mode exhibited higher perceived usability, lower mental workload, overall workload, and improvement in learning outcomes, showing that in training systems with realistic simulations that are safety-critical and timed, the collaboration mode allows better user experiences and training effects. Thus, we suggest designers consider using collaboration mode and choose devices like PCs to allow strategic play with a holistic overview. It should also be acknowledged that immersive devices, such as VR HMD, may encounter challenges in distracting users' attention and affecting their learning efficiency. Our results and the recommendations derived from the user study can assist researchers and designers in developing future game-based educational systems, especially in the decision-making related to game modes, role-playing, and devices.

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