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Comparing two navigation aids in a VR environment

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Comparing two different wayfinding cues in a VR environment

Virtual Reality (VR) environments can be difficult to navigate, so designers implement wayfinding cues to assist navigation through the simulation. There are variety of ways to guide the user and this thesis investigates and compares two wayfinding cues: signage and verbal instructions provided by a non-playable character (NPC) guide. The thesis also studies better practices for VR environment design and user experience.

Participants (n = 20) were divided into two groups to play a VR emergency building exit simulation. Group A was tasked to follow fire exit signs and Group B had a guide giving them verbal instructions to the next destination. Both filled out a pre- and a post-questionnaire to evaluate their experience and to establish background variables.

Due to low participant count and a biased VR experience background the simulation did not find conclusive data to support either wayfinding method but affirms that previous experience in VR gives an advantageous position to learn new skills from simulations.

Keywords:

Virtual reality, simulation, wayfinding

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Kahden suunnistusmetodin vertaaminen VR-ympäristössä

Virtuaalisen todellisuuden (VR) ympäristö voi olla hankala suunnistaa, joten suunnittelijat lisäävät suunnistusmetodeja auttamaan käyttäjää suunnistamaan simulaatiossa. On monta tapaa opastaa käyttäjää oikealle reitille. Tässä opinnäytetyössä tutkittiin, onko kahden eri suunnistusvihjeen välillä on merkittävää eroa VR-hätäpoistumistiesimulaatiossa. Opinnäytetyön tavoitteena oli myös selvittää parempia käytäntöjä VR-ympäristön suunnitteluun ja käyttökokemukseen.

Osallistujat (n = 20) jaettiin kahteen ryhmään pelaamaan VR-hätäpostumistiesimulaatiota. Ryhmä A:ta pyydettiin seuraamaan hätäpostumistiekylttejä ja ryhmä B:llä oli virtuaaliopas antamassa verbaalisia ohjeita seuraavaan määränpäähän. Molemmat ryhmät täyttivät esi- ja jälkikyselyn, jotta heidän kokemuksensa ja taustansa voidaan ottaa huomioon arvionnissa.

Vähäisen osallistujamäärän ja B-ryhmää puoltavan VR-kokemuksen takia, opinnäytetyössä ei löydetty suoraa näyttöä osoittamaan kumpaakaan suunnistusmetodia toista paremmaksi. Työn tulokseksi kuitenkin saatiin, että aikasempi VR-kokemus antaa paremmat edellytykset oppia uutta simulaatiossa.

Asiasanat:

Virtuaalitodellisuus, simulaattori, suunnistusmetodi

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List of abbreviations (or) symbols

3D	Three Dimensional
AR	Augmented Reality
HMD	Head-mounted Display
HUD	Heads-up Display
NPC	Non-player Character
VE	Virtual Environment
VR	Virtual Reality

1 Introduction

Virtual Reality, or commonly referred as VR, has had a succession of both good and bad reputation ever since the first commercial head mounted display (HMD) was released in 2016. Most recent discussion revolving around the possibility of a metaverse, immersive and holistic world experienced inside the internet, faded almost as fast as it arrived in mainstream media. While the possibilities for VR sometime seem almost too impossible to comprehend, there are several smaller tasks that it excels at.

One exciting example is its use in training simulations (Xie, et al., 2021). Lower material costs, mobility and time-saving properties have many institutions and companies incorporating it in their employee training (Holmes, 2021) and its flexibility provides efficient ways to stay in touch with the newest mandates and policies (Xie, et al., 2021). The recent worldwide pandemic Covid-19 also had a hand in pushing companies to find remote collaboration solutions which reflects well how VR rose in sales by 50% from 2019 to 2020 (Vardomatski, 2021). In a VR simulation training, the trainee can experiment in a safe environment and repeat the simulation as many times as needed to learn the necessary skills, and it allows for mistakes without risking any real-life equipment, which can be quite costly (Xie, et al., 2021).

VR training simulations are not without their challenges. One essential and necessary one is locomotion (Keil, Edler, O'Meara, Korte, & Dickmann, 2021). Locomotion is how the user moves inside a virtual space. While it is certainly easier to have the participant move only by walking in real life space, it is not always feasible due to room size or physical restraints such as cables. Most popular solutions are either teleportation or gameplay reminiscent steering. Out of the two, teleportation is often the most favoured choice due to the less nauseating experience (Langbehn, Lubos, & Steinicke, 2018, April).

Once the user has access to the virtual space around them, they will also need help navigating it. There are several ways of providing navigation information, many of them use the area on heads up display (HUD), where a representation

of the area is provided by a small two-dimensional map (Mahalil, Yusof, Ibrahim, Mahidin, & Rusli, 2019, November). HUD is also slightly controversial in VR training as it can obstruct part of the trainee's field of view and break immersion for some trainees (Rosyid, Pangetsu, & Akbar, 2021, October),so instead one option is for simulations to provide environmental hints of different wayfinding cues to replace the HUD, such as lighting changes, signs or verbal instructions.

This thesis intends to investigate and compare two wayfinding cues: signage and verbal instructions provided by a non-playable character (NPC) guide. Main goal is to explore which one is more efficient in teaching a fire exit route in a VR training simulation. It is also an interest to study the participant behavior and evaluate their learning experience to gain further insight into the best practices in VR.

This thesis is structured as follows:

Chapter 2 begins with an insight to previous similar studies and their discoveries. Chapter 3 introduces the background information, hardware and the software used. Chapter 4 introduces the pre- and post-questionnaire and the simulation. Chapter 5 introduces the test results from the simulation and pre- and post-questionnaire. Chapter 6 provides a discussion from the gathered data, and chapter 7 summarizes the findings and provides a conclusion to the thesis.

2 Related works

Fire exit simulation is nothing new in the disaster training toolbox. They have been studied that practicing a dangerous situation in safe environment just once improves decision making in the real case scenario, and repeated exposure can yield even better results (Jing, Lijun, & Nan, 2019). So, providing training by simulation will be of great interests for companies that wish to keep a trained staff at hand.

Navigating new areas can be challenging in real life and inside large simulations, therefore users without any previous VR experience, who are coming to terms with the new technology, will most certainly require some form of help to find their way (Jing, Lijun, & Nan, 2019). This is often done by adding wayfinding cues that can vary from arrows to light signals, pointing to the desired direction. By ensuring that adequate wayfinding affordances are present, it helps the user to function successfully inside the simulation (Dondlinger & Lunce, 2009) and by carefully introducing these contextual cues it can improve their overall experience (Irshad, Perkis, & Azam, 2021).

Wayfinding cues can be as simple as the design of the architecture surrounding the user. A study investigated how this affects human behaviour in a fire exit simulation. They considered usage of signage, layout configuration, level of architectural differentiation and visual access in a situation where you do not have much time to think, and smoke can impair sight and it resulted that visual access had the greatest effect when choosing an exit route (Runhe, Jing, Becerik-Gerber, & Li, 2020).

An intuitive way of approaching wayfinding cues was also considered in a study that researched if social wayfinding support could be advantageous in VE navigation. They discovered that users respond well to a virtual guide which verbal instructions seemed to enhance their learning. They also suggested that subtle social cues, like pedestrian flows, improve spatial awareness and could facilitate exploration even further, when compared to virtual guide (Bönsch, Ehret, Rupp, & Kuhlen, 2024).

3 Equipment and introduction to Smart Campus

The project was developed by using Unreal Engine version 4.26.10. The coding language is C++ but Unreal Engine provides a beginner friendly visual scripting tool, that was mainly used. Instead of writing lines of code, the programmer can add and connect several nodes inside a blueprint and attach it to an asset. This makes visual scripting excellent for prototyping for a project like this but can cause lag in performance and become unorganized quickly if used on a bigger scale.

This thesis utilizes Steam VR and Meta Quest, which are necessary to run the VR glasses. Code management was handled by GitLab and GitHub Desktop. The pro- and post-questionnaire were created with Google Forms.

This thesis also utilized Oculus Quest 2 VR glasses (Figure 1) as the previous project used them in their development, and there was no need to change the hardware for this experiment. Otherwise, all the testing was done with school provided personal computers in a laboratory room.

Figure 1. Oculus Quest 2 headset.

3.1 Smart Campus project

Smart Campus (Smart Campus, 2024) is a nationwide innovation collaboration between eight Finnish universities. Its goal is to promote innovations for the future and accelerate digitalization for all platforms. This thesis utilizes a fire-exit simulation created for Smart Camps. It contains a detailed 3D model of the new EduCity-building and ready-made platform for VR navigation with additional timer capabilities.

The project consisted of two levels. In the first one the participant is tasked to navigate and escape the building in case of fire (Figure 2).

Figure 2. First level of Smart Campus.

The second level tasked the user to find a safe room to hide in and barricade the door while waiting for the police (Figure 3).

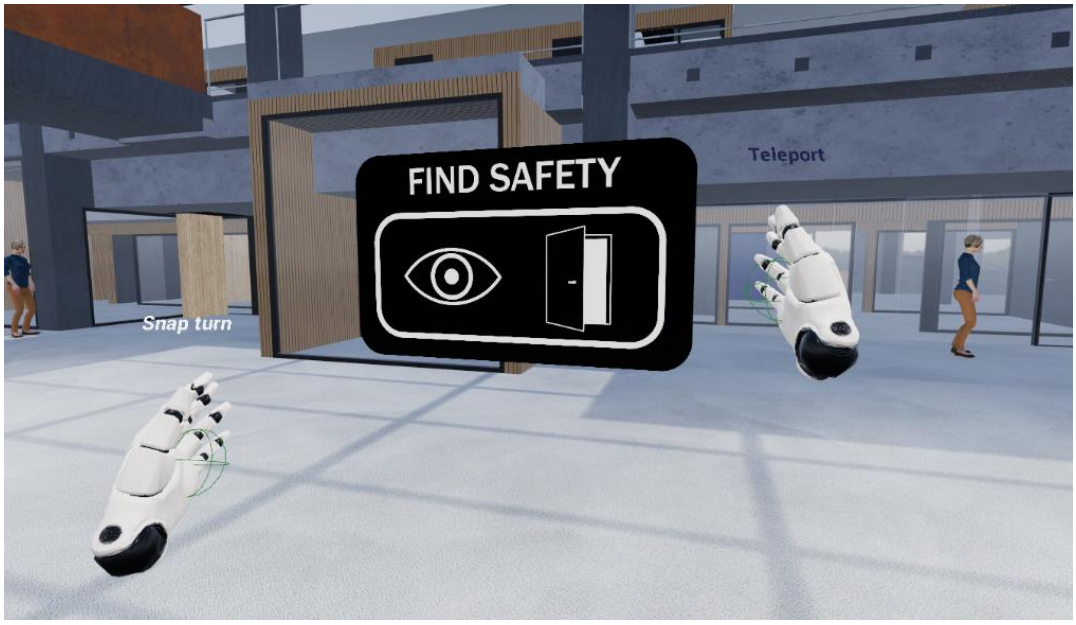

Figure 3. Second level of Smart Campus.

This thesis used the first level as the base for the project, the VR capabilities and time keeping assets were utilized similarly.

3.2 Building escape experiment simulations

Two levels were created from the first level of the Smart Campus project. In them the participants would have to exit the Edu City-building following a pre-determined route to the exit but with two different wayfinding cues.

3.2.1 Virtual guide system

The virtual guide level had three NPCs as guides (Figure 4) placed along the route that gave instructions to the participants. In front of the guides laid a green highlighted area that would trigger verbal instruction and a small hand animation to emphasize the correct direction to the participants.

Figure 4. Example of the virtual guide.

On the 2nd floor, the first instructions to the participants from the guide were to continue straight, turn left, go over the bridge and head down the stairs (Figure 5).

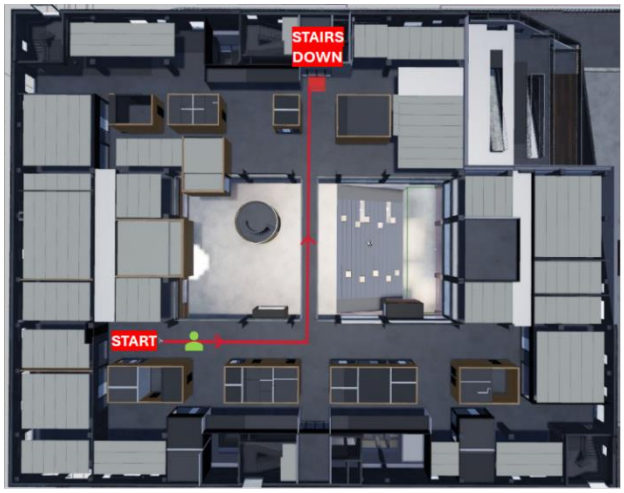

Figure 5. Placement of the virtual guide on the 2nd floor.

On the 1st floor, the second guide instructed participants to turn left and head down the stairs. Third guide instructed to head down through the door, take stairs down and then the exit is to their right (Figure 6).

Figure 6. Placement of virtual guides on the 1st floor.

3.2.2 Fire exit sign system

Group B had seven fire exits signs (Figure 7) that guided the participants from the 2nd floor to the ground level.

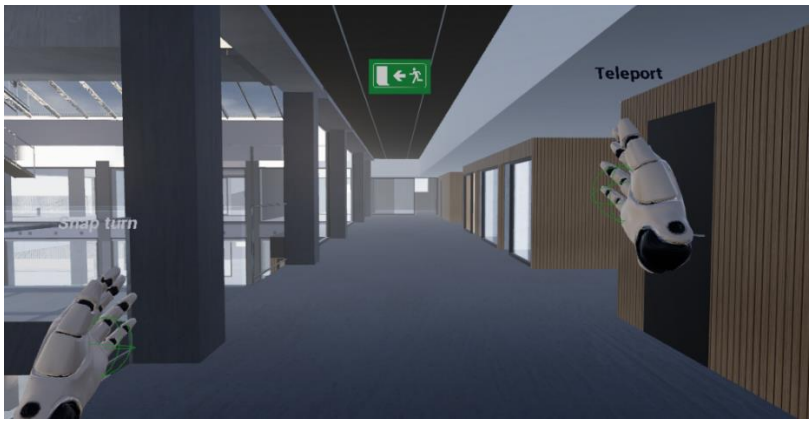

Figure 7. Example of fire exit sign.

The fire exit signs were placed so that while on the correct route, the participants were always able to see the next one. The only exception to this was the central staircase where the elevation blocked the sight to the next fire exit signs.

On the 2nd floor, the first fire exit sign pointed to the bridge, where once the participant turned, they could see the next sign pointing at the staircase (Figure 8).

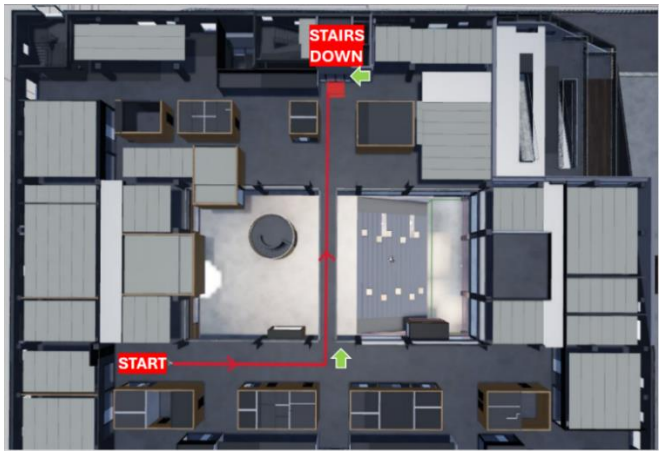

Figure 8. Placement of fire exit signs on the 2nd floor.

On the 1st floor, the first fire exit sign was placed before the central staircase pointing to the left. Once the participants descended the stairs, they were able to see two fire exit signs on top of two doors. Once through the door there was a sign before the stairs pointing left and, in the staircase, pointing to the final door to the right (Figure 9).

Figure 9. Placement of fire exit signs on the 1st floor.

4 Research design

This study had an experiment design where participants were randomly assigned to one of two interventions—virtual guide system or exit sign system. The participants were profiled before the intervention and tested after the intervention to determine what they learned.

4.1 Measurement instruments

Before the participants tried the intervention, they were asked to fill in a pre-questionnaire, which establishes the background of the participants and provides IDs so that gathered data can be handled anonymously. The first two questions were yes or no questions to establish if the participant was an ICT student and whether they had any known colour blindness. The participants were also required to fill five Likert-style self-reflecting questions to measure their skill in VR and their familiarity with the Edu-City building and its fire exits. The pre-questionnaire answers were transformed into points from 1 to 5, so that more experience yielded higher points.

Two groups of 20 participants each experienced one of two versions of the intervention. Each group was required to navigate the same pre-determined route from the 2nd floor to the ground level of the virtual Edu City-building, but with two different wayfinding cues.

a. Group A navigated by virtual guide instructions.

b. Group B navigated by fire exit signage.

Group A had three NPC guides that gave verbal instructions for each new direction towards the exit. To successfully reach the exit, the participant had to listen to each instruction and follow accordingly. Instead of verbal instructions. Group B had fire exit signs placed on walls and on top of doorways to guide

them to the exit. Both groups were timed from the start of the simulation until they reached the ground level fire exit.

After the intervention, participants filled a post-questionnaire that consisted of a short quiz to evaluate the participants- concept of the correct route. Each participant was tasked to replicate the instructed route from the starting point to the exit in only eight steps and to use every option at least once (Figure 10).

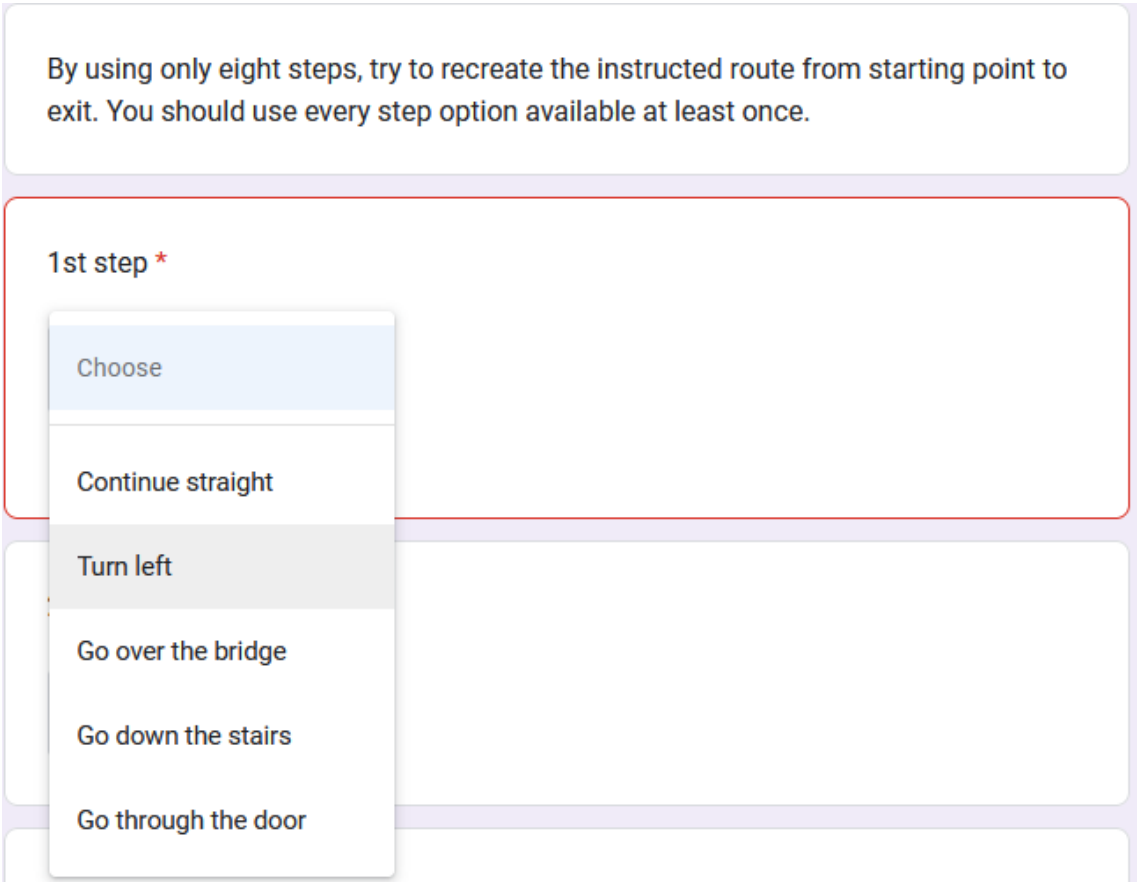

Figure 10. Knowledge acquisition post-questionnaire question.

The post-questionnaire results were evaluated by making a reference map of all the possible combinations of correct steps and applying that how well the participants answers reflected those.

4.2 Research protocol

In total there were 20 participants recruited from an ICT student group and other volunteers. Participants were brought to the testing room one at a time and instructed to finish the pre-questionnaire. Regardless of previous VR knowledge, everyone received a short introduction on how to use the equipment and how the in-game teleportation works. Before starting the simulation, they were reminded to follow the instructions provided inside the simulation and that they can ask assistance if necessary.

While the participant was navigating the simulation, they were monitored from a video feed of their field of view from a separate screen. In case of an unexpected bug or requested assistance the participants were reminded of their task or given a few words of encouragement to find the solution on their own to minimize outside variables. Also, notes were taken down to assess the participants' performance and note down any accidents that might have affected the results.

Once the exit was reached, the time was written down and the participant was directed to the post-questionnaire.

5 Results

The raw data from the questionnaire and the simulation were captured in an Excel spreadsheet and turned into quantitative data. Also, a total of VR experience and Edu-City navigation pre-knowledge points were tallied.

Group A and B were separately investigated to identify any outliers and major variables that were taken into account when the two groups were compared to determine if there was any difference in their learning between following verbal instructions from an NPC guide and following fire exit sings.

5.1 Group A (NPC guided) results

From the pre-questionnaire, 7 out of 10 participants were students from the ICT building and one had colour blindness. 80% had previous experience in VR and 60% felt confident using it. 20% admitted to having had trouble to navigating the Edu City-building and none had knowledge of the official fire exit sign locations. Their average completion time to find the exit in the application was 01:24 minutes and the group’s average post-questionnaire points were 10,1.

5.2 Group B (fire exit signs) results

From the pre-questionnaire, 8 out of 10 participants were students from the ICT building and none had any known colour blindness. 30% had previous experience in VR and 40% felt confident using it. 40% admitted to having had trouble navigating the Ecu City-building and none had knowledge of the official fire exit sign locations. Their average completion time was 01:47 minutes and average post-questionnaire points were 7,2.

5.3 Summary

Table 1 gives a direct comparison of the results for the pre-questionnaire, intervention performance and post-questionnaire score from both groups.

Table 1. Summary of results.

	Group A (NPC guided)	Group B (fire exit signs)
Had previous VR experience	80%	30%
Felt confident using VR	60%	40%
Had trouble navigating Edu-City-building	20%	40%
Knew the fire exits in Edu City-building	0%	0%
Average time taken to exit	01:24	01:47
Average post-questionnaire score	10,1	7,2

6 Discussion

The data collected from the results shows group A completing the intervention faster and gaining more points in the post-questionnaire compared to group B. Though when examining the pre-questionnaire answers, group A having performed better than group B is not a clear indication that the NPC guide teaches more effectively than following fire exit signs. As both groups had similar pre-knowledge of the Edu-City building and its fire exits, the major differences in previous VR experience could provide a more reasonable explanation to group A's success.

As preceding studies (Jing, Lijun, & Nan, 2019) state that repeated exposure to the same environment reduces travel time and improve performance, so might previous exposure to VR. The data suggest that trying out a simulation for the first time, without any previous knowledge of VR, might hinder learning and navigation. Especially as this thesis utilized teleportation as the locomotion method, which can be less intuitive for first time users (Sayyad, Sra, & Höllerer, 2020, Nov 13). Therefore, users with prior experience might use less time adjusting to the virtual environment and hesitate less when navigating, which could leave more time to observe surroundings and memorize the route.

An additional contributing factor might be stress. While stress response is individualistic and still a major field requiring more research, participants who tried out VR simulation for the first time might have experienced heightened levels of anxiety. In a study researching word memorization under stress, participants experiencing anxiety suffered a 30% reduction in their recognition performance and recall (Schwabe & Wolf, 2010). Similar effects might be at play while users try to learn new routes in a virtual environment.

Overall, the research question of which wayfinding cue preforms better to teach the fire exit route, could not be determined from the received data. Future studies should consider the participants background of previous experiences in more detail and perform a study designed with the method in mind, that instead of randomly assigning participants to a group, they would be profiled early and

divided equally based on their background, which would shift the attention from personal experiences to the effects of the wayfinding cues.

7 Conclusion and recommendations

This study intended to investigate and compare two wayfinding cues: signage and verbal instructions provided by an NPC guide, and to study better practices for VR environment design and user experience. This was done by creating two simulation levels with different wayfinding cues and having two groups to play through them and answer a pre- and a post-questionnaire to compare their results.

Due to the low participant amount and that the two groups had majorly different backgrounds in VR experience, no clear conclusion could be derived from the results to compare verbal instructions to following fire exit signs. Though the results seem to affirm preceding studies that previous experience with VR provides advantages when learning new information in a simulation and such it is strongly recommended for future training simulations to take this into account. Providing a tutorial in VR could lessen the stress experienced in a learning simulation and as such provide better capability to learn new things.

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